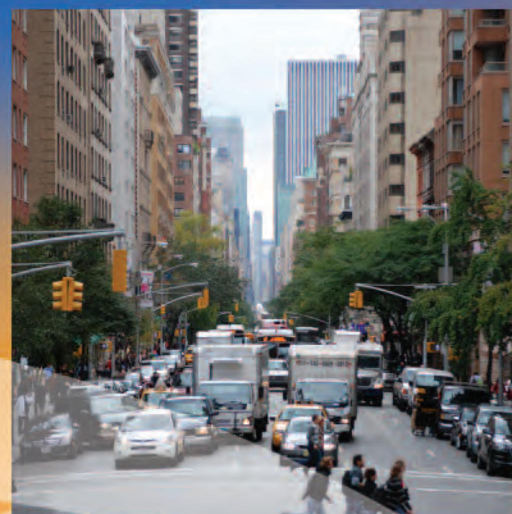
The New York City Community Air Survey

Results from Year One Monitoring 2008-2009



NYC Health

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Letter from the Commissioner and Director

April 2011

Dear Fellow New Yorker:

Four years ago, PlaNYC set in motion a range of actions to make the City's environment more sustainable, healthier and enjoyable for its growing population. Compared to most U.S. cities, New York is already among the most transit-friendly and walkable, affording its residents and those of neighboring communities access to jobs, entertainment and recreation with less need for driving and its attendant impact on the environment. But more remains to be done. Our vibrant, densely developed city that brings people together also puts many residents near concentrations of emission sources – especially buildings and traffic. As the New York City Community Air Survey (NYCCAS) has shown, too many New Yorkers live, work, shop and attend school in neighborhoods with poor air quality.

NYCCAS, a PlaNYC initiative, is an important part of the Health Department's work to track environmental quality and its impacts on the health of New Yorkers. The reports generated by this landmark survey provide the public and officials with important information they need to develop policies to enhance air quality and public health.

We hope that you will find it useful and informative.

Sincerely,

Thomas Farley, M.D., M.P.H.
Commissioner
Department of Health
and Mental Hygiene

David Bragdon
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planYC

NYC Health

Executive Summary

The most basic need for a healthy living environment is clean air; pollution of the air can pose a major threat to the well-being of all New Yorkers. To improve the health of its residents, the city launched its first comprehensive sustainability plan, PlaNYC, to establish goals and initiatives that improve air quality. One such initiative charged the Department of Health and Mental Hygiene with developing the New York City Community Air Survey (NYCCAS) to study geographic patterns of air pollution across the 5 boroughs. Since its launch in December 2008, the survey has measured street-level air pollution at 150 locations across the city over every season of the year, gathering data on common air pollutants that affect public health such as fine particles, elemental carbon, nitric oxide, nitrogen dioxide and ozone (summer only), sulfur dioxide (winter only) and certain metals.

Prior NYCCAS reports have shown that winter pollutant levels are higher in areas that have a high density of buildings with boilers burning fuel oil, particularly residual fuel oil (grade #4 and #6 heating oil). Both winter and summer pollution levels tend to be higher in areas where traffic is concentrated.

This report summarizes the results of the first 4 seasons (from December 2008 to December 2009) of NYCCAS monitoring for 4 pollutants—fine particles ($PM_{2.5}$) elemental carbon (EC), nitric oxide (NO) and nitrogen dioxide (NO_2)—which varied 2-fold or more across the monitoring sites. High levels of all 4 pollutants were detected in midtown and downtown Manhattan, and in sections of the Bronx, Brooklyn, Queens and Staten Island along busy freeways. The high levels are driven, in part, by major emissions sources, such as traffic and building-related emissions, specifically heating oil. Although direct emissions from buildings are highest during the wintertime heating season, hot water heating and cooking are year-round sources of combustion emissions.

In NYCCAS models, indicators of these pollutants are the density of boilers and, specifically, the density of oil burning boilers (significant predictors of EC), density of residual oil-burning boilers (a significant predictor of $PM_{2.5}$) and building density (a significant predictor of NO_2 and NO). Building density may also reflect vehicle emissions, since commercial areas with high concentrations of large buildings also tend to have high volumes of traffic and congestion.

Indicators of on-road vehicle traffic were predictive of all 4 pollutant concentrations—total traffic with $PM_{2.5}$, NO and NO_2 levels; truck traffic with $PM_{2.5}$ and EC levels; and location along a bus route with NO levels (bus routes tend to carry more total traffic than other roads, on average). Although NO_2 concentrations might be expected to be highest near highways in less densely developed cities, NYCCAS results showed that in New York City, the highest NO_2 concentrations overall were in Manhattan locations with many busy surface roads and where large commercial and residential buildings are in close proximity. Data from NYCCAS air pollution monitors in Times Square and other midtown locations show that creating traffic-free plazas can immediately improve air quality for many pedestrians.

The findings of this NYCCAS report affirm the need for initiatives to reduce traffic and building-related emissions, especially in the most polluted parts of the city. Prior survey findings showed the local impact of the most polluting heating fuels, spurring state and local measures to reduce heating oil emissions and provide cleaner air with fewer health impacts. Steps to make buildings more energy efficient also will contribute to reducing emissions from heating and electric power generation. Traffic-related pollution poses a greater challenge for policy-makers—trucks, cars and buses are all significant contributors. To achieve goals for cleaner air and reduced CO_2 emissions, and increase physical activity, private car trips must decline in favor of public transit, biking and walking.

Introduction and Background

New York City's first comprehensive sustainability plan, PlaNYC, established goals and initiatives for improving air quality and charged the Department of Health and Mental Hygiene with developing the New York City Community Air Survey (NYCCAS) to study geographic patterns of air pollution across the 5 boroughs. Since its launch in December 2008, NYCCAS has measured street-level air pollution at 150 locations across the city, in each season of the year. NYCCAS measures common air pollutants that affect public health including fine particles, elemental carbon, nitric oxide, nitrogen dioxide and ozone (summer only), sulfur dioxide (winter only) and certain metals.

Prior NYCCAS reports have highlighted large differences in air pollution concentrations in different parts of the city in winter and summer seasons; levels are higher in winter in areas with a high density of buildings that use boilers burning fuel oil, particularly residual fuel oil (grade #4 and #6 heating oil). Both winter and summer pollution levels tend to be higher in areas where traffic is concentrated, including parts of midtown, downtown, and northern Manhattan, and sections of the Bronx, Brooklyn and Queens along major highways. This report summarizes the first 4 seasons of NYCCAS monitoring, from December 2008 to December 2009.

Air pollution is a significant public health problem in New York City.

There is no more basic need for a healthy living environment than clean air; air pollution can threaten the well-being of all New Yorkers. NYCCAS measures common air pollutants, including fine particles ($PM_{2.5}$), elemental carbon (EC) and nitrogen dioxide (NO_2) that have established links to adverse health impacts. These pollutants are associated with exacerbation of asthma and other respiratory diseases, and cardiovascular disease leading to more symptoms and increased emergency department visits, hospital admissions and even deaths. Certain populations are especially susceptible to the effects of air pollution, including young children, who are still developing physically, seniors and people with chronic lung or cardiovascular diseases.

Important sources of many of these pollutants in New York City are fuel combustion emissions from road vehicles, off-road equipment, building heating systems, electric power generators and cooking, among others. City air quality is not only affected by local emissions, but also by emissions transported over long distances, such as coal-fired power stations in the Midwest. Although emissions from distant sources tend to affect all neighborhoods similarly, air pollution sources within the city cause differences in pollution levels among neighborhoods.

NYCCAS assessments complement essential air monitoring by the New York State Department of Conservation, which provides critical data for regulatory purposes to compare city-wide trends with national standards. The limited number of the state's monitors do not provide neighborhood-level detail.

Fine Particles ($PM_{2.5}$) are small, airborne particles with a diameter of 2.5 micrometers or less. $PM_{2.5}$ that can penetrate deep into the lungs, causing inflammation of the airways, exacerbating lung and heart disease, increasing hospital admissions and contributing to premature mortality. Sources of $PM_{2.5}$ include all types of combustion sources; the elemental composition of $PM_{2.5}$ can vary by source and determine $PM_{2.5}$ health effects.

Elemental Carbon (EC) is a component of $PM_{2.5}$ emitted from fossil fuel combustion, including diesel exhaust. EC can cause irritation of the airways and exacerbate asthma, may increase the risk of lung cancer, and like greenhouse gases, can contribute to hotter temperatures in cities (the urban heat island effect).

Nitrogen Oxides (NO_x) are gases produced by fuel combustion. They include nitric oxide (NO), which is rapidly converted to nitrogen dioxide (NO_2) after emission from vehicles and other sources. Exposures have been associated with lung irritation, emergency department visits and hospital admissions for respiratory conditions. Nitrogen oxides also contribute to the formation of ozone.

NYCCAS measures 2 other important local pollutants only during certain seasons. Sulfur dioxide (SO_2) is measured only in winter, when emissions in the city from burning sulfur-containing fuels (such as residual heating oil) increase. Ozone is measured only in the summer, when the highest concentrations occur.

The Community Air Survey aims to understand New York City's air pollution problem and inform future air quality improvement measures.

The goals of NYCCAS are to:

- Measure concentrations of important air pollutants that affect public health.
- Measure how seasonal pollution concentrations near street level vary across the city's diverse neighborhoods.
- Learn how emissions from traffic, buildings and other local sources affect air pollution levels across city neighborhoods.
- Help to inform policy priorities for reducing local emissions and improving air quality.
- Provide information to improve how the city monitors air quality in the future.
- Estimate population exposure to air pollution for future surveillance and health research.

The Department of Health and Mental Hygiene began monitoring air pollutants at 150 locations throughout the city in December 2008. Previous reports describe results from the first winter season (December 2008–March 2009), in December 2009 and summer season (June 2009–August 2009), in July 2010. Supplemental reports and other information about NYCCAS are available at nyc.gov/health/nyccas. This report describes the results from 1 year of monitoring, from December 2008 to December 2009, and is limited to the 4 pollutants that were measured year-round.

Methods

NYCCAS was designed according to established scientific methods for studying variations in air pollution, using air samplers mounted on light poles near street level **(Figure 1)**. The 150 sites chosen represent a wide range of traffic, building density and other neighborhood features **(Figure 2)** to allow for comparisons across the city. If, for example, only high-traffic locations were selected in each neighborhood, the data would not be useful for estimating pollution in other locations or for comparison across neighborhoods. There were 3 steps in selecting sites:

(1) The map of New York City was divided into a grid of more than 7,500 cells, each 300 x 300 meters. Cells were classified according to traffic and building density, 2 key indicators of local emissions near the monitoring locations.

(2) 120 "systematic" sites were selected by taking a random sample of locations; high traffic and high building areas were given priority.

(3) 30 "purposeful" sites were assigned to ensure that at least 1 monitor was located in every community district, to fill geographic gaps in the systematic sites, and to ensure sampling of locations of interest, such as high-traffic areas, or areas near transportation facilities or large construction sites.

The resulting sample includes 141 street-side locations and 14 sites in parks **(Figure 2)**. Each of the 150 NYCCAS sites was monitored, from December 2008 to December 2009 for 1 randomly-assigned, 2-week period in each of the 4 seasons from December 2008 to December 2009. Five reference sites—one centrally located in each borough, away from potential pollution sources—were monitored during each 2-week period. Data from these 5 sites were used to adjust the measurements from other sites for variation that occurs across the city over time, mainly due to weather conditions. Four season-specific measurements, adjusted for time, were averaged to compute an annual average concentration for each site.

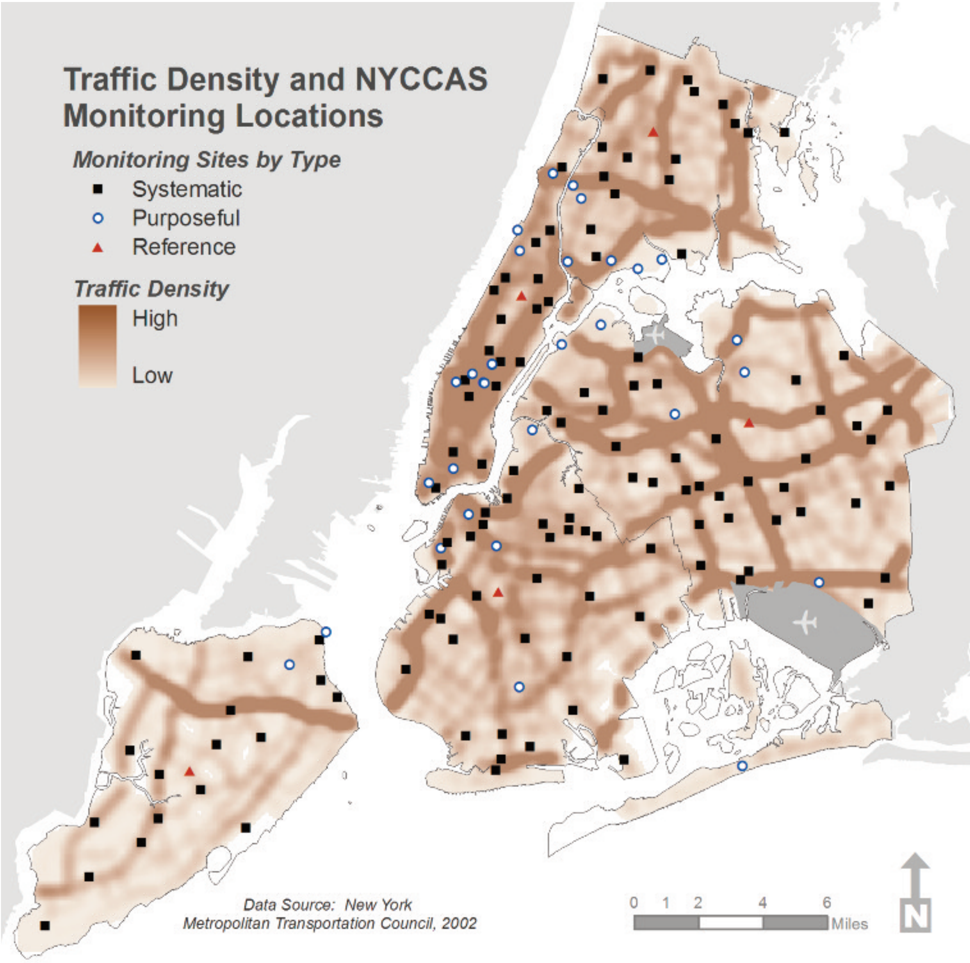
The Winter 2008–2009 report and technical appendices, available at nyc.gov/health/nyccas, provide more details on monitoring methods and quality-control protocols.

Data are analyzed to determine which neighborhood factors and pollution sources predict higher pollutant levels.

While the 150 sites in New York City represent one of the largest and most dense monitoring networks in the country, they do not cover all possible locations in the city. NYCCAS uses a widely-used modeling approach known as land-use regression to provide air pollution estimates for unmonitored locations. Land-use regression has been used previously to study air pollution exposure and health effects in urban areas. The method examines how measured pollution levels vary in relation to traffic, buildings, ground cover and other neighborhood factors near NYCCAS monitor locations. Using the relationship between sources and concentrations of air pollutants at monitored locations, a statistical model is used to estimate annual average air pollution levels throughout city neighborhoods, including locations where no measurements were taken. Further statistical methods were used to smooth the estimates for mapping purposes. More detail on the land-use regression analysis and data sources used to identify factors contributing to air pollution patterns are available online at nyc.gov/health/nyccas.

Figure 1. The New York City Community Air Survey uses portable air samplers mounted 10 to 12 feet from the ground on light poles, close to street level, to collect air samples throughout the 5 boroughs.

Figure 2. New York City Community Air Survey monitoring locations.



Results

Data on average annual pollution levels can provide information on general air quality conditions and exposure to populations. The U.S. Environmental Protection Agency sets certain air quality standards based on annual averages; many epidemiologic studies and data are based on the association between annual average air pollution exposure and health outcomes.

Overall, annual average pollution levels varied widely across locations for each of the 4 pollutants in this report—fine particles ($PM_{2.5}$), elemental carbon (EC), nitric oxide (NO) and nitrogen dioxide (NO_2). Pollution concentrations were strongly associated with geographic patterns of emission sources, such as traffic and buildings. For each pollutant, the data summary contains:

- The range of average concentrations at NYCCAS sites compared to citywide average levels from regulatory monitoring sites
- Average pollutant concentration levels by low, moderate, and high values of the 2 strongest emission source indicators
- A list of other source indicators that were included in the final statistical model
- Maps of estimated pollutant concentrations predicted by the statistical model; the maps show community district boundaries and a reference map labeled with community district numbers is available on page 22. An online annex available at nyc.gov/health/nyccas provides a chart for each pollutant, summarizing the average and range of estimated concentrations by community district.

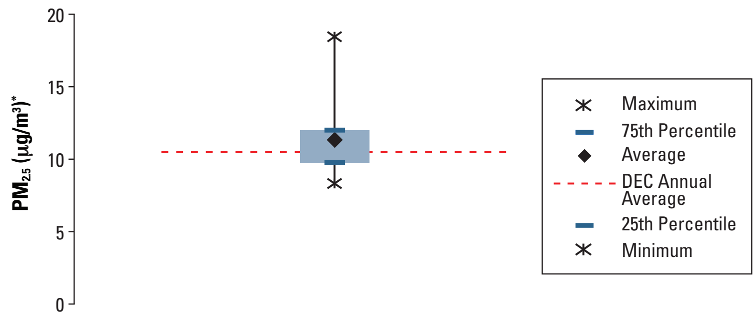
Most of the source indicators identified in the models reflect sources such as traffic within a specified distance (for example, 100 meters) of the sampling location; this does not indicate that more distant sources have no impact at all, only that their influence was not strong enough to be detected in the statistical model.

Fine Particles ($PM_{2.5}$)

Across all NYCCAS sampling sites, after adjusting for differences in weather, annual fine particles ($PM_{2.5}$) at street level averaged 11.3 μg/m^3, compared with 10.5 μg/m^3 at rooftop regulatory monitoring sites **(Figure 3)**. $PM_{2.5}$ concentrations varied from less than 9 μg/m^3 to almost 20 μg/m^3 at NYCCAS sites throughout the city.

These differences in annual average $PM_{2.5}$ concentrations across the sites were most strongly associated with nearby truck traffic **(Figure 4)** and with the density of boilers burning residual heating oil (#4 or #6 grade)[1] **(Figure 5)**.

Figure 3. Annual average $PM_{2.5}$ varies 2-fold across New York City Community Air Survey monitoring sites.§



§ Data show distribution of annual average estimates at 150 NYCCAS sites. New York State Department of Environmental Conservation annual average is calculated using data from the 11 Federal Reference Method monitoring sites within New York City.

* $PM_{2.5}$ = Airborne fine particulate matter that is less than 2.5 micrometers in diameter; μg/m^3 = micrograms per cubic meter

Data source: U.S. Environmental Protection Agency Air Quality System. See the Technical Appendix for calculation methods.

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[1] Number 6 oil is also known as "heavy fuel oil" or residual oil, and is the remainder of crude oil after removing, by distillation, the lighter gasoline and distillate fuel oils. Number 4 oil is a blend of distillate (#2) and residual (#6) fuel oils used in boilers or furnaces for space heating.

In the overall land-use regression model, the following factors were important predictors of annual average $PM_{2.5}$ concentrations at NYCCAS monitoring sites (in order of importance):

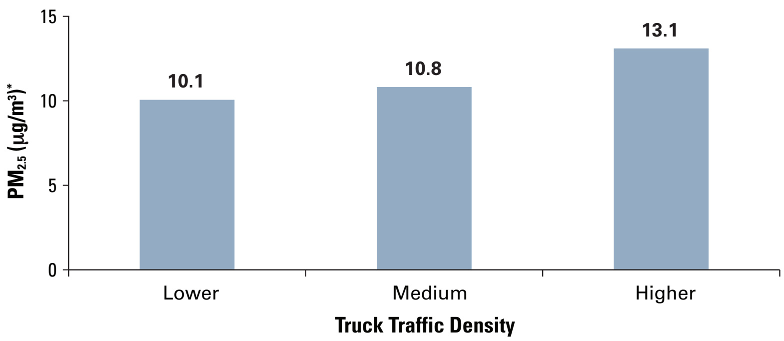
- Average density of truck traffic within 1 mile[2]
- Number of boilers burning residual oil within 1 kilometer
- Area of industrial land use within 500 meters
- Land area with vegetative cover within 100 meters (an inverse association; more vegetative cover was associated with less $PM_{2.5}$)
- Traffic density within 100 meters[2]

The association of $PM_{2.5}$ with industrial land use may partially reflect the presence of additional truck traffic and idling in industrial areas, and localized emissions from industrial equipment, such as generators and boilers. The inverse association with vegetative cover, after accounting for other source indicators, may reflect fewer emission sources in vegetated areas, trapping or deposition of particles by vegetation, or a combination of both. To study this finding further, the association between pollutant concentrations and tree canopy was examined in the summer; data were adjusted for pollution source indicators. Results can be found online in Exploring the Effect of Vegetative Cover on Pollutant Levels. The Health Department is working with the city's Department of Parks and Recreation experts and other scientists to further study the influence of trees on air quality.

The variation in $PM_{2.5}$, while considerable, was less than that for EC, NO and NO_2 because a large portion of $PM_{2.5}$ is produced by major sources outside the city, such as electric power plants in the Midwest. Since local sources, such as traffic, tend to account for the majority of EC and NO_x, these pollutants vary more within the city.

Figure 6 shows the estimated annual average $PM_{2.5}$ concentrations across New York City based on the NYCCAS measurements and land-use regression modeling and smoothing methods. The highest estimated concentrations of $PM_{2.5}$ are evident in areas of the highest traffic and building density, such as in midtown Manhattan. $PM_{2.5}$ concentrations are also relatively higher along highways and major roads. The lowest estimated $PM_{2.5}$ levels are in parts of the outer boroughs, away from major roadways.

Figure 4. Annual average $PM_{2.5}$ levels are 30% higher at sites with higher, compared to lower, truck traffic density.§

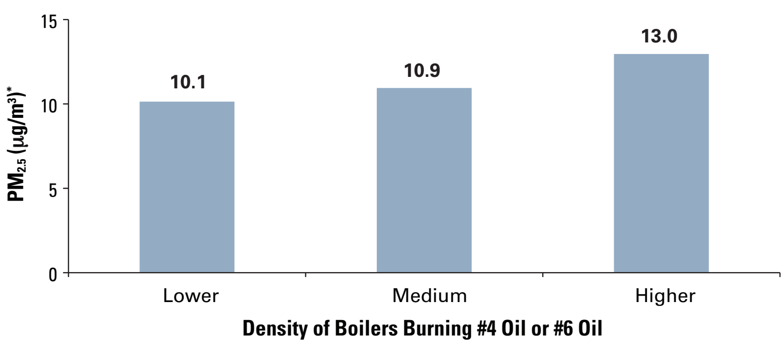


§ Truck Traffic density is estimated based on the average density of truck traffic within 1 mile of sampling locations. Each category includes one-third of sampling sites, with traffic density of lower, 0.03-0.88; medium, 0.88-2.29; and higher 2.29-7.46.

* $PM_{2.5}$ = Airborne fine particulate matter that is less than 2.5 micrometers in diameter; μg/m³ = micrograms per cubic meter

Data source: New York Metropolitan Transportation Council. See Technical Appendix for calculation methods.

Figure 5. Annual average $PM_{2.5}$ is 30% higher at sites in regions of higher, compared to lower, density of boilers burning type #4 or #6 oil.§



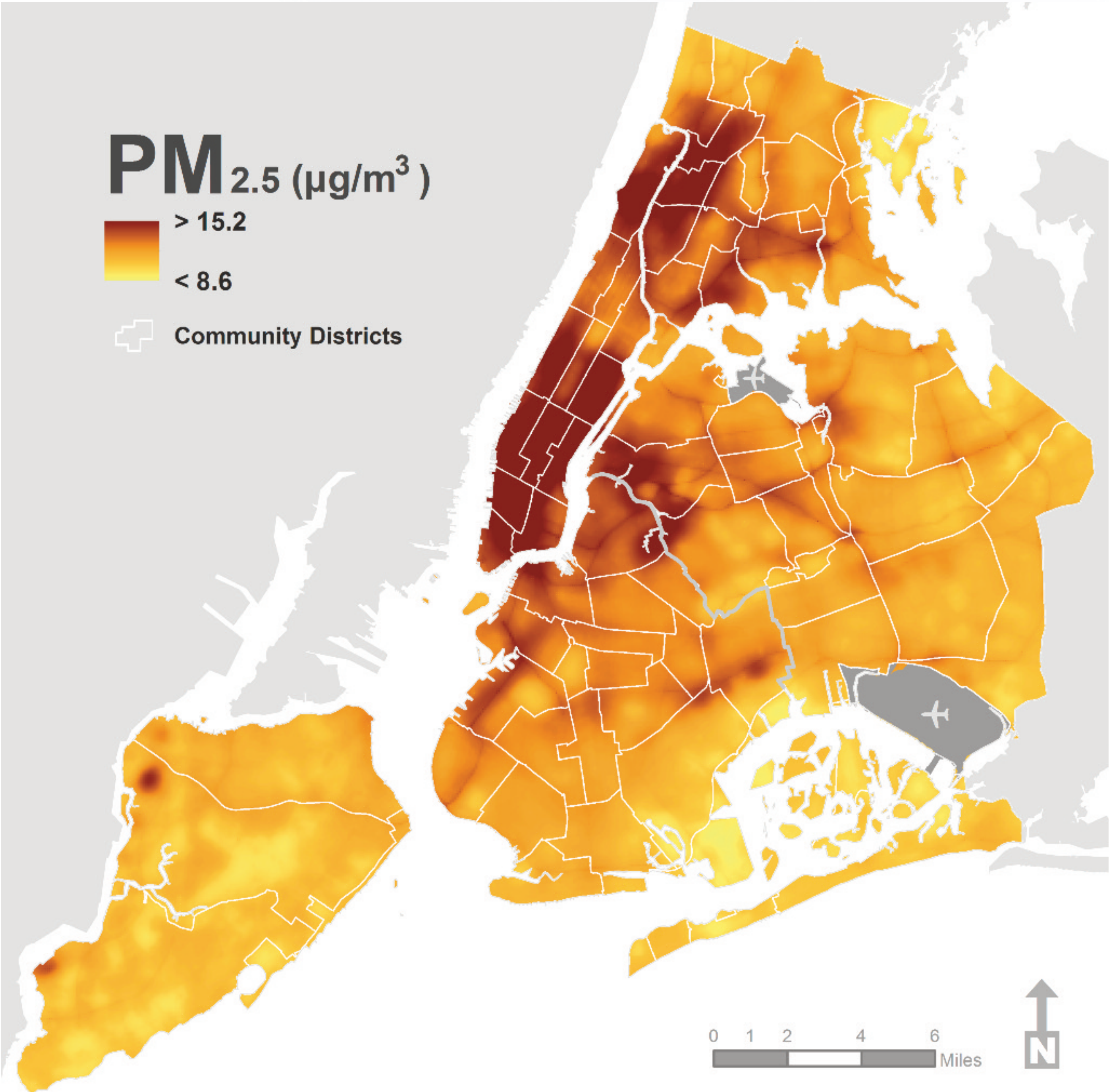
§ Density of oil burning boilers using oil #4 or #6 is estimated within 1 km of sampling location. Each category includes one-third of sampling sites, with count of boilers of lower, 0-4; medium, 4-34 and higher, 34-146.

* $PM_{2.5}$ = Airborne fine particulate matter that is less than 2.5 micrometers in diameter; μg/m³ = micrograms per cubic meter

Data source: New York City Department of Environmental Protection boiler permitting and registration database. See Technical Appendix for calculation methods.

[2] The average was computed using a method that weights traffic on nearby roads more than traffic on distant roads.

Figure 6. Map of estimated $PM_{2.5}$ concentrations, 2008-2009.



* $PM_{2.5}$=fine particulates; ug/m³=micrograms per cubic meter

Elemental Carbon

Elemental carbon (EC) is a component of $PM_{2.5}$. Annual EC concentrations averaged 1.25 absorbance units (abs), which are estimated by measuring the amount of light absorbed by $PM_{2.5}$ deposited on a filter. Higher absorbance indicates larger EC concentrations. EC levels varied significantly across all NYCCAS sites during the year, from just above 0.5 abs to almost 3 abs **(Figure 7)**.

Variations in annual average EC across locations was strongly associated with boiler density. **Figure 8** shows that NYCCAS sampling sites in areas with higher boiler densities (burning any fuel type) had higher EC concentrations (average, 1.6 abs) than sites with lower boiler densities (average, 1.0 abs).

Variations in annual average EC were also strongly associated with nearby truck routes. **Figure 9** shows that sampling sites with at least 1 designated truck route within 100 meters averaged 1.4 abs EC and those with no truck route within 100 meters averaged only 1.1 abs. This finding is consistent with a contribution of diesel emissions to EC concentrations.

The land-use regression model identified the following as important predictors for EC at NYCCAS sample locations (in order of importance):

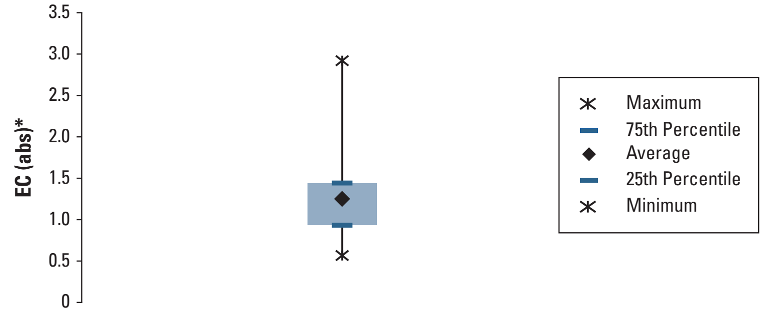
- Boiler density (any fuel) within 200 meters
- Total length of truck routes within 100 meters
- Density of oil burning boilers (grades 2, 4 and 6) weighted by boiler size[3] within 1 kilometer
- Area of industrial land use within 1 kilometer.

As with $PM_{2.5}$, the association of EC with industrial land use may be partially due to truck traffic and idling in industrial areas.

Figure 10 shows higher EC concentrations in Manhattan and the Bronx, and in other areas that have more truck routes, industrial land use, and large buildings that require large heating boilers.

[3] Weighted by boiler rated output in British Thermal Units

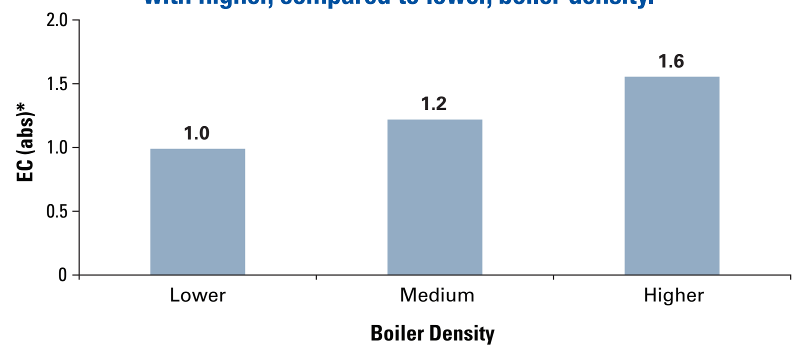
Figure 7. Annual average elemental carbon varies 5-fold across New York City Community Air Survey monitoring sites.§



§ Figure shows distribution of annual average estimates at 150 New York City Community Air Survey sites. See Technical Appendix for calculation methods.

* EC=elemental carbon; abs=absorbance

Figure 8. Elemental carbon levels are 60% higher at sites with higher, compared to lower, boiler density.§

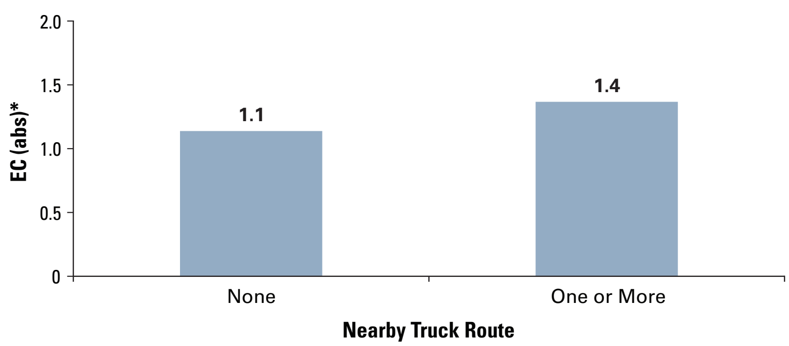


§ Boiler density is estimated based on the number of building boilers registered with the Department of Environmental Protection burning any type of fuel within 200m of each sampling location. Each category includes one-third of sampling sites, with boiler counts of lower, 0-3; medium, 3-18; and higher, 19-188.

* EC=elemental carbon; abs=absorbance

Data source: NYC Department of Environmental Protection (DEP) boiler permitting and registration database. See Technical Appendix for calculation methods.

Figure 9. Annual average elemental carbon levels are 20% higher at sites near a truck route.§

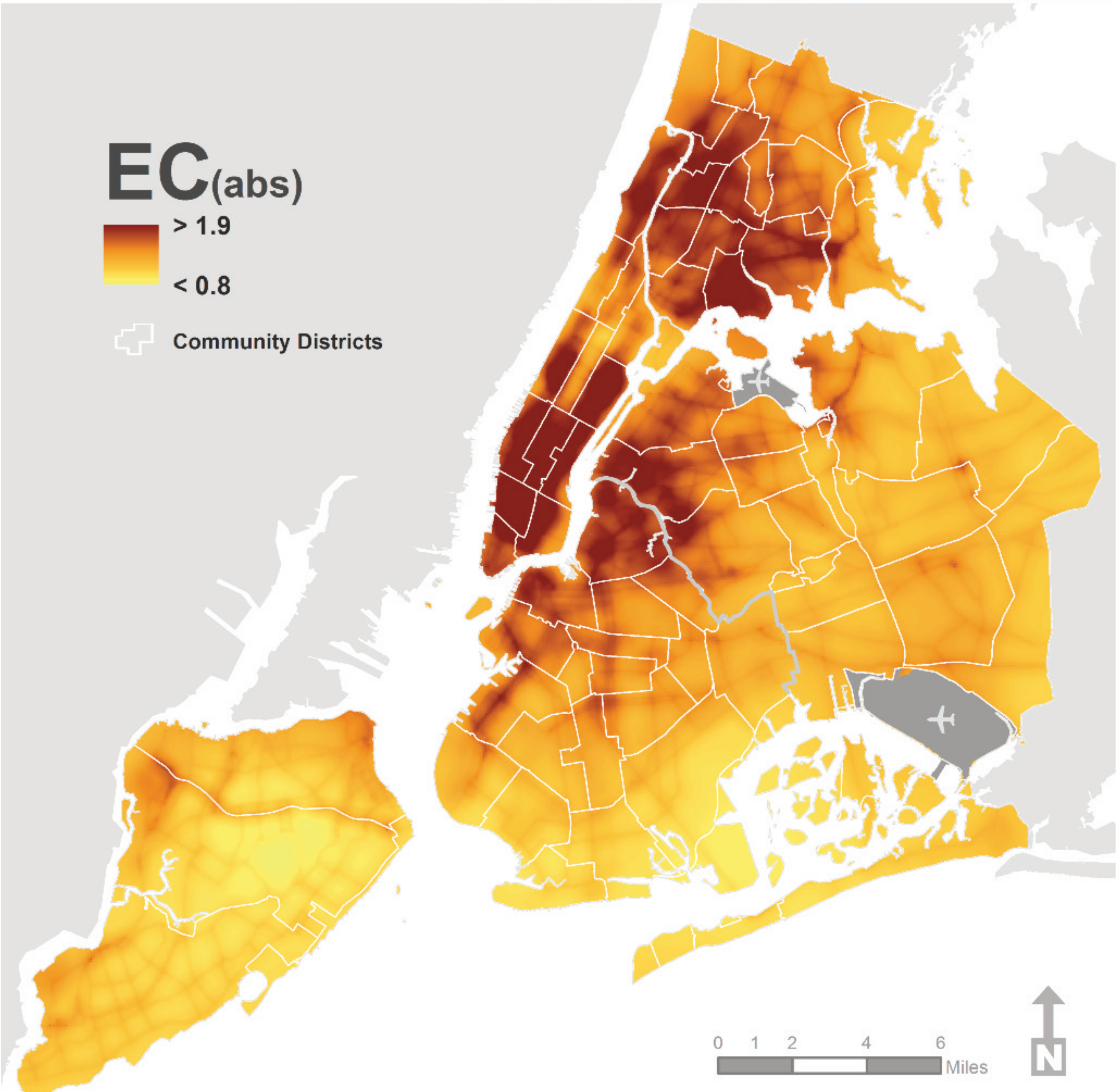


§ Nearby truck routes are those within 100 meters of the sampling location.

* EC=elemental carbon; abs=absorbance

See Technical Appendix for calculation methods.

Figure 10. Map of estimated elemental carbon concentrations, 2008-2009.



* EC=elemental carbon; abs=absorbance

Nitric Oxide

Annual average nitric oxide (NO) averaged about 31 ppb, but varied widely across NYCCAS sites (from less than 10 to almost 130 ppb) **(Figure 11)**.

Differences across locations in annual average NO levels were most closely associated with local building density, which may be an indication of emissions from hot water boilers, cooking and other building-related combustion, but may also reflect congested and idling traffic in densely developed parts of the city.

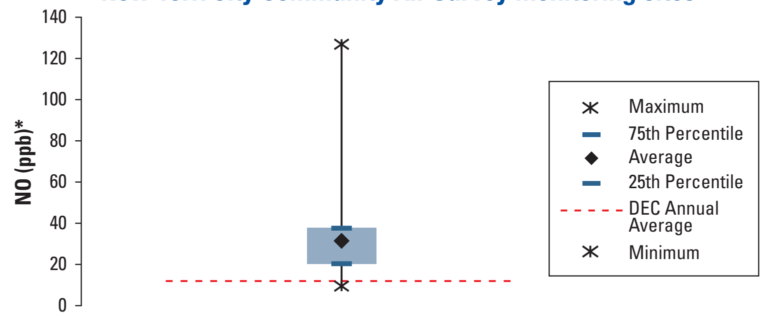
Traffic density within 100 meters of the sampling site also contributed to notable differences in annual average NO concentrations across the city; in areas of heavy traffic, the average was 43 ppb, almost twice that of low-traffic density areas **(Figure 13)**. NO concentrations are high near busy roadways because they are a component of fresh traffic emissions. Rapid conversion of NO to NO_2 by a chemical reaction causes NO concentrations to decline steeply over relatively short distances from roadways.

The land-use regression model approach identified the following as important predictors of NO concentrations at NYCCAS sites:

- Interior square footage of buildings within 1 kilometer
- Traffic density within 100 meters
- Vegetative cover within 100 meters (an inverse association)
- Bus traffic density within 100 meters

Buses tend to travel on busier roads; the association with bus traffic may be partially due to heavy overall traffic on bus routes. The inverse association between NO and vegetative cover may indicate fewer emissions sources in areas with higher densities of green space and trees, or physical and chemical processes associated with trees and plants that may affect NO concentrations (e.g., chemical reactions with leaves, air cooling or differences in relative humidity).

Figure 11. Annual average nitric oxide varies 13-fold across New York City Community Air Survey monitoring sites.§



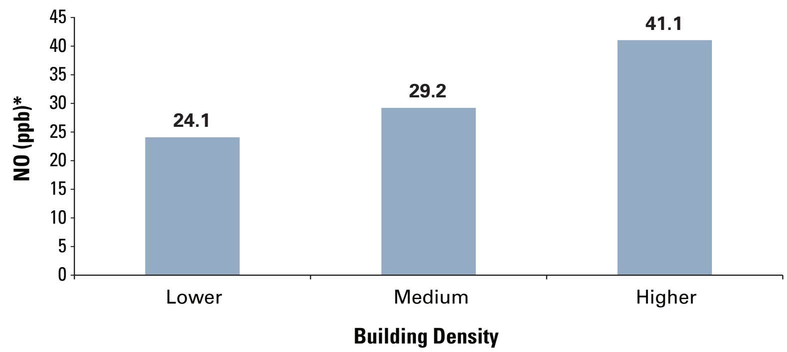
§ Figure shows distribution of annual average estimates at 150 New York City Community Air Survey sites. Department of Environmental Conservation annual average was calculated using data from 3 monitoring sites for NO within New York City.

* NO=nitric oxide; ppb=parts per billion

Data source: U.S. Environmental Protection Agency Air Quality System .

See Technical Appendix for calculation methods.

Figure 12. Annual average nitric oxide levels in areas with high building density are 70% higher than those in areas with low building density.§

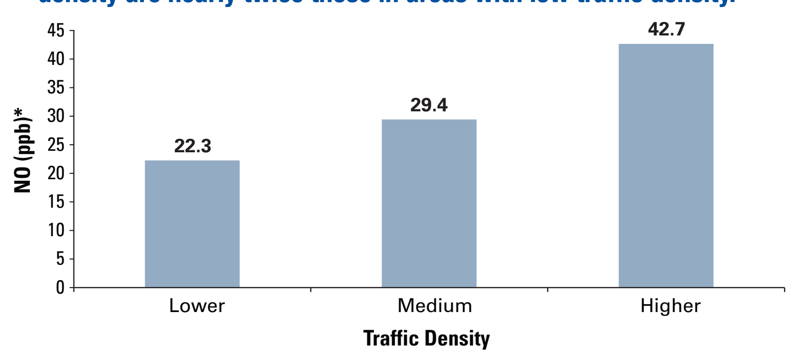


§ Building density is estimated as total interior built space within 1 km. Each category includes one-third of sampling sites, with total interior built space area of lower, 0-1.3; medium, 1.3-3.1; and higher, 3.1-26.1 square kilometers. Visit gov/health/nyccas for calculation methods.

* NO=nitric oxide; ppb=parts per billion

Data source: New York City Planning MapPLUTO buildings data. See Technical Appendix for calculation methods.

Figure 13. Annual average nitric oxide levels in areas with high traffic density are nearly twice those in areas with low traffic density.§

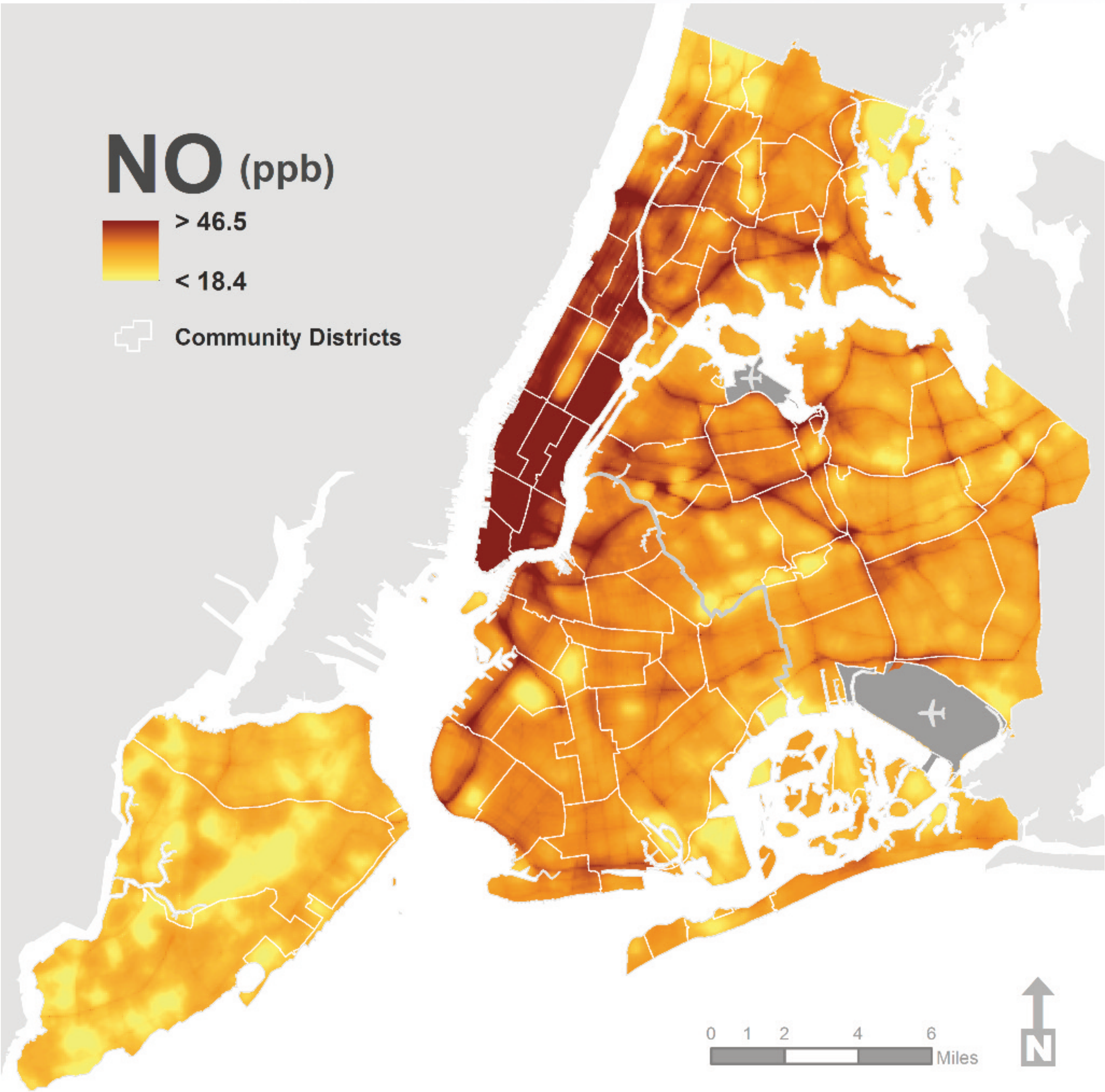


§ Traffic density is estimated based on the length of roads and road types within 100 meters of each sampling location weighted by the average traffic volume by roadway type for each borough. Each category includes one-third of sampling sites, with weighted traffic density of lower, 0-33.4; medium, 33.4-76.8; and higher, 76.8-452.6 vehicle-kilometers per hour.

* NO=nitric oxide; ppb=parts per billion

Data source: Market Planning Solutions Inc. and New York State Office of Cyber Security and Critical Infrastructure. See Technical Appendix for calculation methods.

Figure 14. Map of estimated nitric oxide concentrations, 2008-2009.



* NO=nitric oxide; ppb=parts per billion

Figure 14 shows estimated annual average NO concentrations across the city; concentrations are generally higher in Manhattan, other areas with a high density of buildings, and along major roadways in the outer boroughs.

Nitrogen Dioxide

Annual average nitrogen dioxide (NO_2) averaged about 27 ppb, but ranged from 12 to about 60 ppb across survey sites throughout the city **(Figure 15)**.

Differences in NO_2 across locations were most strongly predicted by density of built space within 1 kilometer of the sampling site and the amount of traffic within 100 meters **(Figures 16 and 17)**.

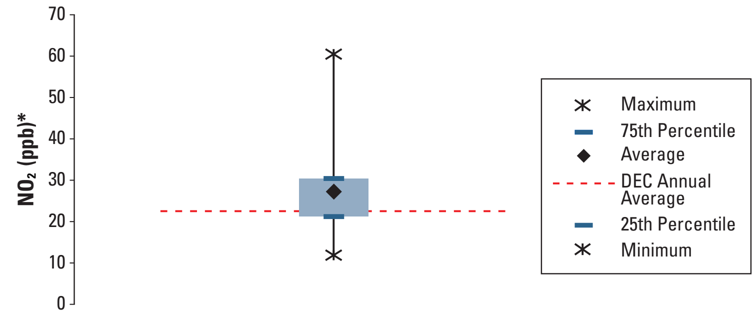
The land-use regression model identified the following as important predictors of NO_2 concentrations at NYCCAS sampling locations:

- Interior square footage of buildings within 1 kilometer
- Traffic density within 100 meters of the sampling site
- Vegetative cover within 100 meters (an inverse association)
- Location on a bus route (compared to non-bus route locations)
- Nighttime population within 1 kilometer

The inverse association between NO_2 and vegetative cover may simply indicate fewer emissions sources in areas with higher plant density, or it may indicate physical and chemical processes associated with plants and trees that affect NO_2 concentrations (e.g., chemical reactions with leaves, air cooling and differences in relative humidity). Most bus routes are also heavily-travelled roads; this effect may be due in part to heavy overall traffic.

Figure 18 shows estimated annual average nitrogen dioxide concentrations across the city. These concentrations are generally higher in Manhattan and other areas with high traffic densities, and along major roadways in the outer boroughs.

Figure 15. Nitrogen dioxide varies 5-fold across New York City Community Air Survey monitoring sites.§

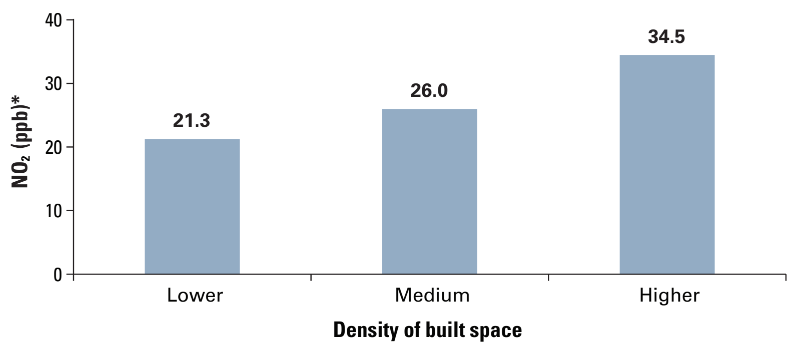


§ Figure shows distribution of annual average estimates at 150 New York City Community Air Survey sites. Department of Environmental Conservation annual average is calculated using data from the 3 monitoring sites for NO_2 within New York City.

* NO_2=nitrogen dioxide; ppb=parts per billion

Data source: U.S. Environmental Protection Agency Air Quality System. See Technical Appendix for calculation methods.

Figure 16. Annual average nitrogen dioxide levels are 60% higher in areas with higher, compared to lower, density of built space.§

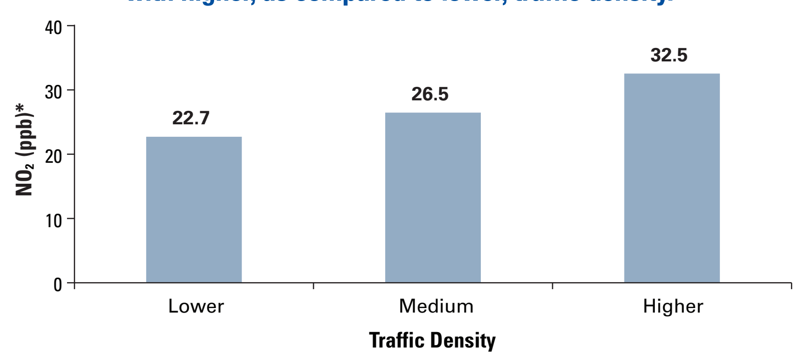


§ Square footage of built space is estimated within 1 km of sampling location. Each category (includes one-third of sampling sites, with built space density of lower, 0-1.34; medium,1.34-3.13; and higher, 3.13-26.08 square kilometers.

* NO_2=nitrogen dioxide; ppb=parts per billion

Data source: New York City Planning MapPLUTO buildings data. See Technical Appendix for calculation methods.

Figure 17. Nitrogen dioxide levels are 43% higher in areas with higher, as compared to lower, traffic density.§

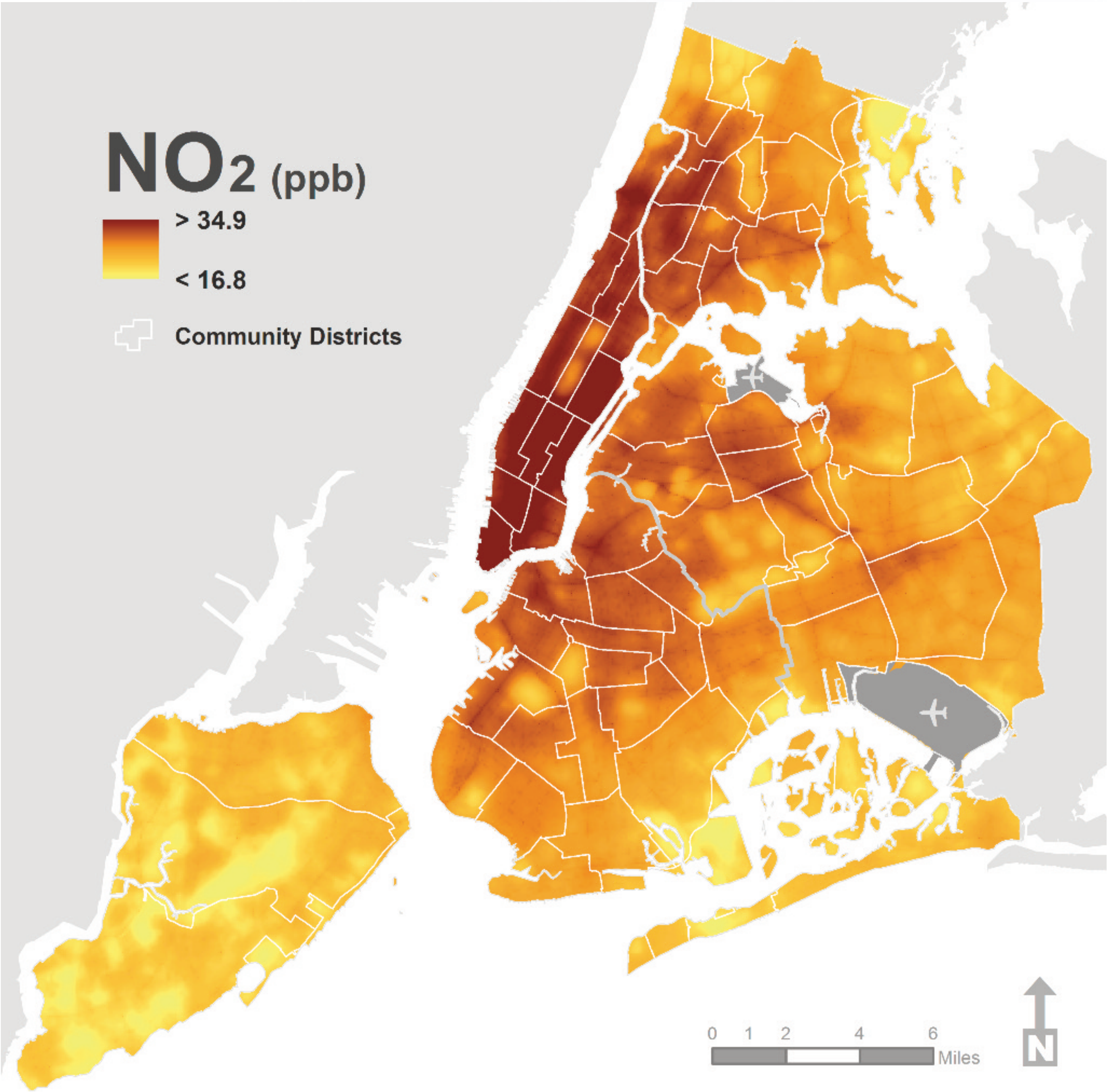


§ Traffic density is estimated based on the length of roads and road types within 100 meters of each sampling location weighted by the average traffic volume by roadway type for each borough. Each category (lower, medium, and higher) includes one-third of sampling sites, with weighted traffic density of lower, 0-33.4; medium, 33.4-76.8; and higher, 76.8-452.6 vehicle-kilometers per hour.

* NO_2=nitrogen dioxide; ppb=parts per billion

Data source: New York Metropolitan Transportation Council. See Technical Appendix for calculation methods.

Figure 18. Map of estimated nitrogen dioxide concentrations, 2008-2009.



* NO_2=nitrogen dioxide; ppb=parts per billion

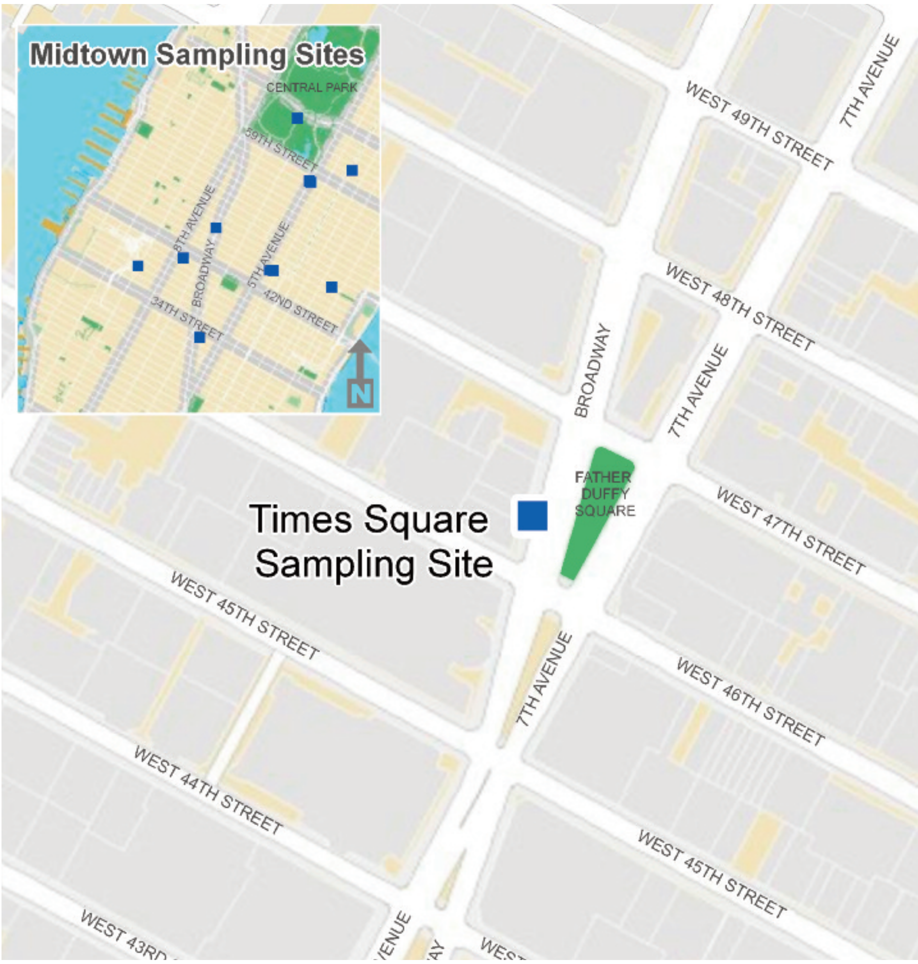
Case Study

Air Quality at Times Square Before and After Pedestrian Plazas Were Established

On Memorial Day weekend 2009, traffic was routed away from Broadway between 42nd and 47th Streets in Times Square, simplifying traffic patterns, reconnecting 7th Avenue through Times Square, and converting 5 blocks of Broadway to pedestrian space for shoppers, office workers and tourists. The project was initiated as a 6-month pilot and was made permanent in early 2010.

The project evaluation showed that travel times improved by 15% for traffic travelling northbound on 6th Avenue and by 7% overall in the project area. The initiative also reduced the number of pedestrian injuries by 35% and increased the number of pedestrians moving through Times Square along Broadway and 7th Avenue by 11 percent. The more than 350,000 daily pedestrians who visit Times Square had additional space; previously, people walking through the area routinely overflowed the sidewalks, creating safety concerns and discouraging many people from visiting the area. Combined traffic volumes on Broadway and 7th Avenue at 44th Street declined from about 2,400 per hour (between 7 a.m. and 8 p.m.) to 1,550 per hour after implementation. See Green Light for Midtown Evaluation Report for more information.

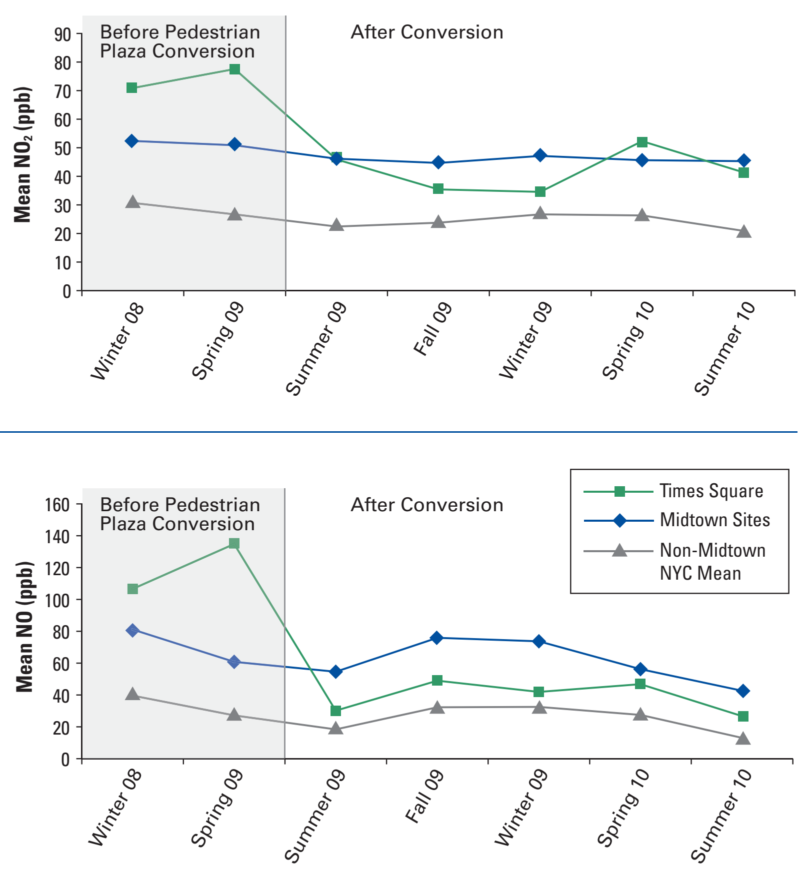
Figure 19. New York City Community Air Survey monitor locations in Times Square.



NYCCAS monitors were placed in Times Square and throughout midtown prior to the traffic closures, including a monitoring site at Broadway between 46th and 47th Streets, near the north end of the pedestrian areas **(Figure 19)**. Data from winter and spring 2009 air monitoring, prior to the closure, showed that concentrations in Times Square of NO and NO_2, 2 pollutants that are closely associated with traffic, were among the highest in city locations, and were much higher than the average in other midtown locations **(Figure 20)**. After the pedestrian plazas were created, concentrations of these same pollutants during the same seasons in the next year were substantially lower and less than in other locations; $PM_{2.5}$ (which is not as strongly related to traffic as NO and NO_2) did not show a consistent decline in the area after the conversion. The NYCCAS monitors also showed that concentrations of traffic-related air pollutants did not worsen in other midtown locations—in fact, they improved slightly.

In combination, these data indicate that, along with improving in traffic flow, safety and available public space, the Times Square project resulted in much less exposure of pedestrians (more than a quarter-million daily) to traffic-related pollutants.

Figure 20. Oxides of nitrogen concentrations at Times Square monitoring sites before and after the conversion to a pedestrian plaza.



* NO_2=nitrogen dioxide; NO=nitric oxide; ppb=parts per billion

Case Study

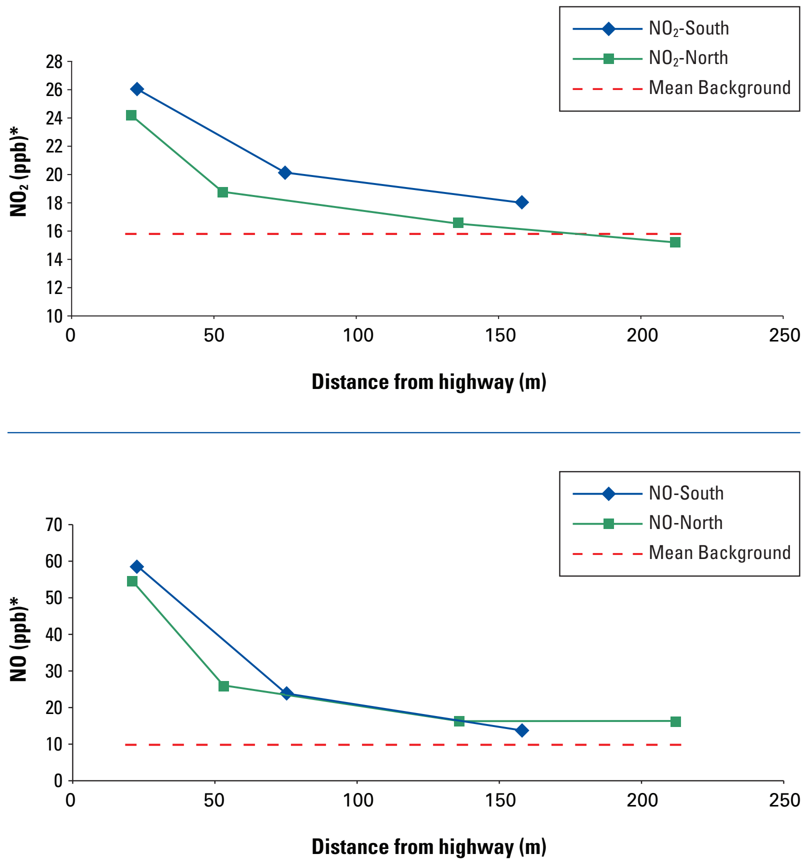
Traffic Pollution on Residential Streets Near the Long Island Expressway

As described in this and prior NYCCAS reports, air samples collected across the city show that oxides of nitrogen (NO and NO_2) are strongly related to traffic; the highest concentrations have been recorded close to busy roadways. To evaluate this pattern near a busy highway with relatively light traffic and no large buildings or other facilities nearby, supplemental air survey monitors were placed for a 2-week period in summer along residential streets, at distances ranging from 20 to 200 meters perpendicular to, and on the north and south sides of, the Long Island Expressway in Eastern Queens **(Figure 21)**.

Figure 21. New York City Community Air Survey monitoring locations along Long Island Expressway, Eastern Queens.

Concentrations of both NO and NO_2 decreased with distance from the Long Island Expressway. NO_2 concentrations within 50 meters of the expressway were 50% higher and NO levels were almost 4 times the concentrations at the monitoring sites more than 150 meters from the highway **(Figure 22)**. These data reflect the pattern that occurs across the city—ambient oxides of nitrogen, which are strongly related to nearby traffic, are higher near busy roadways. While the concentrations measured are lower than in mid-town, the results also show that even in more suburban neighborhoods, residents living nearest to freeways will experience higher exposures to traffic pollutants outdoors near their homes. These exposures could be reduced by a combination of lower traffic volumes and cleaner vehicles on the busiest roadways.

Figure 22. Nitrogen oxide levels decline in areas further away from the Long Island Expressway in Queens, New York City.



* NO=nitric oxide; NO_2=nitrogen dioxide; ppb=parts per billion

Limitations of NYCCAS

The pollution concentrations observed from the 12-month period of December 2008 to December 2009, may differ from concentrations during other years, but citywide patterns are likely to be similar from year-to-year, reflecting a fairly consistent source of major pollution, such as highways.

Land-use regression models cannot evaluate the impact of any single facility or precisely predict concentrations at specific locations, such as at individual street corners or addresses. Despite these limitations, the results are useful for identifying areas of the city with higher or lower pollution levels and common sources, such as traffic, that affect these patterns.

Discussion

Air pollution is a major cause of illnesses and death in New York City and in other urban areas across the United States. Common pollutants in the air emanate from sources that are distant, regional and local; therefore, only a combination of federal, state and local efforts will improve air quality in all New York City neighborhoods. NYCCAS is an important initiative in New York City that informs local actions with concrete data about the city's air pollution problem.

Prior survey findings on wintertime air pollution (see the NYCCAS Winter Report and nickel monitoring Nickel Concentrations in Ambient Fine Particles: Winter Monitoring, 2008-2009) have already helped to spur measures to control and eventually eliminate emissions from an especially polluting type of heating oil, known as residual or grade #6 oil. This report on average air pollution levels across all 4 seasons affirms the importance of heating oil as a local pollution source.

Emissions from traffic also degrade year-round air quality in all 5 boroughs—from traffic-choked Midtown to quieter neighborhoods near major highways. This report details the impact of pollution from traffic in 2 specific locations (near the Long Island Expressway in the spring of 2009 and Times Square before and after traffic closures in May 2009) and the potential for reducing it. Although these findings were not unexpected and have been identified in other cities, NYCCAS, for the first time, contains data on these associations that can inform priorities for local action.

Air pollution levels vary by neighborhood.

NYCCAS monitoring described in this report shows enormous variation in neighborhood air pollutant levels. Pollutants with mostly local sources, such as EC, NO_2 and NO, in particular, can vary 5- to 13-fold from one location in the city to another. While each pollutant has its own unique geographic pattern, the maps of all 4 pollutants show important similarities, such as high levels in midtown and downtown Manhattan, and in sections of the Bronx, Brooklyn, Queens and Staten Island along busy freeways. These high levels are driven in part by a convergence of important emission sources, such as traffic and buildings.

NO_2 is often used as an indicator of traffic pollution. NYCCAS monitoring shows higher NO_2 concentrations close to busy roadways throughout the city; this pattern was confirmed with several samples collected near the Long Island Expressway. The recently updated National Ambient Air Quality Standard for NO_2 establishes a new, 1-hour maximum standard of 100 ppb. This standard creates a need for new monitoring locations near the busiest highways since, throughout the United States, the highest amount of NO_x emissions (38%) emanate from on-road vehicles.

In contrast to what might be expected in less densely-developed cities where highway traffic produces the highest density of NO_x emissions, NYCCAS monitoring shows that the highest NO_2 concentrations citywide are in Manhattan at locations where a number of busy surface roads and large commercial and residential buildings are in close proximity. NO_x emissions from buildings and related stationary sources in the city are 25% of the local total (compared to 3% nationally), nearly as high as the 30% locally from on-road vehicles (U.S. Environmental Protection Agency, 2005). Meeting the new NO_2 standards in the busiest New York City neighborhoods will require new initiatives to reduce both traffic and building emissions. Data from the New York City Department of Transportation and the NYCCAS air pollution monitors in Times Square and other midtown locations show that creating traffic-free pedestrian plazas can immediately improve air quality for pedestrians while maintaining or improving the flow of traffic elsewhere.

Although direct emissions from buildings are highest during the winter heating season, hot water heating and cooking are year-round sources of combustion emissions. Indicators of these in NYCCAS models include density of boilers and, specifically, density of oil-burning boilers (significant predictors of EC), density of residual oil-burning boilers (a significant predictor of $PM_{2.5}$), and building density (a significant predictor of NO_2 and NO).

Building density may also be a measure of vehicle emissions since commercial areas with high concentrations of large buildings also tend to have high volumes of traffic and congestion.

What are the implications of the study for public health?

NYCCAS monitors pollutants that are proven to have adverse health effects at concentrations that are common in the city. The pollutants evaluated for this report include $PM_{2.5}$, which is associated with the exacerbation of cardiovascular and lung diseases (including asthma), and contributes to work and school absences, emergency room visits, hospitalizations and premature mortality. Elemental carbon is a marker of exposure to diesel exhaust, which is linked to chronic lung inflammation, may cause or exacerbate allergies, and is a probable human carcinogen. NO_2 is a respiratory irritant that can exacerbate respiratory illnesses, such as asthma, and also can result in emergency department visits and hospitalizations.

There are factors responsible for the public health impact of New York's air pollution other than concentrations of single pollutants. These pollutants emanate from certain common sources; many New Yorkers are exposed to high concentrations of multiple, harmful pollutants (including those measured in NYCCAS and others, such as benzene and ultra-fine particles). The tendency for higher concentrations of pollutants to occur in densely-populated neighborhoods exacerbates the potential public health impacts of air pollution. In addition, the sectors of the population who are especially susceptible to air pollution (for example, people with asthma), varies greatly across all city neighborhoods.

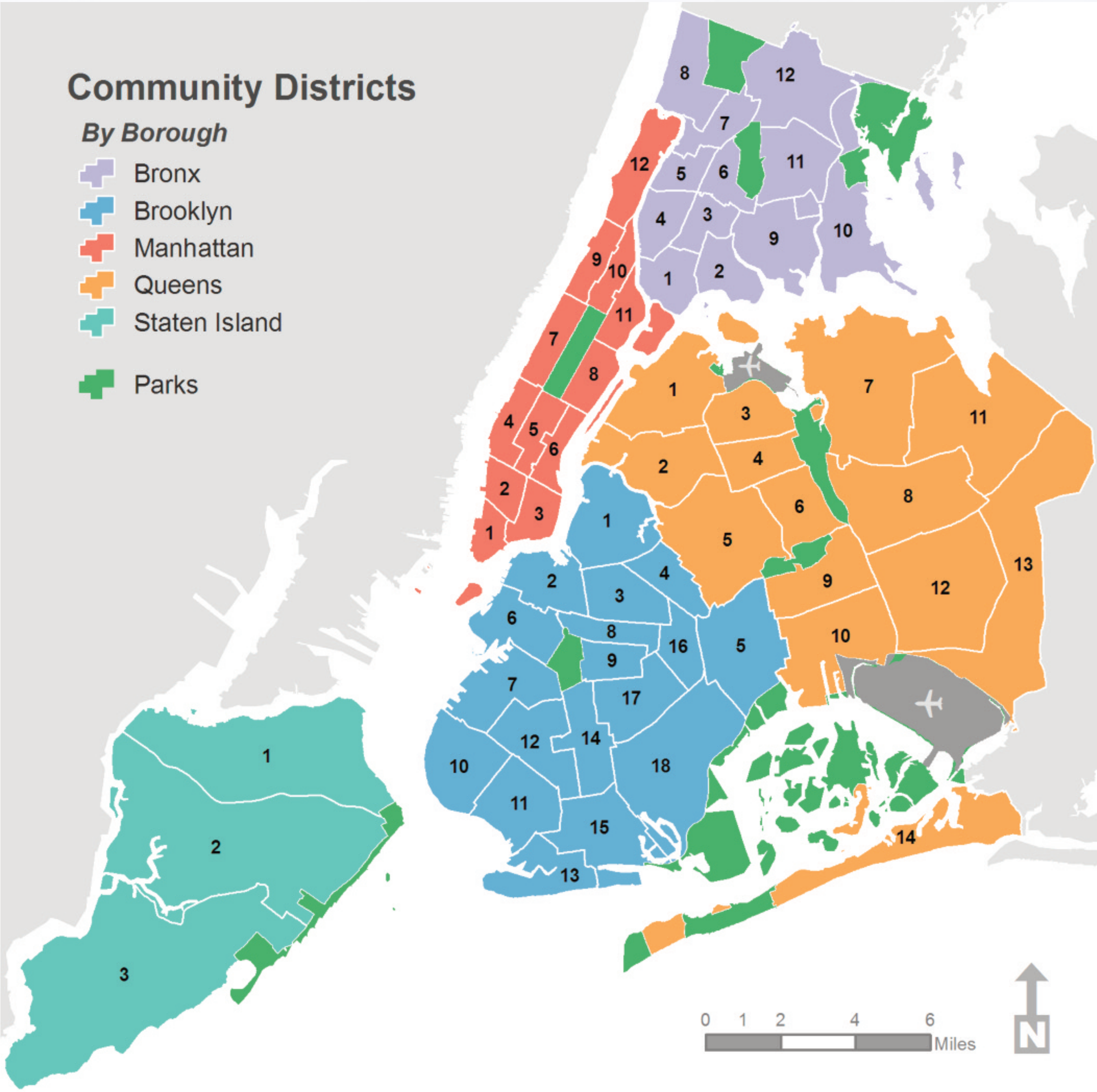
Emissions should be reduced.

The findings in this report affirm the need for more local action to reduce traffic- and building-related emissions, especially in the most polluted parts of the city. Recent state and local measures to reduce, and eventually eliminate, the most polluting heating fuels are expected to result in cleaner air and fewer health impacts. Steps towards making buildings more energy efficient will also reduce emissions from heating and electric power generation.

Traffic-related pollution poses a greater challenge; trucks, cars and buses are all significant contributors. Replacing and retrofitting old, heavy-duty diesel vehicles should be expanded and accelerated. Continued conversion of the taxi fleet to hybrids is a priority, as taxis account for a significant amount of vehicle traffic in midtown Manhattan, adding to already high levels of pollution. Changes in vehicles themselves, however, will produce slow progress at best. The number of private automobile trips must decrease in favor of public transit, biking and walking; such changes will produce cleaner air, reduce CO_2 emissions and increase physical activity. Improvements in access to, and the efficiency of, mass transit should be coupled with planning new housing and commercial development in neighborhoods that are already close to public transit. Creating plazas to separate people from vehicles in some of the city's busiest neighborhoods can significantly improve air quality for pedestrians and create quieter and more pleasant places to walk, shop and enjoy the city.

There are many components to the PlaNYC initiatives to improve air quality; to learn more, visit nyc.gov/html/planyc2030/html/home/home.shtm.

Annex: Reference Map of Community Districts.



Manhattan

Battery Park City, Tribeca (1)
Greenwich Village, SOHO (2)
Lower East Side, Chinatown (3)
Chelsea, Clinton (4)
Midtown Business District (5)
Stuyvesant Town, Turtle Bay (6)
West Side, Upper West Side (7)
Upper East Side (8)
Manhattanville, Hamilton Heights (9)
Central Harlem (10)
East Harlem (11)
Washington Heights, Inwood (12)

Bronx

Melrose, Mott Haven, Port Morris (1)
Hunts Point, Longwood (2)
Morrisania, Crotona Park East (3)
Highbridge, Concourse Village (4)
University Hts., Fordham, Mt. Hope (5)
East Tremont, Belmont (6)
Bedford Park, Norwood, Fordham (7)
Riverdale, Kingsbridge, Marble Hill (8)
Soundview, Parkchester (9)
Throgs Nk.,Co-op City, Pelham Bay (10)
Pelham Parkway, Morris Park, Laconia (11)
Wakefield, Williamsbridge (12)

Brooklyn

Williamsburg, Greenpoint (1)
Brooklyn Heights, Fort Greene (2)
Bedford Stuyvesant (3)
Bushwick (4)
East New York, Starrett City (5)
Park Slope, Carroll Gardens (6)
Sunset Park, Windsor Terrace (7)
Crown Heights North (8)
Crown Heights South, Wingate (9)
Bay Ridge, Dyker Heights (10)
Bensonhurst, Bath Beach (11)
Borough Park, Ocean Parkway (12)
Coney Island, Brighton Beach (13)
Flatbush, Midwood (14)
Sheepshead Bay, Gerritsen Beach (15)
Brownsville, Ocean Hill (16)
East Flatbush, Rugby, Farragut (17)
Canarsie, Flatlands (18)

Queens

Astoria, Long Island City (1)
Sunnyside, Woodside (2)
Jackson Heights, North Corona (3)
Elmhurst, South Corona (4)
Ridgewood, Glendale, Maspeth (5)
Forest Hills, Rego Park (6)
Flushing Bay Terrace (7)
Fresh Meadows, Briarwood (8)
Woodhaven, Richmond Hill (9)
Ozone Park, Howard Beach (10)
Bayside, Douglastown, Little Neck (11)
Jamaica, St. Albans, Hollis (12)
Queens Village, Rosedale (13)
The Rockaways, Broad Channel (14)

Staten Island

Stapleton, Port Richmond (1)
New Springville, South Beach (2)
Tottenville, Woodrow, Great Kills (3)

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NYC Health

QUEENS COLLEGE