The New York City Community Air Survey

Results from Summer Monitoring 2009

NYC
Health

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Letter from the Commissioner and Acting Director

Dear Fellow New Yorker:

PlaNYC, the ambitious sustainability initiative launched in 2007, set in motion a range of initiatives to make New York City a healthier and more livable place. It recognizes that our future growth will require more of some things (housing, heat, electricity and transportation) and less of others, especially air pollution and greenhouse gases. By reducing emissions from buildings, vehicles and other local sources, we can accelerate progress towards giving New York City the cleanest air of any large U.S. city.

PlaNYC's premier air quality initiative, the New York City Community Air Survey (NYCCAS), is the first of its kind in any American city. By systematically assessing street-level air quality in all of our neighborhoods at different times of the year, this survey identifies the leading sources of neighborhood pollution and informs strategies to reduce them. Since its launch in 2008, the Community Air Survey has already yielded important insights. The first two reports, issued in 2009 and 2010, documented significant differences in wintertime pollution among different parts of the city. The current report, the third, uses survey results from 2009 to assess the city's summertime pollution patterns.

Sustainability and public health policies must be grounded in science. By illuminating the local sources and patterns of air pollution and their effects on public health, NYCCAS fills critical gaps in our knowledge. Results from these and future studies will help achieve PlaNYC's goal of improving air quality for all New Yorkers. We hope you will find it useful and informative.

Sincerely,

Thomas Farley

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

Adam Freed

Adam Freed
Acting Director
Office of Long-Term Planning
and Sustainability

Executive Summary

Launched in 2007, PlaNYC, New York City's first comprehensive sustainability plan, proposed a broad and ambitious air quality improvement strategy and several specific initiatives aimed at reducing emissions. As part of the strategy, PlaNYC charged the Department of Health and Mental Hygiene with developing the New York City Community Air Survey (NYCCAS), to provide data on neighborhood air quality. Launched in December 2008, NYCCAS is one of the largest studies to date of urban air quality. The survey measures, year-round at 150 street-level locations throughout the city, common air pollutants that impact public health. NYCCAS then uses these pollution measurements—and the distribution of known pollution sources such as traffic and oil-burning boilers—to estimate concentrations of air throughout the city. The first two NYCCAS reports contained data from the winter of 2008-2009. Those reports highlighted emissions from motor vehicles and from heating fuels (in particular, #4 or #6 heating oil) as sources of air pollution.

This report summarizes findings from NYCCAS air monitoring during the summer of 2009. Concentrations of the five pollutants included in this report—fine particles ($PM_{2.5}$), elemental carbon (EC), nitric oxide (NO), nitrogen dioxide (NO_2) and ozone (O_3)—varied two-fold or more across the monitoring sites. The highest summertime concentrations of $PM_{2.5}$, EC, NO and NO_2 occurred in areas of heavy traffic concentrations—including parts of Manhattan (such as midtown and downtown) and the sections of the Bronx, Brooklyn, Queens and Staten Island that run along busy freeways. Pollution levels were also higher in more populous areas (a significant predictor of $PM_{2.5}$ and EC) and in areas with more large buildings (a significant predictor of NO_2). Both indicators may reflect building-related emissions (from cooking and water heating), or emissions from greater numbers of cars, delivery trucks and diesel-powered buses in densely-populated commercial areas.

Summertime $PM_{2.5}$ was associated with daytime population density and traffic. During the winter, $PM_{2.5}$ was most strongly predicted by building-related emissions for heating; in the summer, this effect was much smaller, as expected. EC was predominantly associated with truck traffic and daytime population, which may also proxy for the effects of heavy truck traffic and general traffic in dense parts of Manhattan.

NO and NO_2 concentrations during the summer differed dramatically throughout the city, and both were predominantly influenced by traffic density. Areas with the greatest traffic density had three times the concentration of NO, and twice the concentration of NO_2, as those with the lowest traffic density.

Summertime ozone concentrations showed a very different geographic distribution than did other pollutants. Because ozone is a secondary pollutant—not directly emitted from sources, but rather formed through chemical reactions of emissions in the presence of sunlight—levels tend to be higher downwind from concentrations of combustion emissions. In locations with high concentrations of nitrogen oxides (NOx) from "fresh" emissions (those directly emitted from a tailpipe or other source), ozone is rapidly consumed in a chemical reaction known as scavenging. As a result, ozone concentrations are often highest in downwind, suburban areas with less traffic, such as the Rockaways and lower Staten Island. Air quality in these communities could be improved through reductions in traffic and other combustion source emissions in the denser parts of the city and metropolitan area.

Trees may have a direct influence on air quality, but the strength of this effect remains unclear. Sites with higher tree density did have slightly lower concentrations of $PM_{2.5}$, EC, NO and NO_2. However, lower concentrations in these areas may be due to fewer local emissions, rather than particle deposition on foliage or chemical reactions between gaseous pollutants and leaf surfaces.

These summertime NYCCAS findings support PlaNYC initiatives to reduce local emissions, especially those from traffic, which is associated with higher levels of multiple pollutants across many neighborhoods. To accelerate progress toward PlaNYC's clean air goals, and to reduce air pollution near busy roadways and in downwind communities, New York City must continue to expand mass transit, facilitate walking and biking, shift to cleaner vehicles, and take other measures to reduce traffic emissions.

By law, PlaNYC must be updated every four years. NYCCAS findings will help inform the next iteration of the plan, to be released in 2011.

Introduction and Background

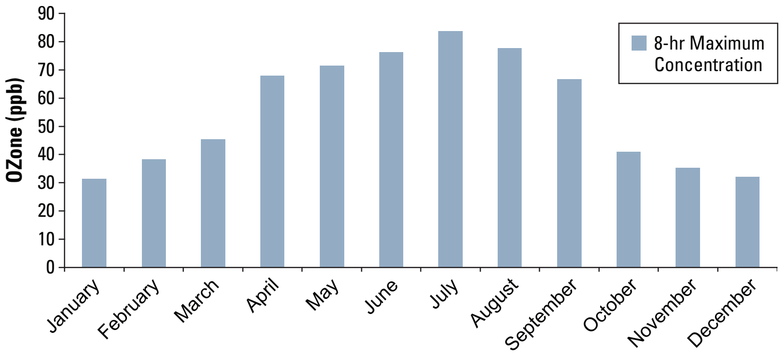
Air pollutants measured by NYCCAS during the summer:

- Fine Particles ($PM_{2.5}$)
- Elemental Carbon (EC)
- Nitrogen Oxides (NO_x)
- Ground-level Ozone (O_3)

In 2007, New York City's first comprehensive sustainability plan, PlaNYC, set the ambitious goal of achieving "the cleanest air quality of any big U.S. city" by 2030 through several City-led initiatives to reduce emissions. To provide data on neighborhood air quality, PlaNYC charged the Department of Health and Mental Hygiene with developing the New York City Community Air Survey (NYCCAS), one of the largest local air quality studies conducted to date. Launched in December 2008, NYCCAS involves measurements of street-level air pollution at 150 locations across the city, in each season of the year.

The first NYCCAS report, published in December 2009, highlighted geographic differences in wintertime air pollution levels across New York City, showing that fine particles, elemental carbon, nitrogen dioxide and sulfur dioxide varied two-fold or more across the monitoring sites within the city. The report found that pollutant concentrations were higher in areas of high traffic volume and high density of buildings with boilers burning fuel oil, particularly residual fuel oil (grade #4 and #6 heating oil). Pollution levels tended to be highest in areas where both traffic and large buildings are concentrated, including parts of midtown, downtown, and northern Manhattan, and sections of the Bronx, Brooklyn and Queens along major highways. A second report released in 2010 documented higher concentrations of airborne nickel, a component of fine particles, in certain neighborhoods, confirming the role of residual oil-burning as an important source of particulate air pollution. These reports and other information about NYCCAS are available at www.nyc.gov/health/nyccas.

Figure 1. Ozone concentrations are highest in the summer months.



Data shows the highest daily eight-hour maximum ozone concentration measured in New York City by month, averaged over the 2007-2009 period.

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

*ppb: parts per billion

Among the goals of NYCCAS are to study air pollution patterns year-round and to identify seasonal differences in emission sources. This report details how air quality varied across New York City neighborhoods during the summer of 2009.

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

The health and well-being of all New Yorkers may be affected by air pollution, but some populations are more susceptible. Chronic health problems such as asthma, emphysema and heart disease may be exacerbated by pollution, resulting in hospital admissions and even deaths, and contributing to shortened life expectancy (Pope et al., 2009). Young children, who are still developing physically, and seniors, may also be more susceptible to air pollution. People without air conditioning at home, school or work may also experience more exposure to outdoor air pollution compared to those in air-conditioned environments.

The sources and levels of harmful air pollutants can vary significantly from season to season. Emissions from space heating sources, for example, add to wintertime pollution. Summertime concentrations are affected by spikes in power plant emissions due to air conditioning use. Ozone is formed by a series of reactions involving NO_x, volatile organic compounds and sunlight, and higher temperatures and more daylight hours increase ozone formation. Thus, ozone levels are higher in the summertime **(Figure 1)** and peak in the early afternoon. Because people generally spend more time outdoors in summer, their exposure to harmful outdoor air pollutants such as ozone may be elevated.

New York City measures important summer air pollutants.

NYCCAS measures the air pollutants that have demonstrated strong associations with public health effects (fine particles [$PM_{2.5}$], elemental carbon [EC], nitrogen dioxide [NO_2] and ground-level ozone [O_3]). Important sources for many of these pollutants within New York City are fuel combustion emissions from vehicles, building heating systems, electric power generators and other sources. Emissions from both within and outside the city contribute to outdoor pollution; pollutants that originate outside the city impact air quality relatively evenly, while sources within the city lead to the observed variation over locations for each pollutant.

NYCCAS is intended to complement essential air monitoring by the New York State Department of Conservation (DEC), as required by the U.S. Environmental Protection Agency (EPA), to track long-term air pollution trends across all major metropolitan areas. The DEC's monitors also capture hourly and daily variations in air quality, but only at a limited number of sites in each city. DEC monitoring is used to gauge air quality in relation to national standards, and to alert the public to days with especially poor air quality.

Fine Particles ($PM_{2.5}$) are small, airborne particles with a diameter of 2.5 micrometers or less. $PM_{2.5}$ 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. It can cause irritation of the airways and exacerbate asthma, and it may increase the risk of lung cancer.

Nitrogen Oxides (NO_x) are gases produced by fuel combustion. They include nitrogen dioxide (NO_2) and nitric oxide (NO). 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.

Ozone (O_3) is not directly emitted; it is formed by a series of reactions involving NO_x, volatile organic compounds and sunlight. Levels peak in summer's long daylight hours and high temperatures. In areas of high nitrogen oxide emissions, however, nitrogen oxides can remove ground-level ozone from the air in a reaction known as scavenging. As a result, urban centers with an abundance of emission sources, such as traffic, tend to have lower concentrations of ozone than do more suburban downwind locations. Exposure to ozone causes irritation and inflammation of the lungs, leading to coughing, wheezing and the exacerbation of asthma. NYCCAS measures ozone concentrations in the summer, when exposures are the highest.

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

The goals of New York City Community Air Survey 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 and published the results from the winter season (December 2008–March 2009) in December 2009. This report describes the results from monitoring conducted during the summer of 2009 (June 2, 2009–August 25, 2009). Additional results will be published in future reports.

Methods

NYCCAS was designed using established scientific methods that study variation in air pollution in other cities. The NYCCAS Winter 2008–2009 report and technical appendices, available at www.nyc.gov/health/nyccas, detail monitoring methods and quality-control protocols.

NYCCAS uses portable air samplers mounted on light poles near street level to study how air pollution varies across the five boroughs **(Figure 2)**. The 150 NYCCAS sites represent a wide range of traffic, building density and other neighborhood features **(Figure 3)**. In contrast, the New York State Department of Environmental Conservation monitors specific pollutants at only 3 to 25 sites around New York City.

To meet NYCCAS goals, the 150 locations were chosen 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.) Traffic and building density—two key sources of local emissions near the monitoring locations—were considered in selecting locations to reflect the wide range of conditions found in New York City. This was accomplished in three steps:

(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. In New York City, locations with high traffic and high building density are concentrated in a relatively small area.

(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 one monitor was located in every community district to fill gaps and near select locations of interest, such as high traffic areas or those near transportation facilities or large construction sites.

The resulting sample includes 141 street-side locations and 14 sites in parks **(Figure 3)**.

Each of the 150 NYCCAS sites was monitored for one randomly-assigned, two-week period in the summer season. Five reference sites—one centrally located in each borough, away from potential pollution sources—were monitored during every two-week period. Data from these five sites were used to adjust the measurements from other sites for variation that occurs across the city over time, mainly due to weather conditions.

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

After passing quality-control procedures, NYCCAS data are summarized to examine overall patterns, estimate the average levels during each two-week period, and map the concentrations geographically, adjusted for monitoring period.

The main NYCCAS analysis uses an approach known as land-use regression (LUR), which has been used to study air pollution exposure and health effects in urban areas. This method examines how measured pollution levels vary in relation to traffic, buildings, ground cover and other neighborhood factors near the NYCCAS monitor locations. Using the relationship between sources and levels of air pollutants at monitored locations, a statistical model is used to estimate air pollution levels throughout city neighborhoods, including locations where no measurements were taken. More detail on the LUR analysis and data sources used to identify factors contributing to air pollution patterns are available online at www.nyc.gov/health/nyccas.

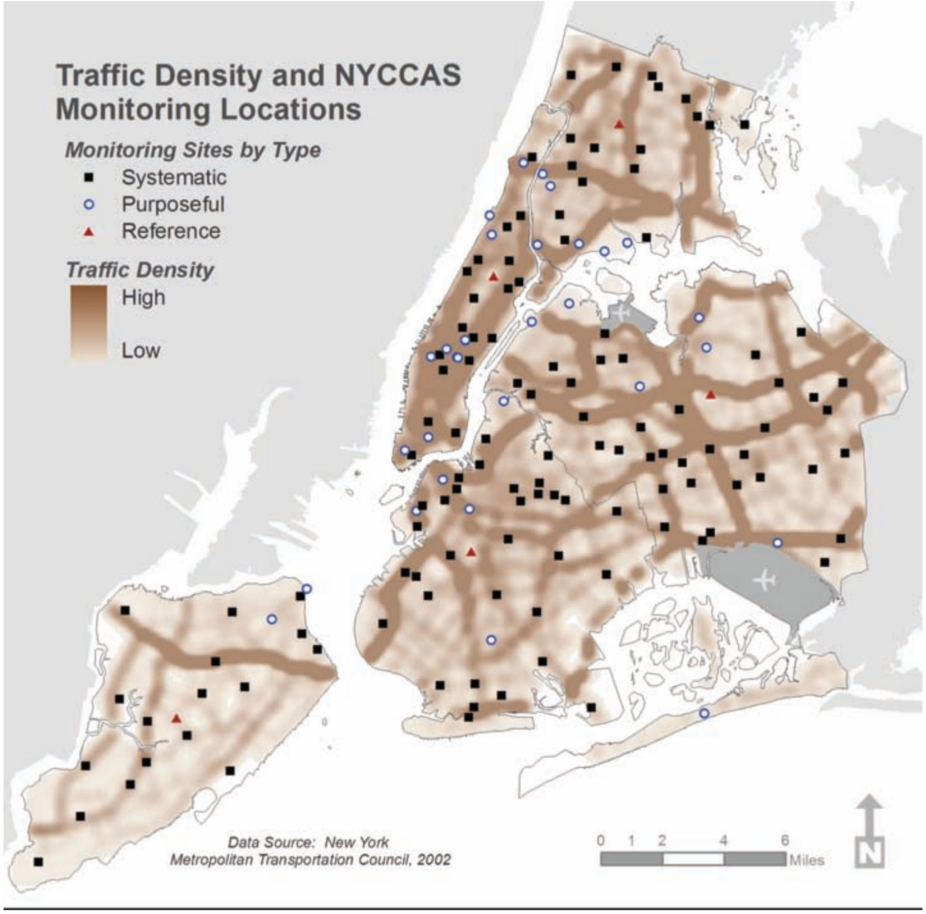
Because ozone is not emitted directly from sources such as tailpipes or boilers, but instead is formed through reactions in the atmosphere, a modified modeling method was applied for predicting ozone levels in unmonitored locations. The method is described in the Results section of this report.

Figure 2. New York City Community Air Survey portable air sampler.

The New York City Community Air Survey uses portable air samplers mounted on light poles close to street level to collect air samples throughout the five boroughs.

- Air samplers are mounted on lamp posts at 10–12 feet.
- Battery-powered, computer-controlled pump- and filter-based collection devices collect fine particles.
- Passive samplers collect nitrogen oxides, sulfur dioxide and ozone.
- Sensors record temperature and relative humidity.
- Elemental carbon is estimated by reflectance analysis of filters.
- Units are deployed once per season for two weeks at each monitoring location to measure average levels during the sampling period.

Figure 3. New York City Community Air Survey monitoring locations.



Data Source: New York Metropolitan Transportation Council, 2002

Results

It is important to note that the data in this report are based entirely on summertime air quality monitoring. They reflect pollution distributions during the summer, along with information about summertime emission sources. The nature of air quality is different in the summer than in winter due to differences in emission sources (e.g., heating emissions are only influential during winter). Weather and sunlight also vary by season and affect pollutant dispersion and chemical reactions in the atmosphere.

These data were collected over one summer (June through August 2009). The pollution concentrations observed that year could differ from those of other years, but citywide patterns should be similar from year to year since the location of major pollution sources, such as highways, are relatively consistent.

The LUR models used to estimate the pollutant concentrations detailed in the maps are based on actual measurements, and may be used to identify areas of the city with higher or lower pollution levels. These models do not, however, predict concentrations at specific locations, such as individual street corners or particular addresses. Although the study can identify important pollution sources, such as traffic or buildings, that are widely but unevenly distributed across the city, it is not designed to evaluate the impact of any single facility on a particular neighborhood. These factors should be taken into consideration when interpreting the study's findings.

Overall, NYCCAS summertime pollution measurements vary widely for each of the five pollutants in this report—fine particles ($PM_{2.5}$), elemental carbon (EC), nitric oxide (NO), nitrogen dioxide (NO_2) and ozone (O_3). As expected, there were significant differences across the six, two-week sampling sessions. These time trends in average pollution levels correlated well with levels at regulatory monitors. The NYCCAS measurements, however, also showed strong differences among locations in summertime air pollution levels across the city. The data show that this variation is strongly associated with geographic patterns of emission sources, such as traffic and buildings. In this data summary, for each pollutant, we provide:

- The range of average concentrations at NYCCAS sites compared to citywide average levels from regulatory monitoring sites,
- Selected emission source indicators and values (low, moderate, high) associated with pollutant levels and trends across locations,
- 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 is available at: www.nyc.gov/health/nyccas, and provides a chart for each pollutant, summarizing the average and range of estimated concentrations by Community District.

Fine Particles

Across all NYCCAS sampling sites, after adjusting for differences in weather, summertime fine particles ($PM_{2.5}$) averaged 11.4 µg/m^3, compared with 10.8 µg/m^3 at regulatory monitoring sites. Temporally-adjusted $PM_{2.5}$ concentrations across the NYCCAS sites showed considerable variation across locations, ranging from less than 9 µg/m^3 to almost 20 µg/m^3 at NYCCAS sites distributed throughout the city **(Figure 4)**.

These differences in $PM_{2.5}$ concentrations across NYCCAS sites were associated with daytime population density and traffic; sites with the highest daytime population densities within 1 kilometer had $PM_{2.5}$ concentrations 22% higher, on average, than sites with the lowest daytime population densities **(Figure 5)**. Higher daytime population density is an indicator of multiple combustion emissions sources, including building-related emissions such as hot water heating, cooking and higher traffic density.

Traffic emissions were also an important contributor to $PM_{2.5}$ concentrations. Sites in the highest third of overall traffic density near the monitor (within 100 meters) had $PM_{2.5}$ levels 15% higher, on average, than sites in the lowest third of traffic density **(Figure 6)**.

Using the LUR modeling approach, the following factors were important predictors for $PM_{2.5}$ concentrations across the city:

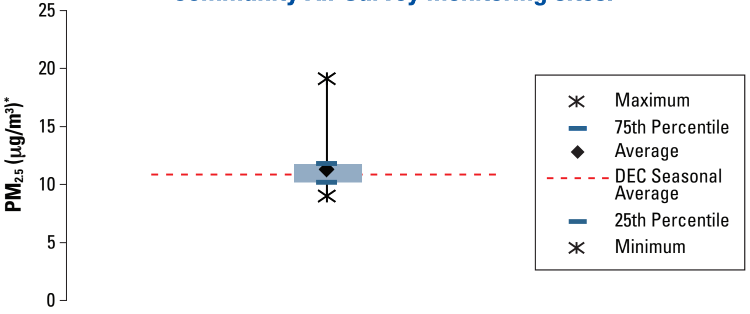
- Daytime population density within 1 kilometer,
- Traffic density within 100 meters of the sampling site,
- Truck traffic within 1 kilometer of the sampling site,
- Tree cover within 100 meters of the site (an inverse association; more tree cover was associated with less $PM_{2.5}$).

Sampling sites with more tree cover within 100 meters had slightly lower $PM_{2.5}$, on average, after they were adjusted for population and traffic indicators. Although some $PM_{2.5}$ is deposited on tree foliage, it is unclear how much this changes $PM_{2.5}$ concentrations at street level. It is important to note that areas with more trees tend to have fewer roadways and buildings; therefore, tree density may indicate an absence of pollution sources, rather than, or in addition, to the physical deposition of fine particles on tree leaves.

This variation among locations in $PM_{2.5}$, while considerable, was less than that for EC, NO and NO_2. This is because $PM_{2.5}$ is also produced by major sources outside the city, such as electric power stations in the Midwest. Total $PM_{2.5}$ concentrations are also strongly influenced by meteorological factors, such as wind speed and direction, and mixing height (the atmospheric height below which urban pollutants mix). Because local sources tend to account for the majority of EC and NO_x, these vary more across locations within the city.

Figure 7 shows estimated summertime $PM_{2.5}$ concentrations across New York City based on the NYCCAS summertime measurements and LUR modeling and smoothing methods. Notably, higher estimated concentrations of $PM_{2.5}$ are evident in Manhattan and the Bronx, especially in areas of high population and traffic density, such as in midtown. $PM_{2.5}$ 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.

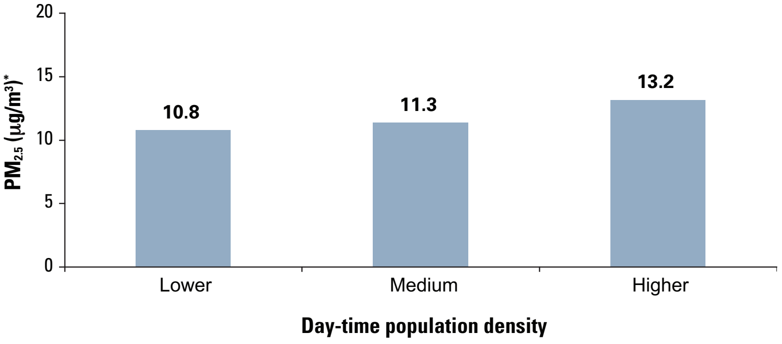
Figure 4. Summertime $PM_{2.5}$ varies two-fold across New York City Community Air Survey monitoring sites.



Data shows distribution of 145 temporally-adjusted New York City Community Air Survey measurements. New York State Department of Environmental Conservation (DEC) seasonal average is calculated using data from the 11 Federal Reference Method (FRM) New York State DEC monitoring sites for $PM_{2.5}$ within New York City. See Technical Appendix at www.nyc.gov/health/nyccas for calculation methods.

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

Figure 5. $PM_{2.5}$ is 22% higher at sites with higher, compared to lower, daytime population density.

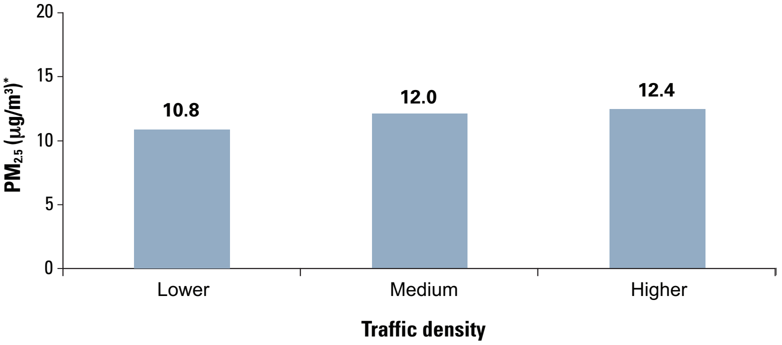


Daytime population is estimated within 1 km of sampling location. Each category (lower, medium, and higher) includes one-third of sampling sites, with day-time population of 0-23,278, 23,278-51,893, and 51,893-770,034 persons within 1 km, respectively. See Technical Appendix at www.nyc.gov/health/nyccas for calculation methods.

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

Data source: Oak Ridge National Laboratory LandScan database measurements

Figure 6. $PM_{2.5}$ levels are 15% greater at sites with higher, compared to lower, traffic density.

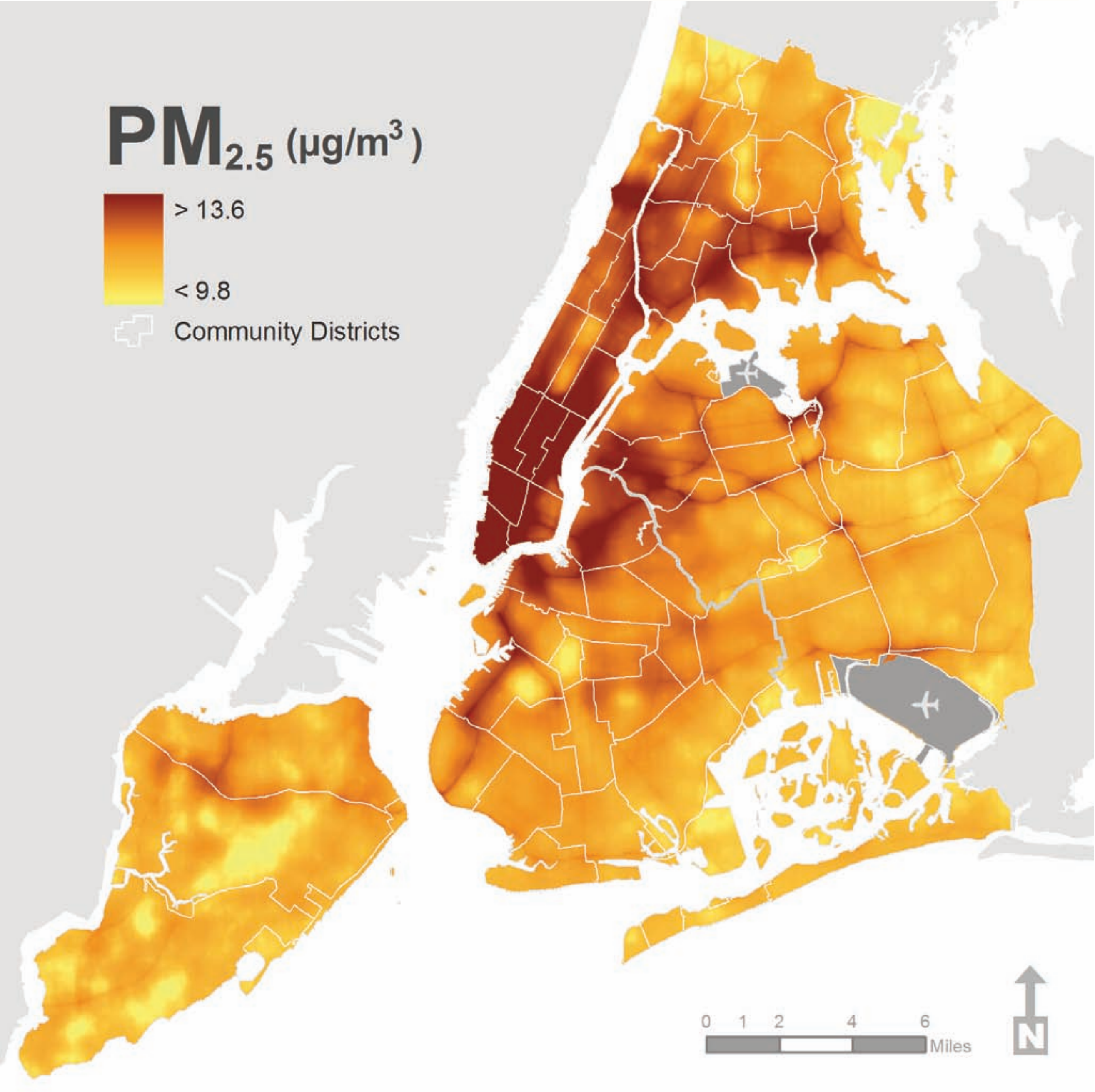


Traffic density is estimated using the length of roadways within 100 meters of each sampling location, weighted by the average traffic volume by roadway type for each borough. Each category (lower, medium, and higher) includes one-third of sampling sites, with traffic density of 0-33.8, 33.8-74.8, 74.8-452.6 vehicle-kilometers per hour, respectively. See Technical Appendix at www.nyc.gov/health/nyccas for calculation methods.

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

Data source: MPSI Traffic Count Data and New York State Office of Cyber Security and Critical Infrastructure

Figure 7. Map of estimated $PM_{2.5}$ concentrations, summer 2009.



See Technical Appendix (www.nyc.gov/health/nyccas) for calculation methods.

Elemental Carbon

Elemental carbon (EC) is a component of $PM_{2.5}$. EC concentrations averaged 1.5 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 showed significant variability across all NYCCAS sites during the summer season, from less than 1 abs to almost 4 abs, averaging 1.5 abs **(Figure 8)**.

Variability in EC across locations was strongly associated with truck traffic. **Figure 9** shows that NYCCAS sampling sites with a higher density of truck traffic within 1 kilometer averaged 1.7 abs EC and those with low densities averaged only 1.0 abs. This finding is consistent with results from other studies in which EC has been linked to diesel emissions from truck and buses.

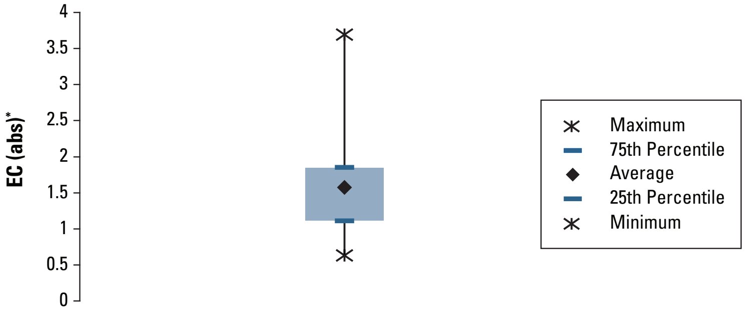
Total traffic also contributed significantly to EC concentrations—sampling sites in higher-traffic areas had higher EC concentrations (average, 1.6 abs) than sites with less traffic (average, 1.1 abs) **(Figure 10)**.

The land-use regression modeling approach identified the following as important predictors for EC across locations:

- Truck traffic within 1 kilometer,
- Traffic density within 100 meters of the sampling site,
- Daytime population within 1 kilometer,
- Tree cover within 100 meters of the site (an inverse association).

In this model, daytime population may reflect building-related fuel combustion and may also reflect emissions from trucks and buses associated with traffic congestion and idling in commercial areas. These factors may not be fully captured by other traffic indicators. The inverse effect for tree cover indicates that areas with more trees have slightly lower EC concentrations, on average. As with $PM_{2.5}$, it is not clear whether tree density in this model is a proxy for lower source densities in areas with more trees, an effect of deposition on tree leaves, or both.

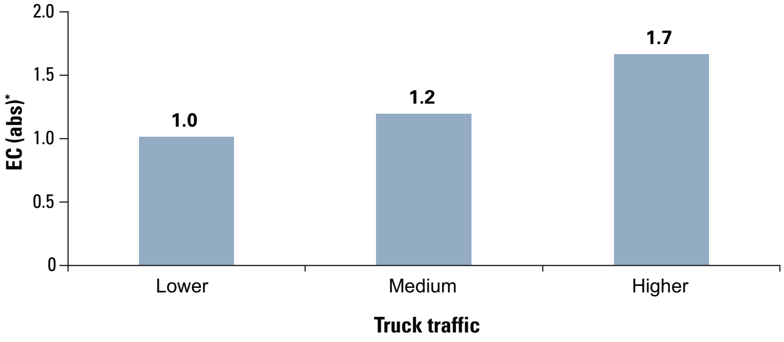
Figure 8. Elemental carbon varies six-fold across New York City Community Air Survery monitoring sites.



Data shows distribution of 145 temporally-adjusted NYCCAS measurements. See Technical Appendix at www.nyc.gov/health/nyccas for calculation methods.

*EC = Elemental Carbon; abs = absorbance

Figure 9. Elemental carbon levels are 64% higher at sites with higher, compared to lower, levels of truck traffic.

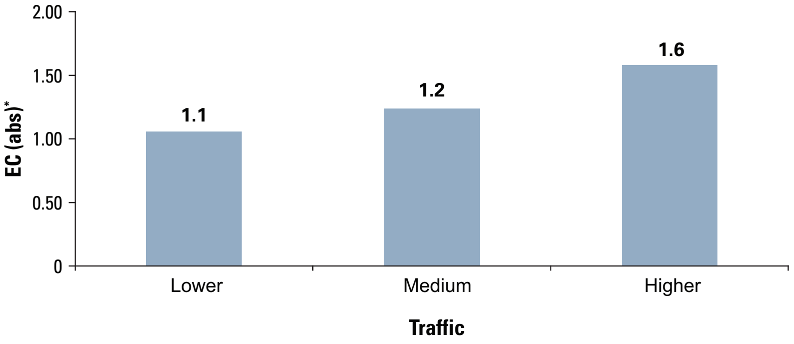


Nearby truck traffic is estimated as total length of truck routes within 1 km of sampling location. Each category (lower, medium, and higher) includes one-third of sampling sites, with truck route lengths of 1.3-5.1, 5.1-8.7, 8.7-21.8 kilometers, respectively. See Technical Appendix at www.nyc.gov/health/nyccas for calculation methods.

*EC = Elemental Carbon; abs = absorbance

Data source: New York Metropolitan Transportation Council

Figure 10. Elemental carbon levels are 50% higher at sites with higher, compared to lower, levels of total traffic.

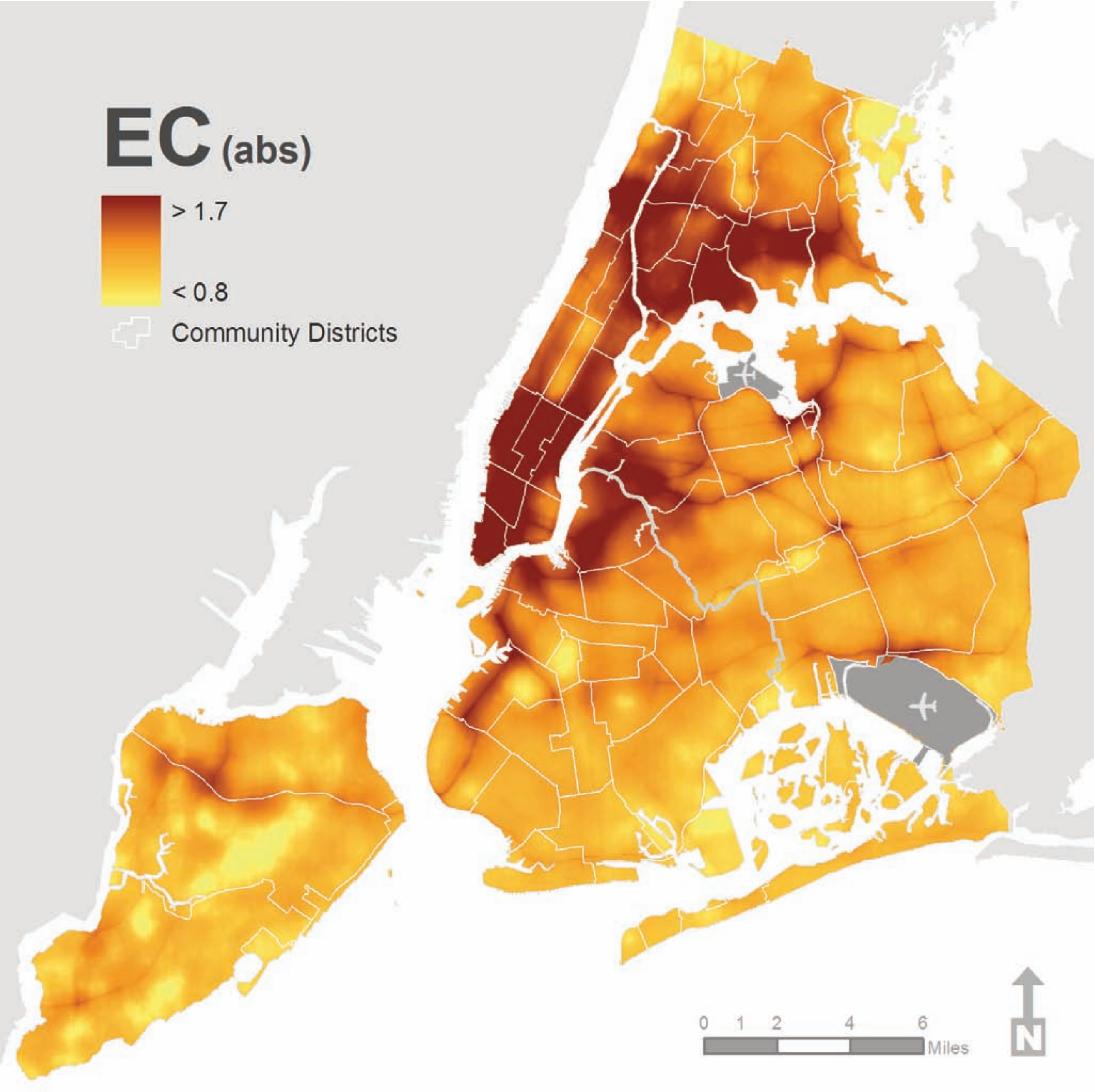


Traffic density is estimated using the length of roadways within 100 meters of each sampling location, weighted by the average traffic volume by roadway type for each borough. Each category (lower, medium, and higher) includes one-third of sampling sites, with traffic density of 0-33.4, 33.4-73.5, 73.5-452.6 vehicle-kilometers per hour, respective See Technical Appendix at www.nyc.gov/health/nyccas for calculation methods.

*EC = Elemental Carbon; abs = absorbance

Data source: MPSI Traffic Count Data and New York State Office of Cyber Security and Critical Infrastructure

Figure 11. Map of estimated elemental carbon concentrations, summer 2009.



See Technical Appendix (www.nyc.gov/health/nyccas) for calculation methods.

Figure 11 shows EC in higher concentrations in Manhattan and the Bronx, and other areas with high truck traffic, total traffic and higher daytime populations. Lower concentrations were noted in the parts of the outer boroughs with less traffic.

Nitric Oxide

Across all summertime sampling sessions and sites, nitric dioxide (NO) averaged about 21 ppb, but varied greatly across NYCCAS sites throughout the city (from less than 10 to almost 120 ppb) **(Figure 12)**.

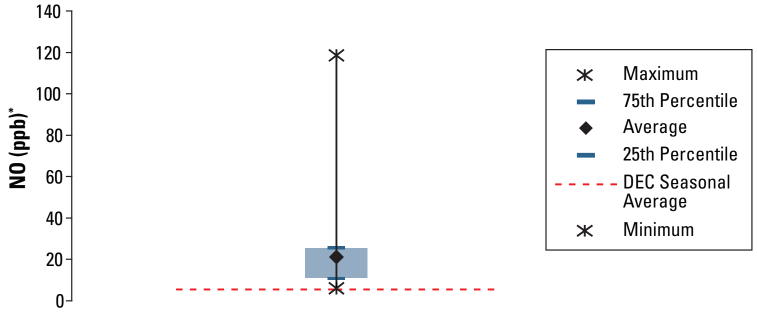
Differences across locations in NO were most closely associated with traffic density within 100 meters of the sampling site; amounts in areas of heavy traffic averaged 30.4 ppb, almost three times higher, on average, than in areas of low traffic density **(Figure 13)**. NO, a component of fresh emissions, has been associated with nearby traffic density in other cities as well.

Local building density also contributed to notable differences in NO concentrations across the city. Sampling sites in areas of high building density (more than 3.1 kilometers built space within 1 kilometer of the sampling site) had average NO levels of 28.4 ppb; the average level was 14.9 ppb in low building density sites **(Figure 14)**. Building density 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.

The land-use regression modeling approach identified the following as important predictors for NO distribution:

- Traffic density within 100 meters of the sampling site,
- Interior square footage of buildings within 1 kilometer of the sampling site,
- Tree density within 100 meters of the sampling site (an inverse association).

Figure 12. Nitric oxide varies 21-fold across New York City Community Air Survey monitoring sites.

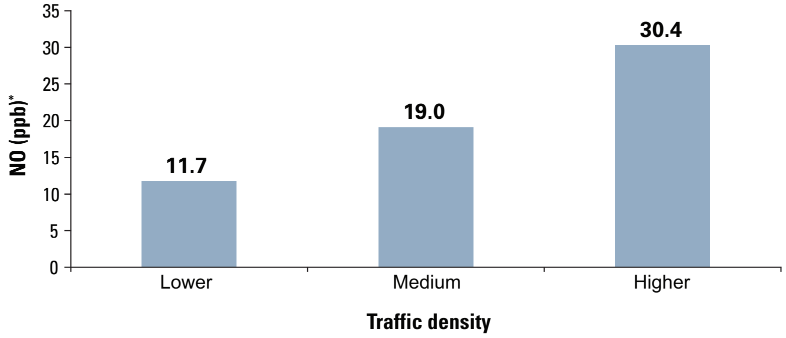


Data shows distribution of 150 temporally-adjusted NYCCAS measurements. Department of Environmental Conservation (DEC) seasonal average was calculated using data from the DEC three monitoring sites for NO in New York City. See Technical Appendix at www.nyc.gov/health/nyccas for calculation methods.

*NO = Nitric Oxide; ppb = parts per billion

Source: US EPA Air Quality System

Figure 13. Nitric oxide levels in areas with high traffic density are nearly three times higher than in areas with low traffic density.

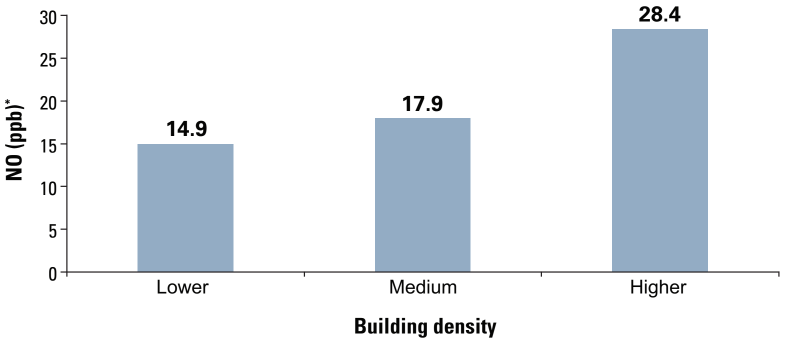


Traffic density is estimated using the length of roadways within 100 meters of each sampling location, weighted by the average traffic volume by roadway type for each borough. Each category (lower, medium, and higher) includes one-third of sampling sites, with weighted traffic densities of 0-33.8, 33.8-74.8, 74.8-452.6 vehicle-kilometers per hour, respectively. See Technical Appendix at www.nyc.gov/health/nyccas for calculation methods.

* NO = Nitric Oxide; ppb = parts per billion

Data source: MPSI Traffic Count Data and New York State Office of Cyber Security and Critical Infrastructure

Figure 14. Nitric oxide levels in areas with high building density are nearly twice those in areas with low building density.

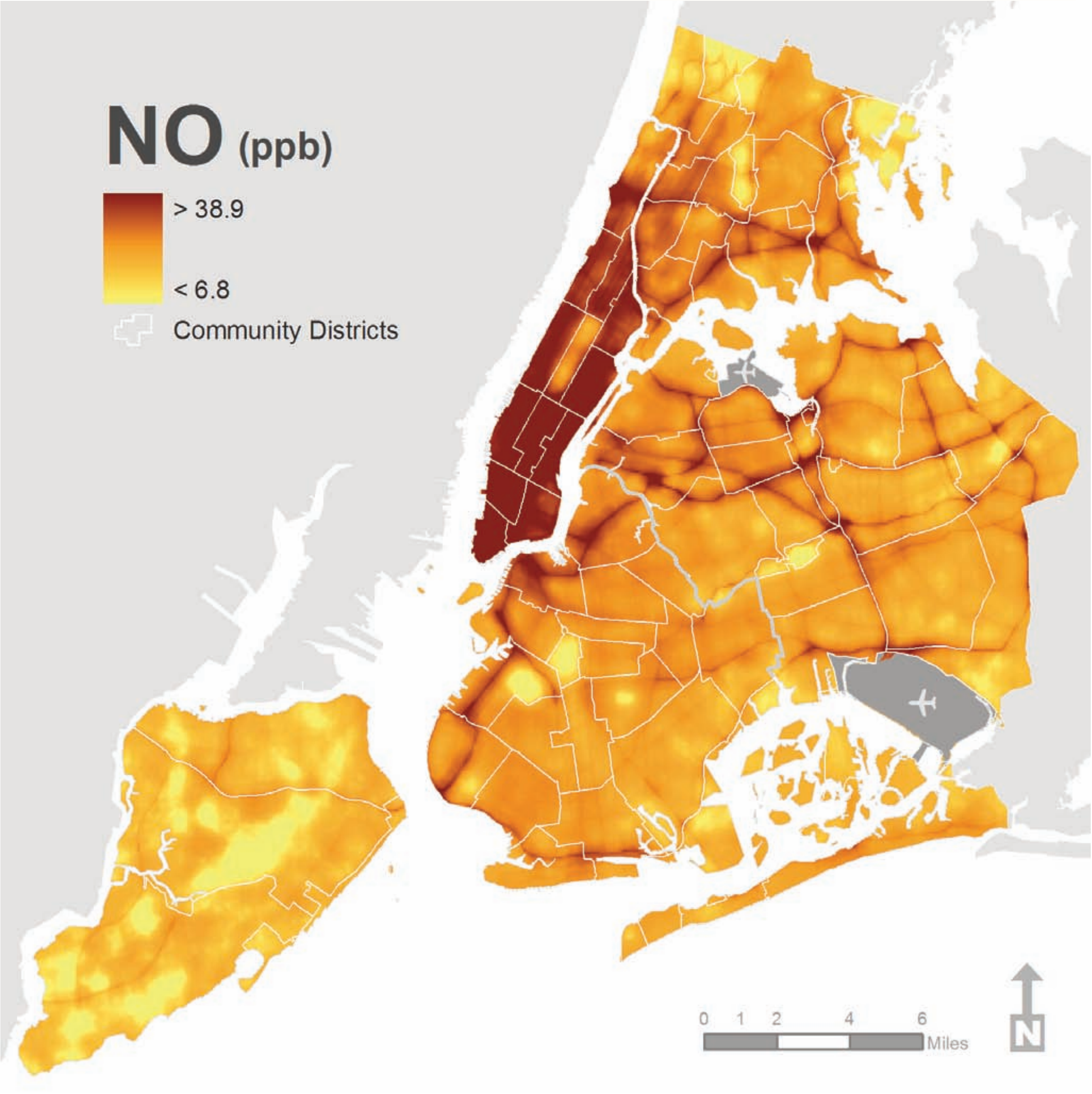


Building density estimated as total interior built space within 1 km. Each category (lower, medium, and higher) includes one-third of sampling sites, with total interior built space area of 0-1.4, 1.4-3.1, 3.1-26.1 square kilometers, respectively. See Technical Appendix at www.nyc.gov/health/nyccas for calculation methods.

*NO = Nitric Oxide; ppb = parts per billion

Data source: New York City Planning Map PLUTO buildings data.

Figure 15. Map of estimated nitric oxide concentrations, summer 2009.



See Technical Appendix (www.nyc.gov/health/nyccas) for calculation methods.

The inverse association between NO and tree density may indicate fewer emissions sources in areas with higher tree density, or it may indicate physical and chemical processes that may affect NO concentrations near trees (e.g., chemical reactions with leaves, air cooling or differences in relative humidity).

Figure 15 shows estimated average summertime 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

Across all wintertime sampling sessions and sites, nitrogen dioxide (NO_2) averaged about 24.0 ppb, but varied greatly across NYCCAS sites throughout the city (from less than 10 to about 60 ppb) **(Figure 16)**.

Differences in NO_2 across locations were most strongly predicted by traffic density within 1 kilometer of the sampling site. Concentrations in areas of high traffic density averaged 32.5 ppb, almost twice as high those as in areas of low traffic density **(Figure 17)**.

Bus traffic density also contributed to variations in NO_2 concentrations across the city. Sites near heavy bus traffic (within 100 meters) had average levels of about 30 ppb and low density sites had average NO_2 levels of about 21 ppb **(Figure 18)**. Most bus routes are also heavily-travelled roads; this effect may be due in part to heavy overall traffic.

The land-use regression modeling approach identified the following as important predictors for NO_2 distribution:

- Traffic density within 1 kilometer of the sampling site,
- Bus traffic density within 100 meters of the sampling site,
- Tree density within 100 meters of the sampling site (an inverse association).

Figure 16. Nitrogen dioxide varies seven-fold across New York City Community Air Survey monitoring sites.

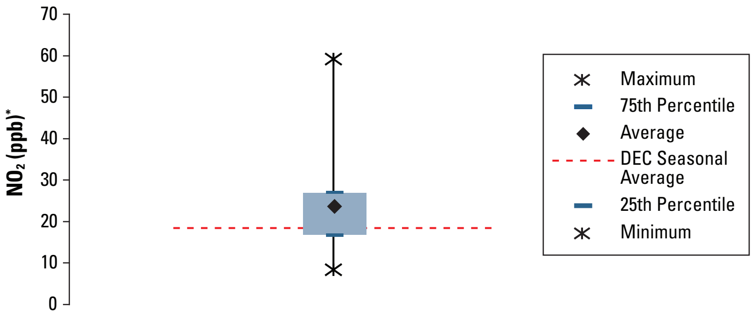
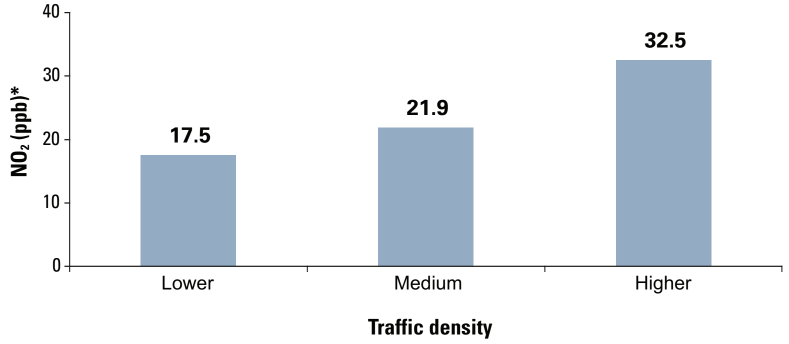


Figure shows distribution of 150 temporally-adjusted NYCCAS measurements. DEC seasonal average is calculated using data from the three DEC monitoring sites for NO_2 within New York City. See Technical Appendix at www.nyc.gov/health/nyccas for calculation methods.

*NO_2 = nitrogen dioxide; ppb = parts per billion

Data source: New York State Department of Environmental Conservation Air Monitoring Center data (www.dec.ny.gov/airmon/index.php)

Figure 17. No$_2$ levels in areas with high traffic density are nearly twice those in areas with low traffic density.

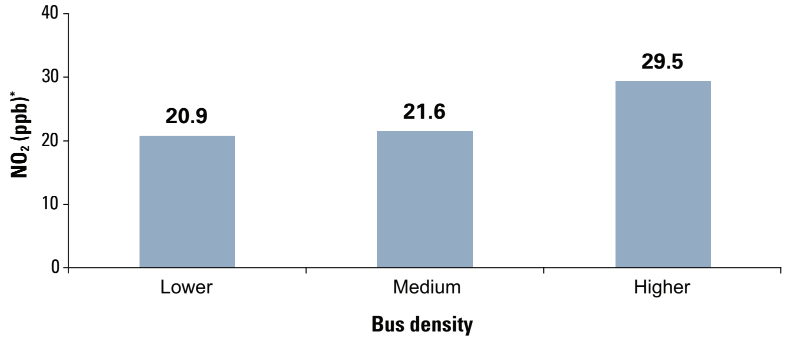


Nearby traffic is estimated within 1 km of sampling location. Each category (lower, medium, and higher) includes one-third of sampling sites, with a weighted traffic density of 1.9-24.2, 24.2-37.3, 37.3-74.9 vehicle-kilometers per hour, respectively.

*NO_2 = nitrogen dioxide; ppb = parts per billion

Data source: New York Metropolitan Transportation Council

Figure 18. Nitrogen dioxide levels are 40% higher at sites with higher, compared to lower, densities of bus traffic.

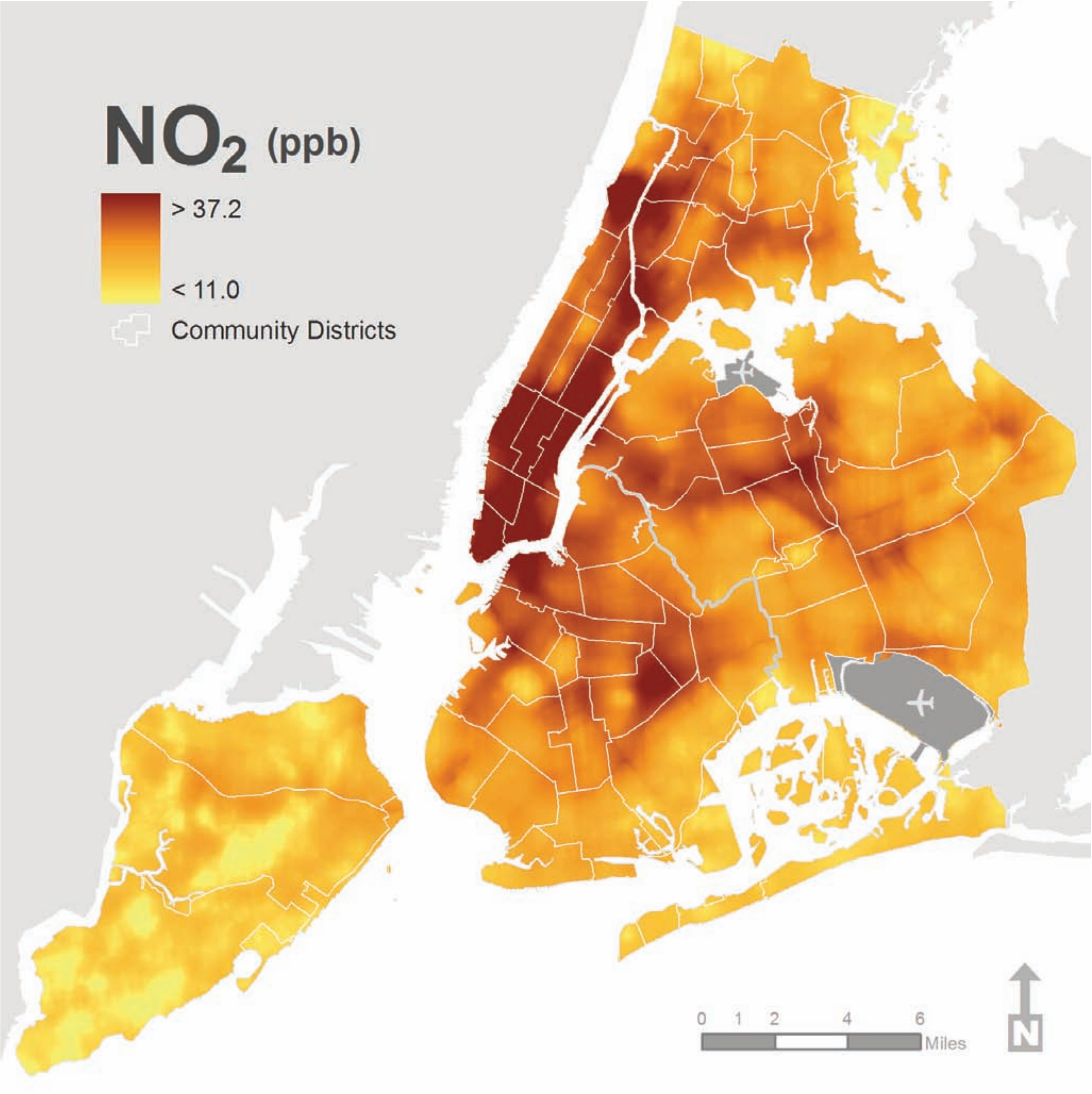


Density of bus traffic within 100 meters of sampling locations. Each category (lower, medium, and higher) includes one-third of sampling sites, with bus traffic of 0-0.1, 0.1-1.5, 1.5-23.8 vehicle-kilometers per hour respectively. See Technical Appendix at www.nyc.gov/health/nyccas for calculation methods.

*NO_2 = nitrogen dioxide; ppb = parts per billion

Data source: New York Metropolitan Transportation Council

Figure 19. Map of estimated nitrogen dioxide concentrations, summer 2009.



See Technical Appendix (www.nyc.gov/health/nyccas) for calculation methods.

For NO, the inverse association between NO_2 and tree density may simply indicate fewer emissions sources in areas with higher tree density, or it may indicate physical and chemical processes that affect NO_2 concentrations near trees (e.g., chemical reactions with leaves, air cooling and differences in relative humidity).

Figure 19 shows estimated average summertime NO_2 concentrations across the city. NO_2 concentrations are generally higher in Manhattan and other areas with high traffic densities, and along major roadways in the outer boroughs.

Ozone

Ozone (O_3) is different from the other pollutants in this report because it is a secondary pollutant, formed through reactions in the atmosphere. When NO and NO_2 are emitted from a vehicle's tailpipe, they combine with other airborne pollutants, in a reaction enabled by sunlight, to form ozone. Therefore, measured ozone concentrations are often highest downwind from high-emissions areas.

Another feature of ozone chemistry is that high concentrations of NO_x from fresh combustion emissions can react with O_3 and scavenge (reduce) apparent O_3 concentrations in the immediate vicinity of roadways or other fresh emissions sources.

O_3 concentrations averaged 24.3 ppb across NYCCAS sampling sites, which was lower than at regulatory monitors **(Figure 20)**. This is likely because regulatory monitors are generally located away from local emissions sources; there is probably less chemical scavenging of ozone at these sites than at NYCCAS sites.

Within the city, the pattern for O_3 across locations can be broadly described as the opposite of the NO_2 pattern—areas of high NO_2 (reflecting higher concentrations of fresh emissions from traffic or building heating systems) tend to have lower concentrations of O_3, and vice-versa.

The land-use regression modeling approach identified the following as important predictors for O_3 distribution:

- NO_2 concentrations at the same monitor and,
- Tree density within 100 meters of the sampling site (an inverse association).

Higher tree density was associated with lower O_3 concentrations, but only after adjusting for the pattern across locations for NO_2. (A simple comparison between only O_3 and tree cover showed that areas with more tree cover had higher O_3 levels). Because NO_2 and O_3 interact chemically, and both may be influenced by tree cover, it is difficult to quantify the precise effect of tree cover on ozone. The observed effect of tree density in this model may reflect characteristics of the chemical conversion between NO_x and O_3, which is different in shaded than in non-shaded areas. On the other hand, this effect may suggest uptake by (or deposition on) tree leaves, or other physical and chemical factors that can affect NO_x-O_3 chemical processes near trees (e.g., VOC emissions from foliage, air cooling and differences in relative humidity).

Figure 21 depicts model-predicted summertime average O_3 concentrations across New York City. Concentrations are estimated to be higher in areas with fewer large emissions sources, such as highways or large buildings. Higher ozone concentrations were evident in some less populated suburban areas, such as the Rockaways and lower Staten Island.

Figure 20. Ozone varies four-fold across New York City Community Air Survey monitoring sites.

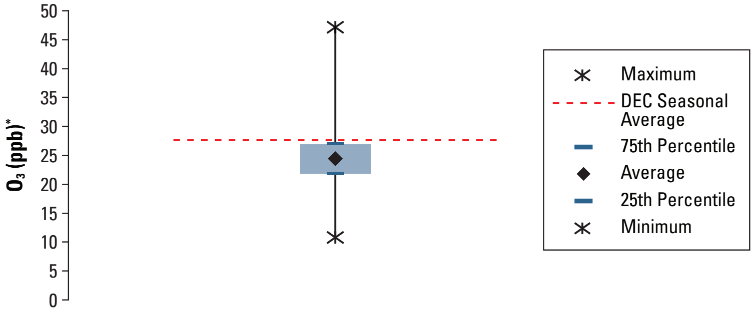
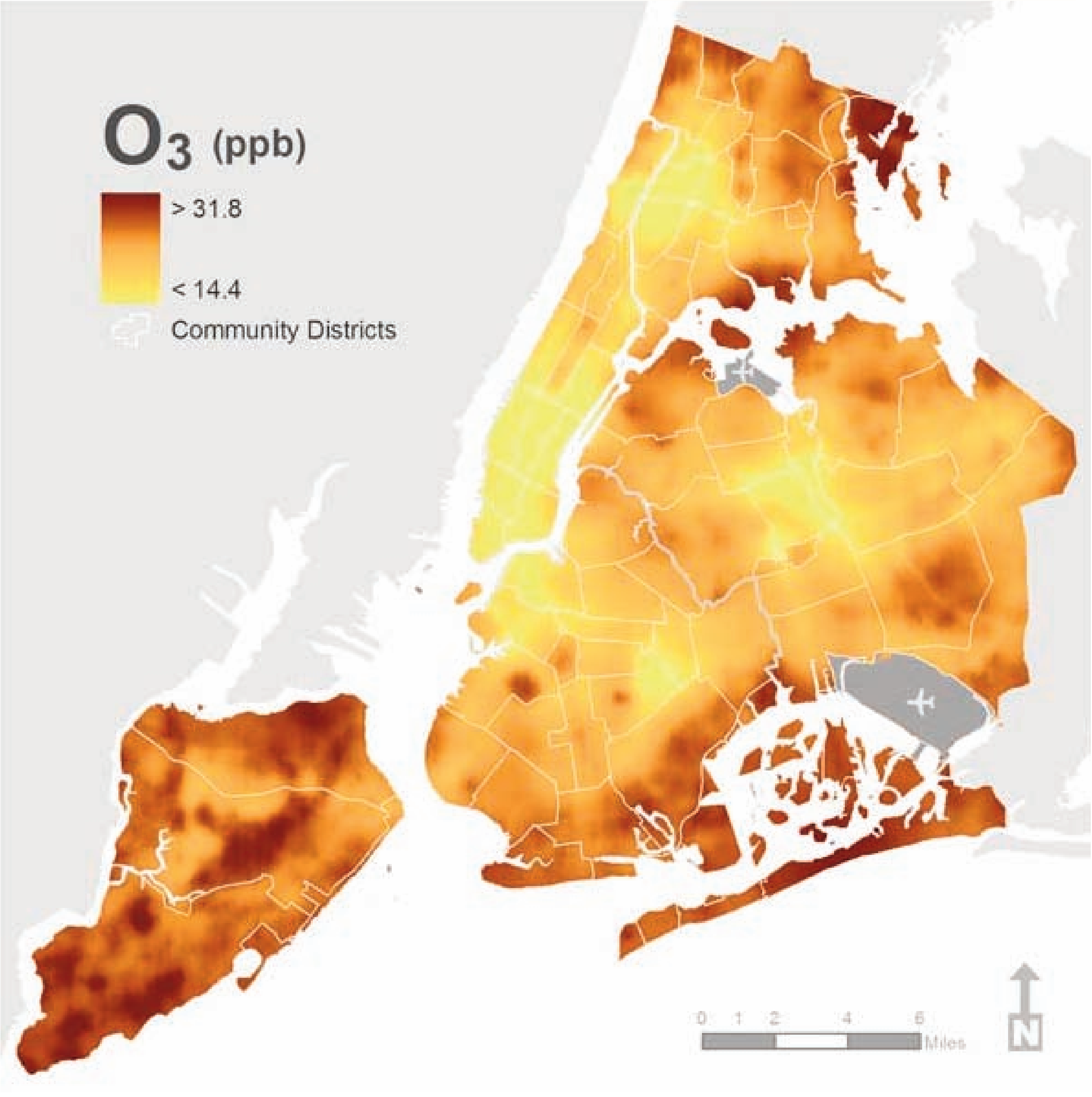


Figure shows distribution of 150 temporally-adjusted NYCCAS measurements. See Technical Appendix at www.nyc.gov/health/nyccas for calculation methods. DEC seasonal average was calculated using data from the five DEC monitoring sites for O_3 within New York City.

*O_3 = ozone; ppb = part per billion

Data source: US EPA Air Quality System.

Figure 21. Map of estimated ozone concentrations, summer 2009.



See Technical Appendix (www.nyc.gov/health/nyccas) for calculation methods.

Discussion

The launch of PlaNYC in 2007 marked New York City's commitment to air quality improvement efforts that exceed federal requirements. PlaNYC highlighted the need for systematic data on air pollution patterns within the city, to better guide and inform air quality improvement efforts. NYCCAS was developed to supply that vital data. It has begun to chart variations in air pollutants across all the city's diverse neighborhoods.

The first NYCCAS report, released in December 2009, measured variations in wintertime air quality across the five boroughs. That initial report identified the importance of building emissions, especially the burning of #4 and #6 grade heating oil. This study —conducted in the summertime, when heating-related pollutants are less prevalent—suggests that traffic-related emissions account for a majority of summertime variability acrosslocations.

The five pollutants included in this report ($PM_{2.5}$, EC, NO, NO_2, and O_3) varied two-fold or more across the citywide NYCCAS monitoring sites. Regulatory monitors show that citywide air quality varies considerably hour-to-hour and day-to-day, largely due to weather and pollution sources both within and outside the city. NYCCAS data show the extent to which pollution levels vary across the city. They also show that the variability across locations is not random. Higher pollution concentrations occur in areas with more combustion sources, especially traffic. This association allowed the agency to develop a statistical model to make estimates at unmonitored locations, using source indicators derived from geographic information systems (GIS), which are available across the city.

The data on summertime air quality in this report add to results from prior studies showing that traffic emissions are an important contributor to variations in air pollution among New York City neighborhoods. For the first time, NYCCAS is quantifying these differences across all neighborhoods and during all seasons of the year. The agency documented varying pollution exposures that may contribute to disparities in rates of respiratory and cardiovascular disease across the city, and provided data to inform future air pollution control initiatives. NYCCAS findings, especially regarding the importance of traffic in determining within-city air pollution patterns, are consistent with those from studies in other cities.

Summertime air pollution levels vary geographically.

Each of the pollutants in this report showed a variety of geographic patterns influenced by traffic—including general, bus and truck traffic. Although the pattern varied (ozone was generally the opposite of other pollutants), levels for most pollutants were highest in areas of heavy traffic concentrations, including parts of Manhattan, such as midtown and downtown, and sections of the Bronx, Brooklyn, Queens and Staten Island along busy freeways.

Although direct emissions from buildings have less impact during summer than during the wintertime heating season, hot water heating and cooking are year-round sources of combustion emissions. Indicators of these in NYCCAS summertime models included population density (a significant predictor of $PM_{2.5}$ and EC) and building density (a significant predictor of NO_2). These indicators may also reflect vehicle emissions, as commercial areas with high daytime populations and concentrations of large buildings also tend to have high volumes of traffic and congestion, and more diesel-powered buses and delivery trucks.

The geographic patterns of these air pollutants across the city are consistent with those observed in other urban areas. In one of the first land-use regression studies of urban air pollution, NO_2 concentrations in Amsterdam, Prague and Huddersfield, England, were associated with indicators of nearby traffic and land use (Briggs et al., 1997). In Munich, estimated annual average $PM_{2.5}$ and levels of elemental carbon varied more than two-fold across 40 monitoring sites—higher levels were associated with traffic density and population (Brauer et al., 2003). NO_2 levels in Toronto were associated with the density of nearby traffic, buildings and industrial land use (Jerrett et al., 2007). There are not many other studies at this time, however, that have examined geographic patterns in several pollutants across different seasons.

There are few studies on variations in ozone (O_3) levels within cities. The geographic pattern in O_3 differed substantially from the other pollutants because O_3 is a secondary pollutant. This means that O_3 forms through a series of chemical reactions in the atmosphere instead of being emitted directly from pollution sources. NO_x and hydrocarbons, directly emitted from vehicle tailpipes and other sources, are important contributors to ozone formation; ozone concentrations tend to be highest downwind from concentrated emissions sources. In locations with high concentrations of fresh NO_x emissions from vehicle exhaust and other sources, ozone can be broken down in a chemical process known as scavenging and as a result, concentrations are higher in some suburban areas, such as the Rockaways and lower Staten Island, where other pollutants are relatively low.

For the New York City community, the ozone map tells a more complicated story than do the maps of primary pollutants. On one hand, the high ozone levels in many less-densely populated neighborhoods are produced by emissions from traffic and other sources miles upwind. Air quality in these communities could be improved through reduced traffic and buildings emissions in the denser parts of the city and metropolitan area.

The lower concentrations of street-level ozone in certain high-traffic neighborhoods, on the other hand, do not reflect good air quality. Ozone in those communities is scavenged by fresh emissions, especially from vehicles, which increase exposure to other harmful pollutants, including NO_x, EC, ultra-fine particles and volatile organic compounds.

Although trees can have direct influences on air quality, the size and pattern of such effects are unclear and will continue to be studied. Although the effect was small, sites with higher tree density had slightly lower concentrations of $PM_{2.5}$, EC, NO, NO_2, and O_3. As noted in the Results, areas with more trees tend to have fewer emissions sources. Tree density may simply indicate an absence of pollution sources, rather than, or in addition to, physical deposition of fine particles on tree leaves, or chemical reactions between gaseous pollutants and leaf surfaces. The negative effect of trees on O_3 is especially difficult to interpret because of the complex chemistry affecting ozone near ground level combustion sources. We did not hypothesize a significant effect of trees on air quality during winter (when deciduous trees are not in leaf), and thus this effect was not examined in detail for the winter report. In future analyses, the agency will examine whether the effect of trees is stronger during summer than during winter.

In addition to potential direct effects of trees on air quality (e.g., deposition on leaf surfaces), trees can also serve to shade and cool some buildings on hot summer days, reducing the electric demand for air conditioning. This is important because, on hot summer days, peak electricity generation to meet the high electricity demands for air conditioning often requires the activation of some less efficient power generation equipment. As a result, reducing this peak demand can help reduce total combustion emissions.

What are the implications of the study for public health?

Exposure to $PM_{2.5}$ has been linked to exacerbation of cardiovascular disease and lung disease, including asthma, contributing to work and school absences, emergency room visits, hospitalizations and premature mortality. EC is also a respiratory irritant and is often used as a marker of diesel exhaust, which is linked to chronic lung inflammation, may cause or exacerbate allergies, and is a probable human carcinogen. NO, NO_2 and O_3 are respiratory irritants that can exacerbate respiratory illnesses such as asthma and also result in emergency department visits and hospitalizations. Research suggests that, in addition to the individual risks posed by each pollutant, combined exposures to multiple pollutants may be especially harmful. Because multiple combustion pollutants are emitted from the same sources, certain areas of the city have higher concentrations of multiple pollutants.

Fresh vehicle exhaust is a complex mixture and research is ongoing to identify the relative toxicity of its many components (Delfino et al. 2009). Combustion pollutants measured directly in NYCCAS and similar LUR studies may be indicators of geographic patterns in other harmful components of fresh vehicle exhaust. Concentrations of nitric oxide (NO) and ultra-fine particles, for example, both increase sharply near busy roadways, where their concentrations may be correlated (Hagler et al. 2009).

NYCCAS air pollution measures and concentration estimates are not directly comparable to EPA clean air standards, which have been developed from concentration measurements collected at rooftop routine monitoring sites, and associated average population exposures and health effects. Although the average ambient concentrations found at street level are often higher than those at regulatory roof-top monitors, the overall health impacts of air pollution are not necessarily greater.

NYCCAS data indicate that concentrations within the city vary substantially among locations during the summer. This variation in exposure and geographic variations in population susceptibility to air pollution with age, health conditions, health care access and other factors likely contributes to differences in the prevalence and severity of air pollution–related illnesses. Further analyses of year-round NYCCAS data are needed to more systematically assess and quantify the public health implications of air pollution exposure disparities.

Emissions should be reduced.

The NYCCAS summer report findings support PlaNYC initiatives to reduce local emissions, especially from traffic, which is associated with higher levels of multiple pollutants across many neighborhoods. Emissions from vehicles lead to higher concentrations of $PM_{2.5}$, EC and NO_2 in certain areas, and diesel engines in trucks, buses and other vehicles are sources of diesel exhaust particles that contribute to EC and total $PM_{2.5}$. Although passenger vehicles with gas engines emit less $PM_{2.5}$ per mile than do large diesel vehicles, passenger cars, which are more numerous, collectively produce a similar amount of $PM_{2.5}$ emissions.

As newer vehicles replace older, more polluting ones, emissions may be reduced, but these improvements will occur slowly and may be offset by growing traffic and congestion as the economy and population grows. Traffic in New York City has generally increased over the past two decades, with only temporary decreases during economic downturns such as the recent financial crisis. As the city's economy recovers, traffic volume and congestion will likely gradually increase.

To reach the city's clean-air goals, and reduce air pollution for people living near busy roads, efforts must continue to expand mass transit options, facilitate walking and bicycling, reduce the number of vehicles in the city, and speed the shift towards cleaner and more efficient vehicles. PlaNYC's strategy for reducing traffic-related emissions includes measures promoting cleaner vehicles and fuels, reducing traffic congestion, and improving mass transit access and performance.

Other NYCCAS results, especially those from the winter report, highlight the importance of emissions from buildings, especially the use of #4 and #6 grades of heating oil. PlaNYC initiatives are already addressing this issue by upgrading and converting building combustion systems, encouraging a shift to cleaner fuels and energy efficiency in city buildings, and promoting cleaner fuel and efficiency measures in large buildings.

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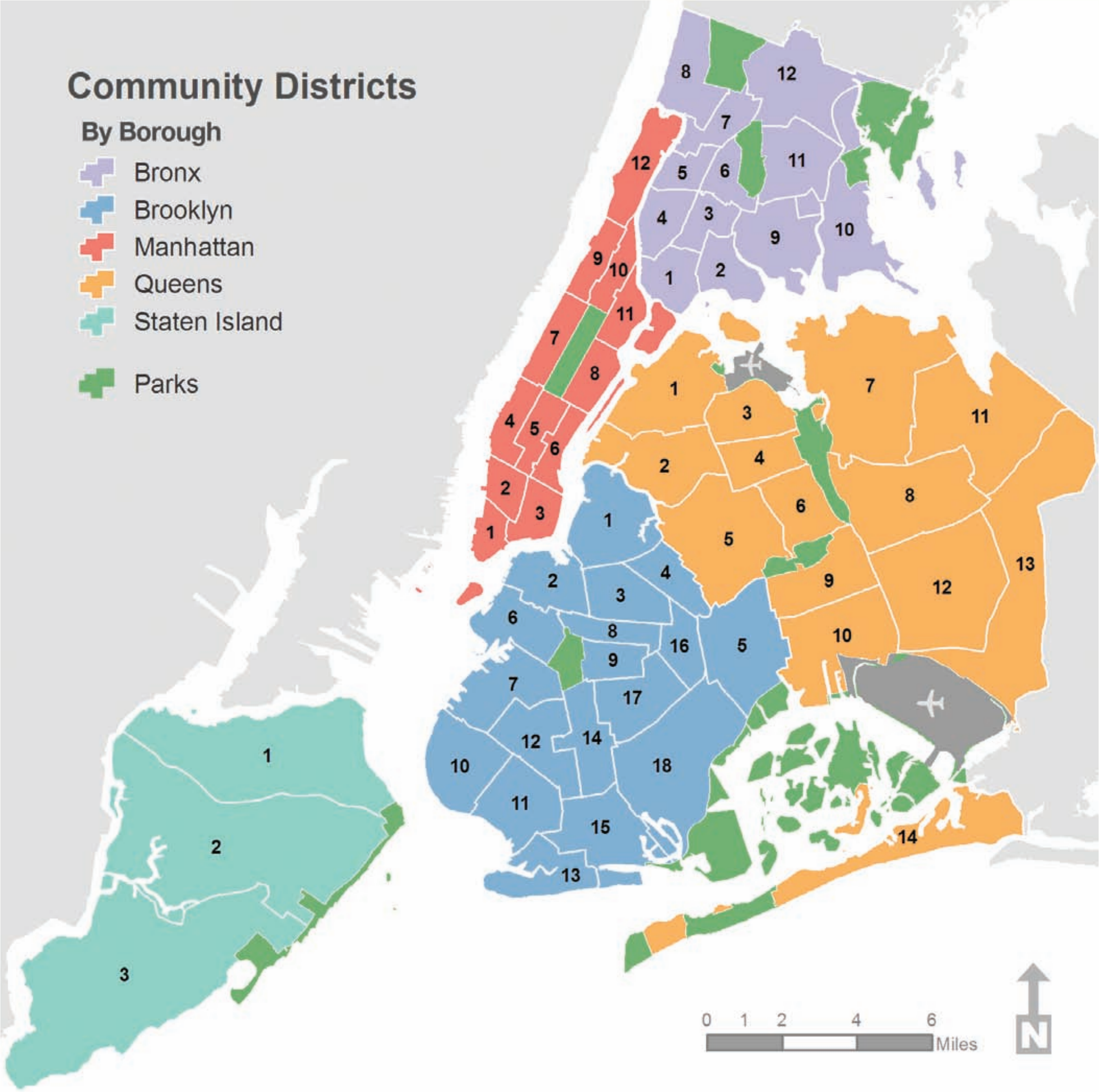
Annex: Reference Map of Community Districts.



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)

planYC

NYC Health

QUEENS
COLLEGE