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The New York City

Community Air Survey

Neighborhood Air Quality
2008 - 2014

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EXECUTIVE SUMMARY

Air quality in New York City has improved over the past several decades but concentrations of multiple air pollutants remain at levels that can be harmful to public health, particularly among seniors, children, and those with pre-existing health conditions. As part of New York City's first long-term plan for environmental sustainability in 2007 the Health Department established the New York City Community Air Survey (NYCCAS), the largest ongoing urban air monitoring program of any U.S. city. NYCCAS provides data to inform local air pollution policies, provide exposure estimates for health research, and track changes in air quality over time. Beginning in 2015, the annual reporting of these results is mandated by Local Law 103 of 2015.

This report:

- provides a summary of the air monitoring program, site selection process, air quality monitoring and analysis methods, and descriptions of the pollutants measured;
- describes the trend in air pollutant levels from winter 2008-2009 through fall 2014 in fine particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2), nitric oxide (NO), wintertime sulfur dioxide (SO_2), and summertime ozone (O_3);
- identifies the sources that contribute to high levels of these pollutants in NYC neighborhoods;
- maps neighborhood air pollution levels, by year and by season.

Major findings include:

- Annual average $PM_{2.5}$, NO_2, and NO levels have declined 16%, 21%, and 24%, respectively, over the 6 year period.
- The largest declines have been observed for SO_2 due to heating oil regulations. Wintertime average levels have declined by 68% over the six year period.
- Summertime average O_3 levels remained relatively stable across the six years.
- Higher levels of $PM_{2.5}$, NO_2, and NO continue to be observed in areas of higher traffic density, building density, areas of residual oil boilers, and industrial areas. SO_2 levels remain higher in areas with remaining residual oil boilers. O_3 levels remain higher in the outer boroughs, in areas that are downwind of high emissions density and have less combustion emissions.

This report underscores the need to continue to reduce emissions citywide through accelerated conversions of more polluting heating oils (No. 4 heating oil) and reducing emissions from traffic sources and other widely distributed sources of pollution such as commercial cooking. Reductions emissions from power plants within and outside the city are needed to reduce pollution levels throughout the city. Implementing new strategies and expanding existing measures within the City's sustainability plan, OneNYC, will contribute to improved air quality in the future.

INTRODUCTION

Air quality in New York City has improved over the past several decades due to actions taken to reduce pollution emissions. Despite this progress, concentrations of multiple air pollutants remain at levels that can be harmful to public health, particularly among seniors, children, and those with pre-existing health conditions. Exposures to air pollutants common in New York City's air have been linked to a variety of adverse outcomes such as exacerbation of cardiovascular and respiratory diseases leading to emergency department visits, hospitalizations and premature death, as well as reduced birth weight and cancer.

As part of New York City's first long-term plan for environmental sustainability, in 2007 the Health Department established the New York City Community Air Survey (NYCCAS), which is the largest ongoing urban air monitoring program of any U.S. city. The air quality monitoring network, which began collecting data in December of 2008, is a collaboration between the Health Department and Queens College.

The objectives of NYCCAS are to:

- measure air pollutants that affect public health across the city;
- identify local emission sources that impact neighborhood air quality;
- inform the public and city officials on clean air priorities;
- provide air pollution estimates for health studies.

This report summarizes the results of air quality monitoring over six years – from Winter 2008-2009 through Fall 2014. This report focuses on six pollutants important to public health:

Fine particles ($PM_{2.5}$) are tiny airborne solid and liquid particles less than 2.5 microns in diameter. $PM_{2.5}$ is the most harmful urban air pollutant, small enough to penetrate deep into the lungs and enter the bloodstream, worsening lung and heart disease and leading to hospital admissions, premature deaths and increasing risk of cancer. $PM_{2.5}$ can either be directly emitted or formed in the atmosphere from other pollutants. Important local sources include fuel combustion in vehicles, boilers in buildings, power plants, construction equipment, and commercial cooking. $PM_{2.5}$ in NYC's air also comes from outside the city, some of it from power stations hundreds of miles upwind.

Nitrogen dioxide (NO_2) and nitric oxide (NO) are part of a group of pollutants called "oxides of nitrogen" (NOx). Exposures to NOx are linked to increased emergency department visits and hospitalizations for respiratory conditions, particularly asthma. NOx also react with other compounds in the atmosphere to form $PM_{2.5}$ and ozone (O_3). NOx are produced from a variety of combustion sources in NYC, including motor vehicles, buildings, marine vessels, and construction equipment.

Sulfur dioxide (SO_2) in NYC is produced mainly from burning oils with high sulfur content, such as No. 4 or No. 6 oil (also known as residual fuel oil) or high sulfur No. 2 oil. Fuel oil in NYC is used mainly to heat buildings and hot water and some high-sulfur oil is also used to generate electric power and power marine vessels. SO_2 exposures can worsen lung diseases, causing hospitalizations and emergency department visits for asthma and other conditions. SO_2 also contributes to $PM_{2.5}$ in the atmosphere, resulting in exposures downwind of where it is emitted.

Ozone (O_3), at ground level, is formed through reactions in the atmosphere when NOx emissions combine with other airborne pollutants in the presence of sunlight. Therefore, measured ozone concentrations are often highest downwind from high-emissions areas. In areas where there are high concentrations of fresh combustion emissions, NOx reacts with ozone to reduce its concentrations. As a result, lower ozone levels are observed near roadways, in city centers and in other areas of high emissions density.

To date, the results of NYCCAS monitoring have been published through multiple public reports, scientific manuscripts and periodic online data updates - all accessible on DOHMH's website at http://www.nyc.gov/health/nyccas. Neighborhood level data and detailed neighborhood air quality reports are available for download through the Department's Environment & Health Data Portal. Beginning in 2015, the annual reporting of these results is mandated by Local Law 103 of 2015.

METHODS

Since December 2008, NYCCAS has measured street-level concentrations of multiple air pollutants that affect public health. Monitoring sites were selected to include the range of the predominant sources of air pollutant emissions in NYC neighborhoods. NYCCAS field teams sampled the air at 150 NYC locations per year during the first two years and at 60 to 100 locations per year in subsequent years (Figure 1). Samples are collected in all seasons.

The original 150 monitoring sites were selected to ensure that the range of traffic conditions, size and number of buildings, and land uses in NYC were adequately included while providing a balance in spatial coverage throughout the city. To do this, a digital map of the city was divided into a grid of more than 7,500 squares, each 300 by 300 meters, and each square was classified based on its traffic and building density. A random selection of squares was then drawn from this set, with high building and traffic density areas having an increased chance of selection as these areas are concentrated in a relatively small area of the city. This random site selection was used to locate 80% of the sampling sites. The remaining 20% of sites were selected in places with large remaining gaps in coverage from the random selection or near areas of interest, such as high traffic areas, transportation facilities, or major ongoing construction. For additional details on the 150 site selection methods, visit (NYCCAS First Winter Results, NYCCAS Design and Implementation).

After the first two years of the study, the number of sites was reduced to between 60 and 100 sites, depending on the year, because of budget constraints and to free up resources to measure other pollutants. The balance of source density and spatial density was preserved, through use of random selection methodologies similar to those described above. The patterns in air pollutant concentrations remained consistent year after year – areas of the city with higher concentrations tend to remain higher over time, while cleaner areas of the city remain cleaner – due to

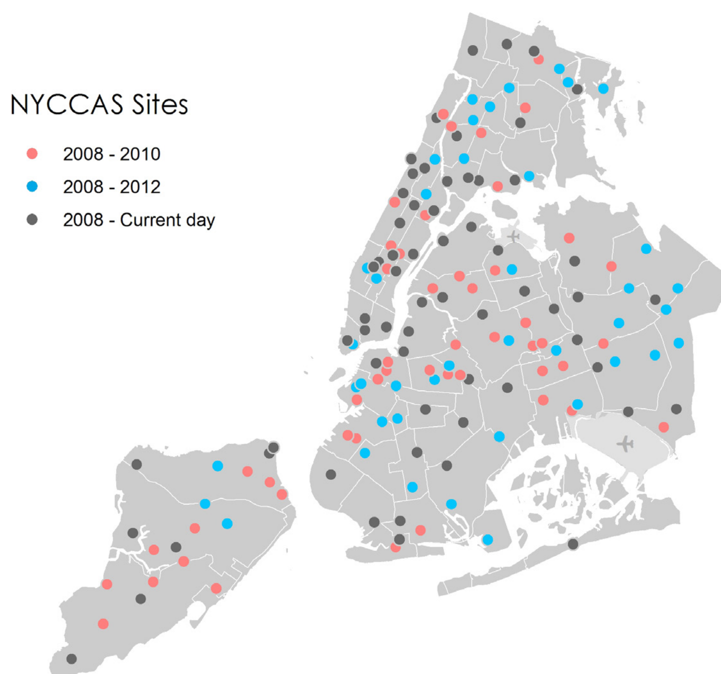


Figure 1: New York City Community Air Survey "core" monitoring locations.

major emissions sources such as buildings and traffic remaining in fixed locations. In comparing year to year patterns in levels, we observed high correlations across all pollutants (range in correlation coefficients: 0.61 to 0.97). Because of this, NYCCAS is able to track the geographic pattern of air quality over time with fewer locations than in the original design. Currently, routine NYCCAS air sampling occurs once per season at 60 of the original 150 sites, known as the 'core' monitoring sites. Fifteen additional sites, described in the following paragraph, are also sampled once per season.

To further augment monitoring in high poverty neighborhoods and provide more data to check exposure estimates for the city's most vulnerable populations, the NYCCAS team supplemented the monitoring network in 2014 with 15 additional sites. These sites were purposefully located in neighborhoods with higher concentrations of poverty. Communities with higher concentrations of poverty have higher rates of health conditions sensitive to air pollution, making them more vulnerable to harm from a given level of exposure. Additional details and results from this monitoring can be found in the supplemental study at the end of this report. Prior to adding these sites, among the 60 core monitoring sites currently being sampled, the density of monitors per square mile was already 80% higher in the community districts with the highest concentration of poverty compared to more affluent neighborhoods. The remaining sections of this report describe analysis and results based on the current 60 core monitoring sites.

NYCCAS sampling is conducted using monitoring units mounted on lamp-posts 10 to 12 feet off the ground. The monitors include an air pump and filters to collect $PM_{2.5}$ while passive samplers mounted on the outside of unit absorb the gaseous pollutants NOx, SO_2, and O_3. Laboratory analysis of the filters and passive samplers determines the quantities of pollutants collected and their concentration in air is calculated. Quality control steps included confirming that the sampling pump was operating normally and collecting duplicate and unexposed samples for comparison with study samples. Air samples were collected at each active NYCCAS site for two weeks in each season. Samples at reference sites located away from potential pollution sources were monitored every two weeks, year-round. Data from the reference sites were used to adjust the measurements from street-side sites for citywide changes in air quality over time, mainly from weather conditions. The number of reference sites was reduced from five to three after the first four years.

NYCCAS team deploys an air monitor in Manhattan. Photo by Jonah Haviland-Markowitz.

NYCCAS data were analyzed using a "land-use regression" (LUR) model, a scientific method widely used in air pollution research studies. LUR models estimate associations among pollution levels, average traffic, building emissions, land use, and other neighborhood factors around the monitoring sites. These associations are then used to estimate the seasonal average air pollution levels at locations across the city, including locations where no measurements were taken. The LUR model is also used to assess sources that appear to contribute most to differences in pollution concentrations. Each NYCCAS monitor site is one in a city-wide sample of possible monitoring locations. Because the conditions near each monitor vary, no single monitor can be used to study air pollution across a neighborhood; the estimates from the LUR model for hundreds of different locations across each neighborhood are a better way to characterize neighborhood air pollution.

For more details on methods, visit NYCCAS at nyc.gov/health/nyccas.

RESULTS

Between winter 2008-2009 (beginning in December 2008) and fall 2014 (ending in November 2014), levels of $PM_{2.5}$, NO_2, NO, and SO_2 have declined, with the largest declines observed for SO_2. Summertime average ozone levels have remained relatively stable over the same time period. The groups of neighborhoods with the higher and lower levels of these pollutants, relative to the city overall, have also remained fairly consistent over time, reflecting the fact that the geographic pattern of predominant sources do not change rapidly from year to year.

Data summarized for each pollutant includes:

1. Trends in seasonal average pollutant concentrations stratified by important nearby sources.
2. Maps of concentrations estimated by the LUR model. The maps first show levels from the most recent year for which data is available, 2014. Next to each map is a smaller set of maps depicting the trend across all years of NYCCAS[1].
3. A description of the source indicators in the model most predictive of place to place differences in air pollutant levels.

Annual, summer, and winter average pollutant concentrations for each neighborhood can be accessed at www.nyc.gov/health/trackingportal.

[1]Color scales of maps in this report have been updated to reflect the most current data and therefore cannot be compared directly to maps published in previous NYCCAS reports.

FINE PARTICULATE MATTER

At NYCCAS sites measured in each season for six years, seasonally adjusted street-level $PM_{2.5}$ levels declined by an average of 0.4 micrograms per cubic meter ($\mu g/m^3$) per year, and by 16% over the six-year period. Wide differences in concentrations persisted across sites. In the most recent year (2014), seasonal average concentrations across NYCCAS monitoring sites ranged from 5.30 $\mu g/m^3$ to 23.25 $\mu g/m^3$. Higher levels were consistently measured at sites with higher boiler and traffic emissions (Figure 2).

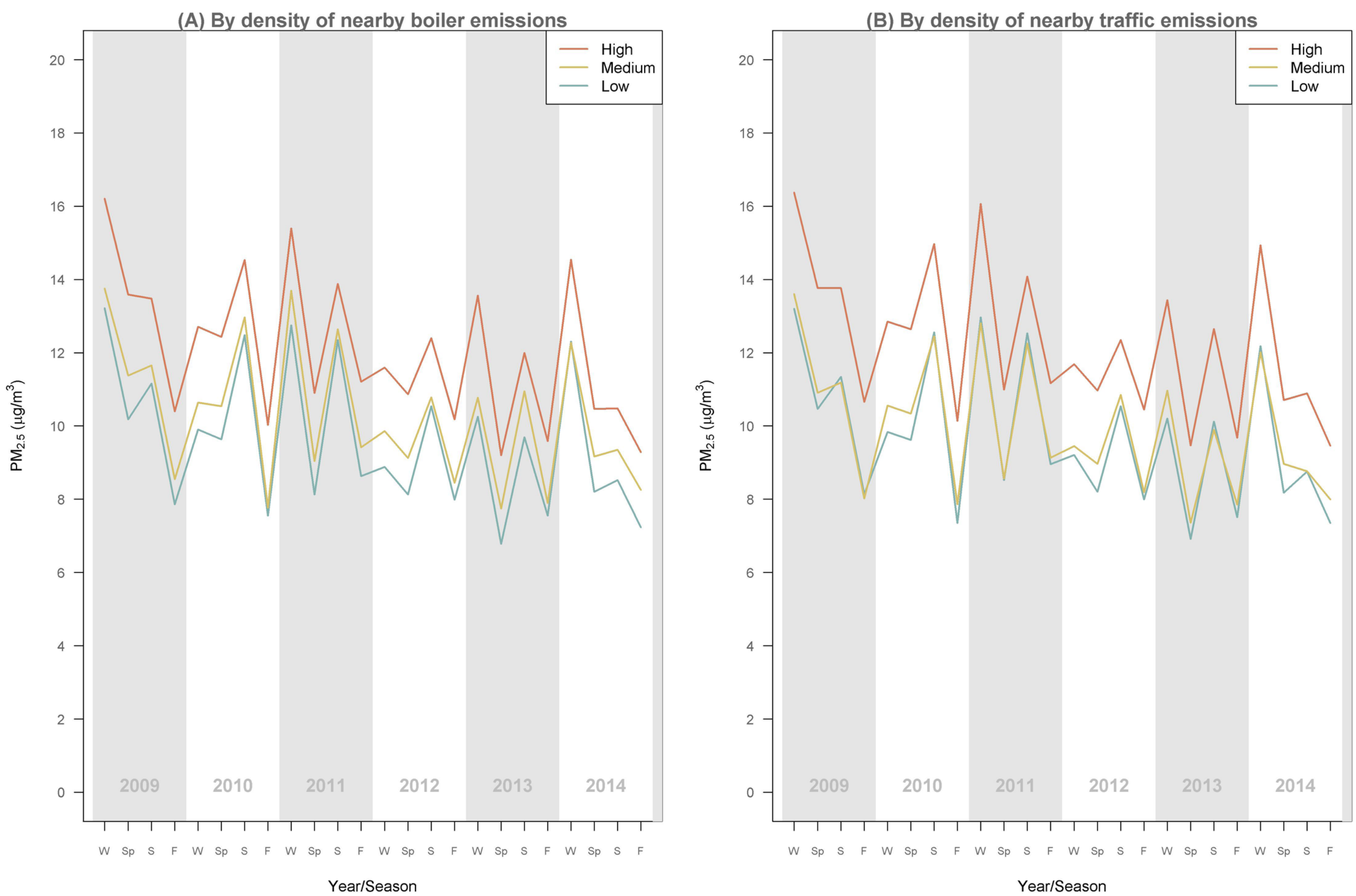


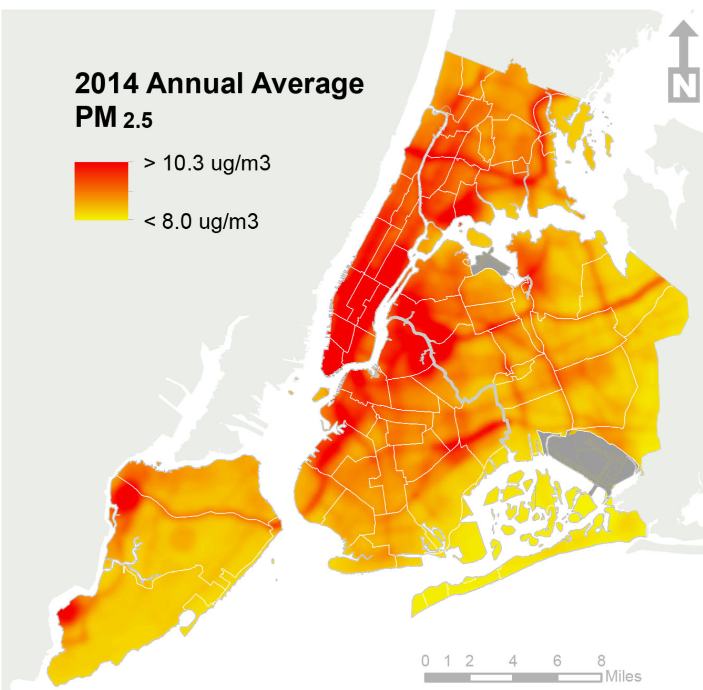
Figure 2: $PM_{2.5}$ levels at NYCCAS monitors, by density of nearby boilers emissions (A) and traffic emissions (B) [2]

[2]Boiler emissions represent estimated $PM_{2.5}$ emissions from all boiler types within 1000 meters. Traffic emissions estimated as total traffic density, weighted by vehicle-specific $PM_{2.5}$ emissions rates from on-road vehicles within 100 meters. High, Medium, and Low represent one third of sites ranked by source indicator density.

In the LUR model, the most important predictors of $PM_{2.5}$ concentrations were, in order of importance:

Indicator	Associated Sources and Interpretation
Emissions from buildings heat and hot water boilers within 1,000 meters (m)	Combustion of heating oil and natural gas
Area of industrial land use within 1,000 m	Diesel exhaust particles from trucks idling and traveling through industrial areas. Industrial combustion equipment
Traffic density, weighted by relative emissions rates by vehicle type (car, truck, bus) within 250 m	Emissions from all on-road motor vehicles based on vehicle miles and the relative emission rates of different vehicle types

While these spatial predictors were based on a single year's emission data, the model allowed the relationships to change year to year, based on the patterns in $PM_{2.5}$ measurements in each year. $PM_{2.5}$ levels remain relatively higher throughout much of Manhattan as well as industrial areas and areas of high building and traffic density in the outer boroughs (Figure 3).



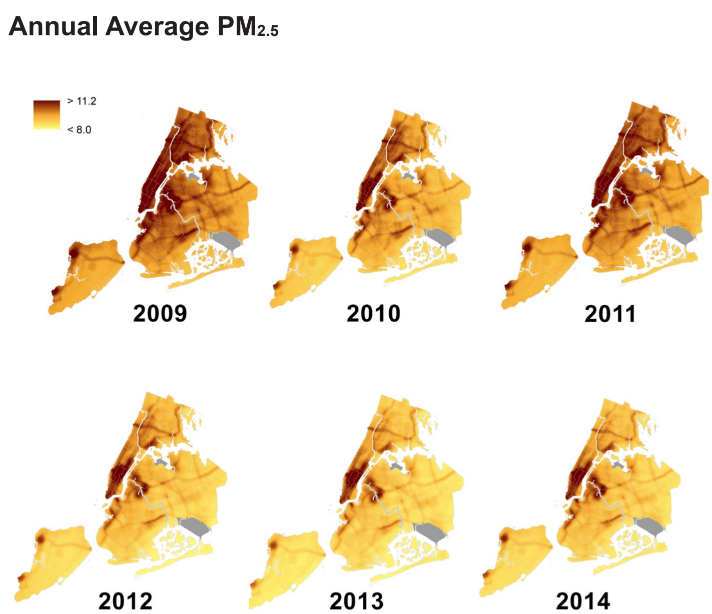


Figure 3: $PM_{2.5}$ concentrations, 2014 annual average (left), and 2009-2014 annual averages (right)

Neighborhood-level changes in $PM_{2.5}$ levels were compared by calculating the reduction in the annual, neighborhood average $PM_{2.5}$ concentrations per year over the six years, as predicted by the LUR model. Annual average, neighborhood-level $PM_{2.5}$ levels were observed to decline at the highest rate in the northern Manhattan community district (CD) of Washington Heights (CD 12) and western Bronx community districts of Bedford Park/Kingsbridge Heights (CD 7), Fordham (CD 5), Riverdale (CD 8), and Highbridge/Concourse (CD 4). These neighborhoods include high densities of residual fuel oil boilers and truck traffic. See Appendix 3 for neighborhood $PM_{2.5}$ concentrations across the six years.

NITROGEN DIOXIDE

At NYCCAS sites measured in each season for six years, seasonally adjusted, street-level NO_2 levels declined by an average of 1.2 parts per billion (ppb) per year, and by 21% over the six-year period. Wide differences in concentrations persisted across sites. In the most recent year (2014), seasonal average concentrations across NYCCAS sites ranged from 5.0 ppb to 52.4 ppb. Higher levels were consistently measured at sites with higher building density and nearby traffic emissions (Figure 4). NO_2 levels remain relatively higher throughout much of Manhattan as well as areas of high building and traffic density in the outer boroughs (Figure 5).

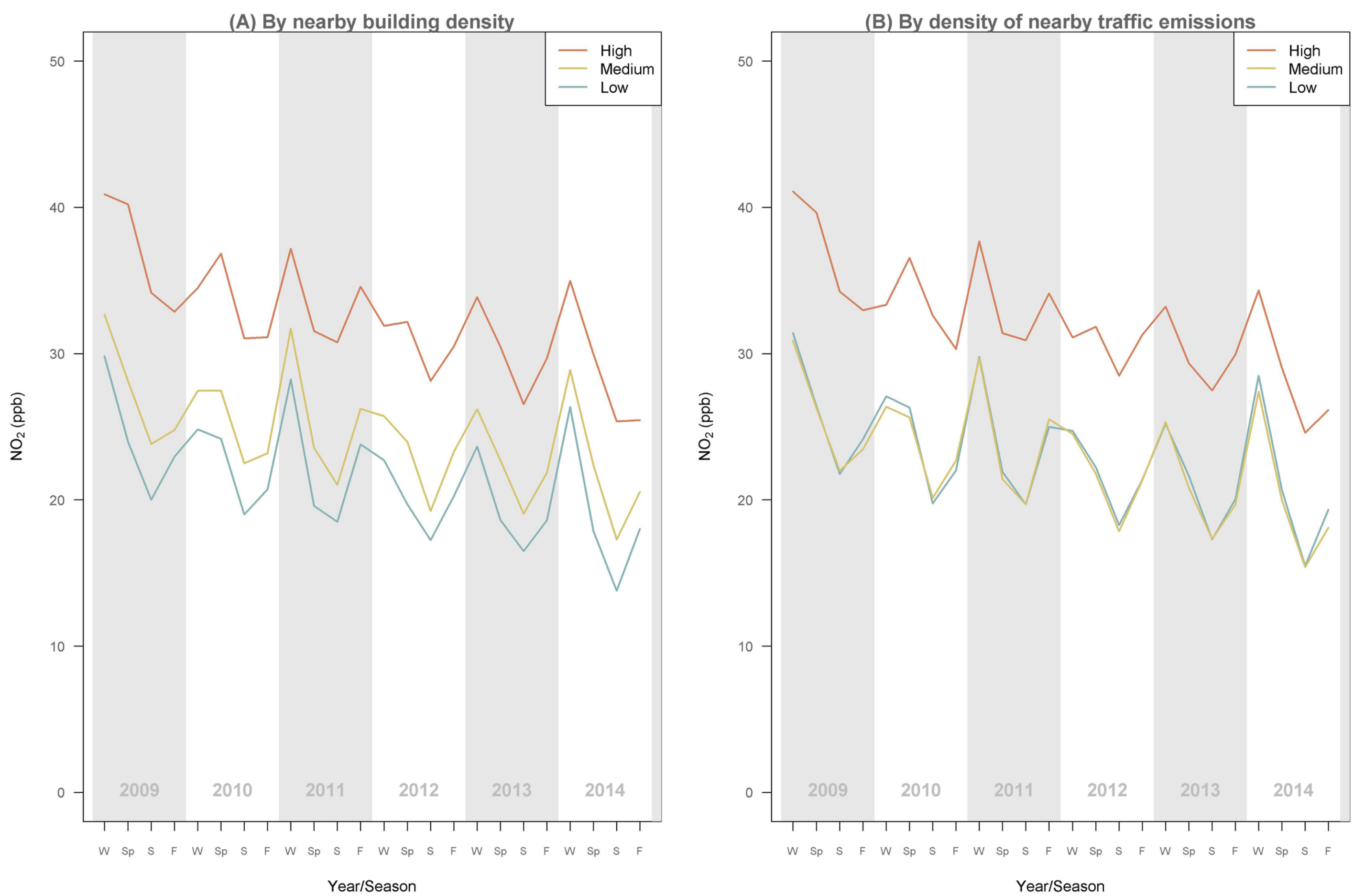


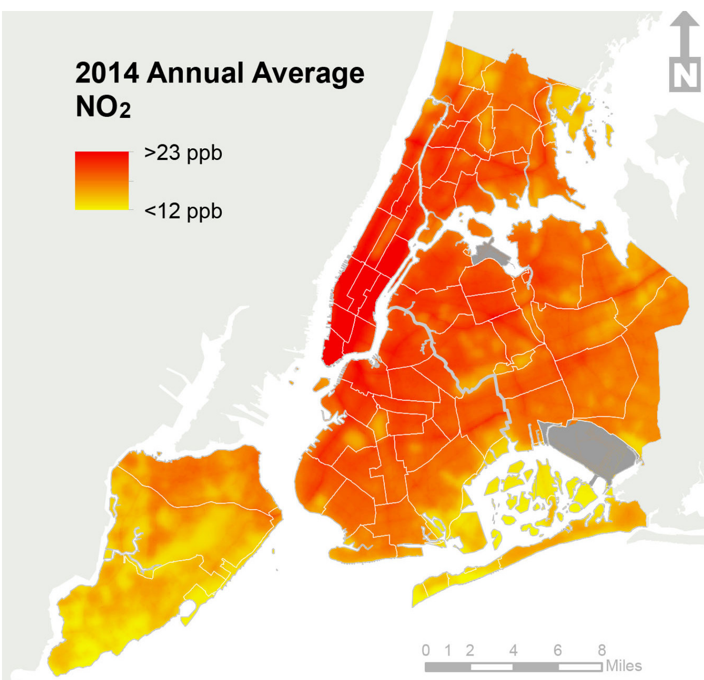
Figure 4: NO_2 levels at NYCCAS monitors, by nearby building density (A) and traffic emissions (B)[3]

[3]Building density is estimated as total interior building area within 1000 meters of monitoring site. Traffic emissions estimated as total traffic density, weighted by vehicle-specific NOx emissions rates from on-road vehicles within 100 meters. High, Medium, and Low represent one third of sites ranked by source indicator density.

In the LUR model, the most important predictors of NO_2 concentrations were, in order of importance:

Indicator	Associated Sources and Interpretation
Area of interior building space within 1,000 m	Combustion of heating oil and natural gas
Traffic density, weighted by relative emissions rates and vehicle type (car, truck, bus) within 100 m	Emissions from all on-road motor vehicles based on vehicle miles and the relative emission rates of different vehicle types
Percent impervious surface within 100 m	Emissions of motor vehicles on paved roadways
Location on a bus route (compared to non-bus route locations)	Emissions from buses and other vehicles on busy roadways. Indicator of traffic congestion

Neighborhood-level changes in NO_2 levels were compared by calculating the reduction in annual, neighborhood average NO_2 concentrations per year over the six years, as predicted by the LUR model. Annual average, neighborhood-level NO_2 levels were observed to decline at the highest rate in Manhattan neighborhoods, namely Midtown (CD 5), Financial District (CD 1), Stuyvesant Town (CD 6), Morningside Heights (CD 9) and Washington Heights (CD 12). These neighborhoods include high densities of motor vehicle traffic on surface roads and built space. See Appendix 3 for neighborhood NO_2 concentrations across the six years.



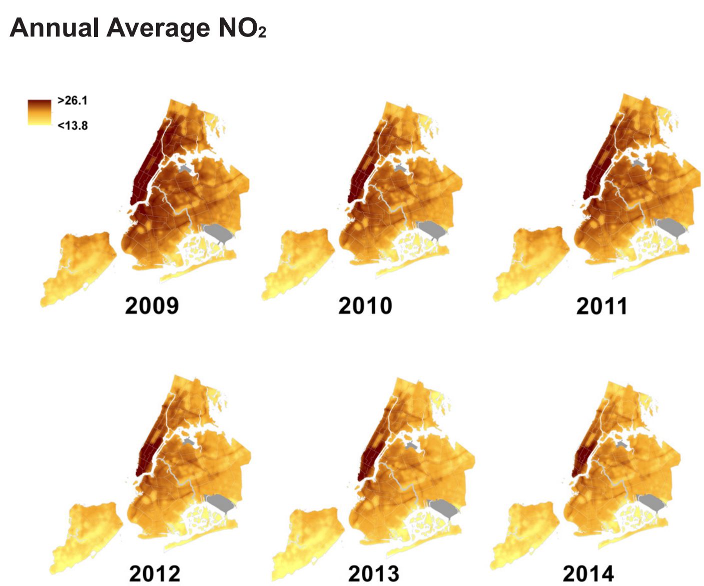


Figure 5: NO_2 concentrations, 2014 annual average (left), and 2009-2014 annual averages (right)

NITRIC OXIDE

At NYCCAS sites measured in each season for six years, seasonally adjusted, street-level NO levels declined by an average of 1.9 ppb per year, and by 24% over the six-year period. Wide differences in concentrations persisted across sites. In the most recent year (2014), concentrations across sites ranged from 4.1 ppb to 102.2 ppb. Higher levels were consistently measured at sites with higher NOx emissions from traffic sources and higher densities of nearby building boilers (Figure 6). NO levels remain relatively higher throughout much of Manhattan as well as areas of high building and traffic density in the outer boroughs (Figure 7).

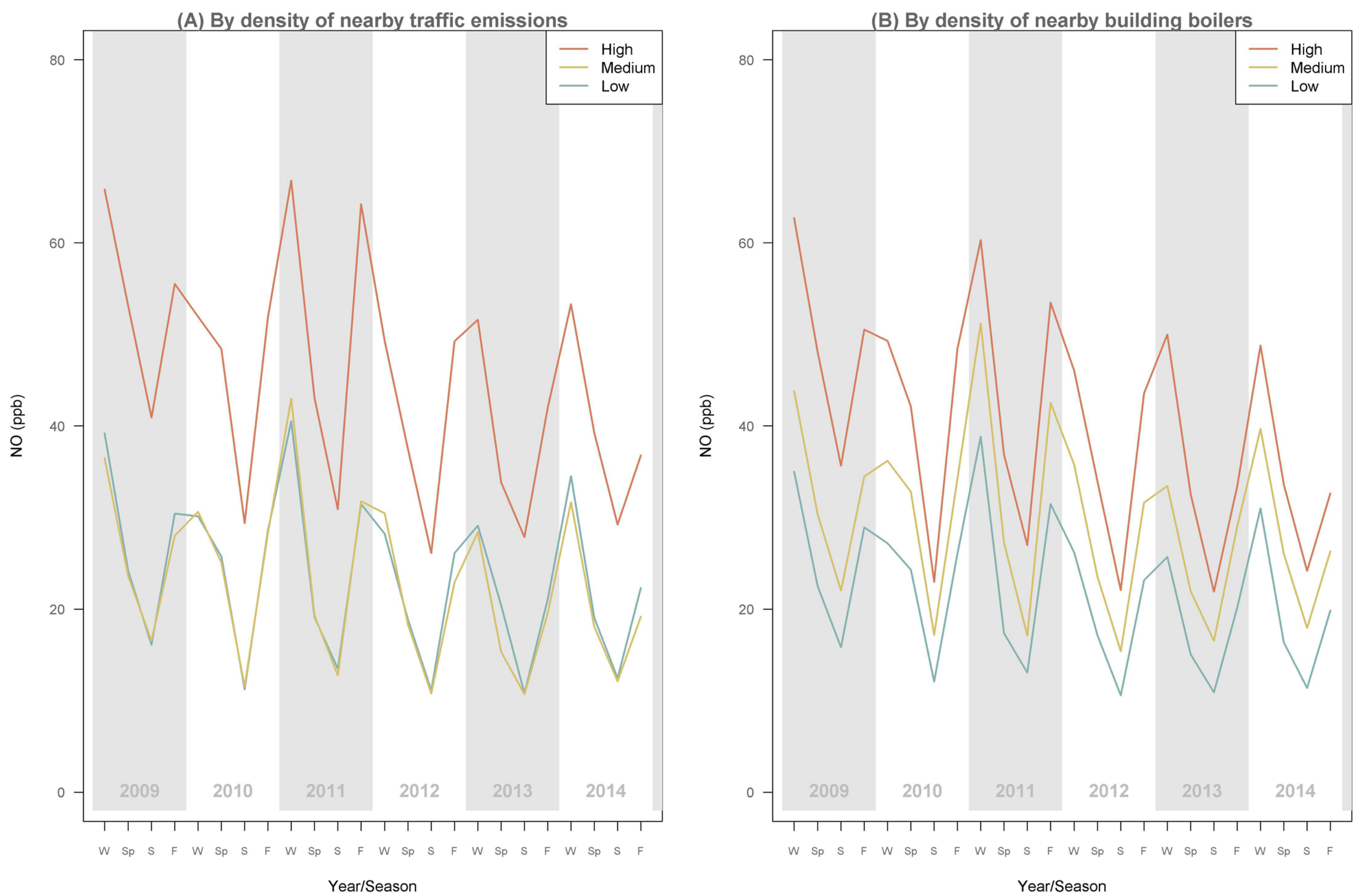


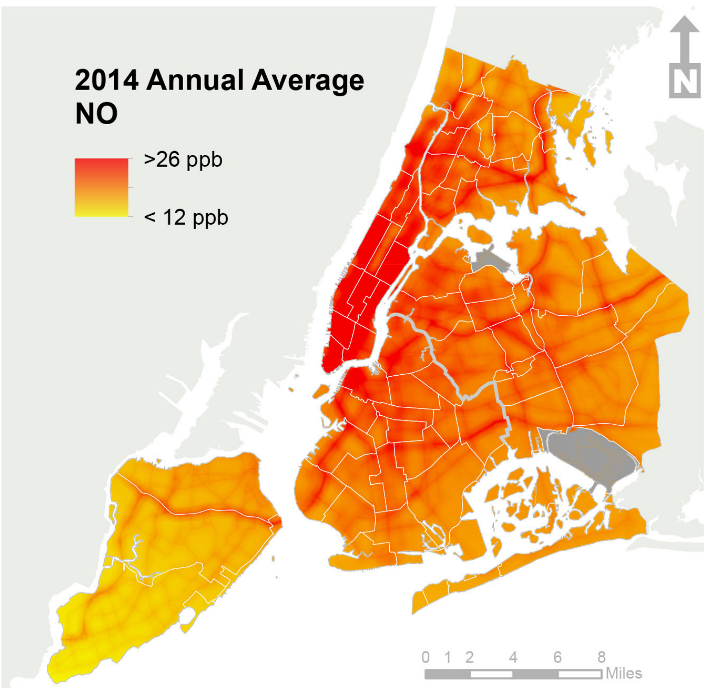
Figure 6: NO levels at NYCCAS monitors, by nearby NOx emissions from traffic (A) and nearby boiler density (B)[4]

[4] Traffic emissions estimated as total traffic density, weighted by vehicle-specific NOx emissions rates from on-road vehicles within 100 meters of monitoring sites. Boiler density estimated by total number of permitted boilers within 250 meters of monitoring sites. High, Medium, and Low represent one third of sites ranked by source indicator density.

In the LUR model, the most important predictors of NO concentrations were, in order of importance:

Indicator	Associated Sources and Interpretation
Traffic density, weighted by relative emissions rates and vehicle type (car, truck, bus) within 100 m	Emissions from all on-road motor vehicles based on vehicle miles and the relative emission rates of different vehicle types
Length of truck route within 50 meters	Diesel exhaust
NOx emissions from buildings heat and hot water boilers within 400 meters (m), taking into account changes in building heating fuels over time.	Combustion of heating oil and natural gas
Number of building boilers within 250 meters	Combustion of heating oil and natural gas

Neighborhood-level changes in NO levels were compared by calculating the reduction in annual, neighborhood average NO concentrations per year over the six years, as predicted by the LUR model. Annual average, neighborhood-level NO levels were observed to decline at the highest rate in Manhattan neighborhoods, with the highest decline rates in Greenwich Village and SOHO (CD 2), Upper East Side (CD 8), Midtown (CD 5), Upper West Side (CD 7) and Stuyvesant Town/Turtle Bay (CD 6). These neighborhoods include high densities of motor vehicle traffic on surface roads and boiler emissions. See Appendix 3 for neighborhood NO concentrations across the six years.



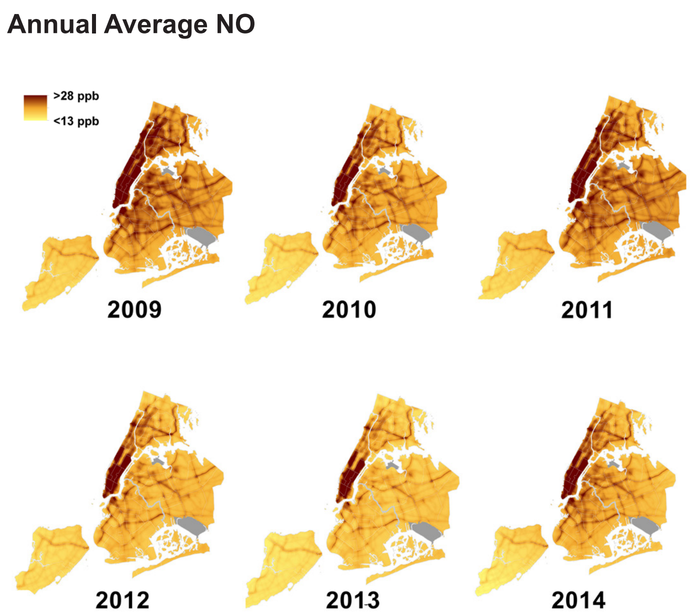


Figure 7: NO concentrations, 2014 annual average (left), and 2009-2014 annual averages (right)

SULFUR DIOXIDE

At NYCCAS sites measured in each season for six winters, seasonally adjusted, street-level SO_2 levels declined by an average of 0.8 ppb per year, and by 68% over the six-year period. In the most recent winter (2013-2014), seasonal average SO_2 varied from 0.6 to 6.7 ppb across the monitoring sites. Higher levels were measured at sites with greater densities of Nos. 4 and 6 boilers (residual oil) and greater nighttime population density (a surrogate of increased heating oil use) (Figure 8). While SO_2 concentrations have declined significantly across the city, due to City and State efforts to phase out high sulfur fuels in the heating and power sector, they remained relatively higher in areas with a higher density of remaining residual oil boilers, particularly areas of the Upper East and West Sides, northern Manhattan, and the western Bronx (Figure 9).

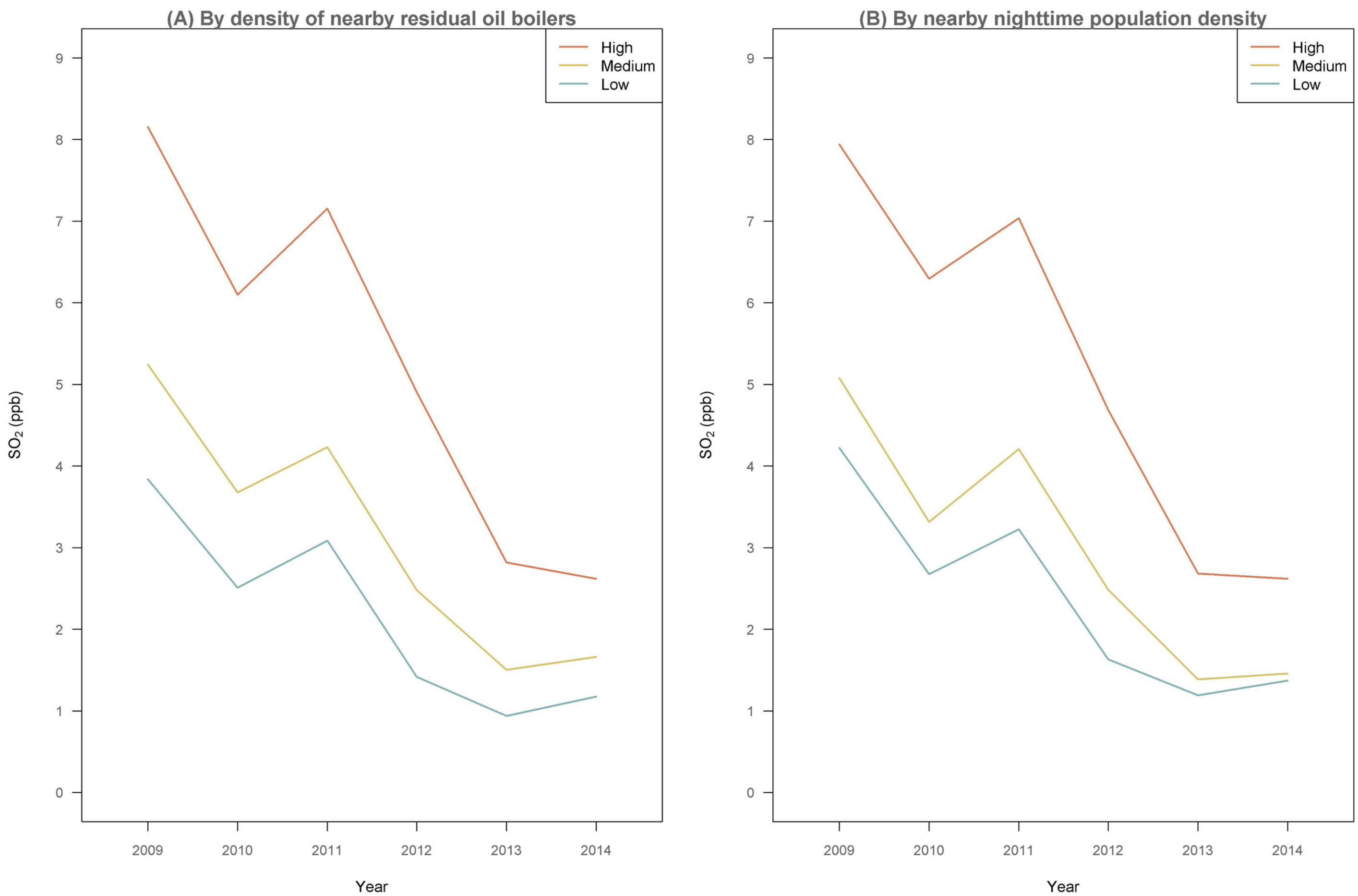


Figure 8: Wintertime SO_2 levels at NYCCAS monitors, by density of nearby residual oil boilers (A) and nearby nighttime population density (B)[5]

[5]Residual oil boiler density estimated as number of Nos. 4 and 6 boilers within 1000 meters of monitoring sites. Nighttime population density estimated as total nighttime population within 1000 meters of monitoring sites. High, Medium, and Low represent one third of sites ranked by source indicator density.

In the LUR model, the most important predictors of SO_2 concentrations were, in order of importance:

Indicator	Associated Sources and Interpretation
Nighttime population within 1000 m	Combustion of heating oil
Time varying counts of boilers burning No. 4 and No. 6 oil	Combustion of No. 4 and No. 6 heating oil, accounting for season-specific estimated counts of boilers

Neighborhood-level changes in SO_2 levels were compared by calculating the reduction in wintertime neighborhood average SO_2 concentrations per year over the six years, as predicted by the LUR model. Annual average, neighborhood-level SO_2 levels were observed to decline at the highest rate in the Bronx neighborhoods of Fordham (CD 5) and Bedford/ Kingsbridge Heights (CD 7) and the Manhattan neighborhoods of the Upper East Side (CD 8), Washington Heights (CD 12) and Upper West Side (CD 7). These neighborhoods include high densities of residual oil heating boilers which have undergone conversion to cleaner, lower sulfur heating oil and natural gas, during this time period. See Appendix 3 for neighborhood SO_2 concentrations across the six years.

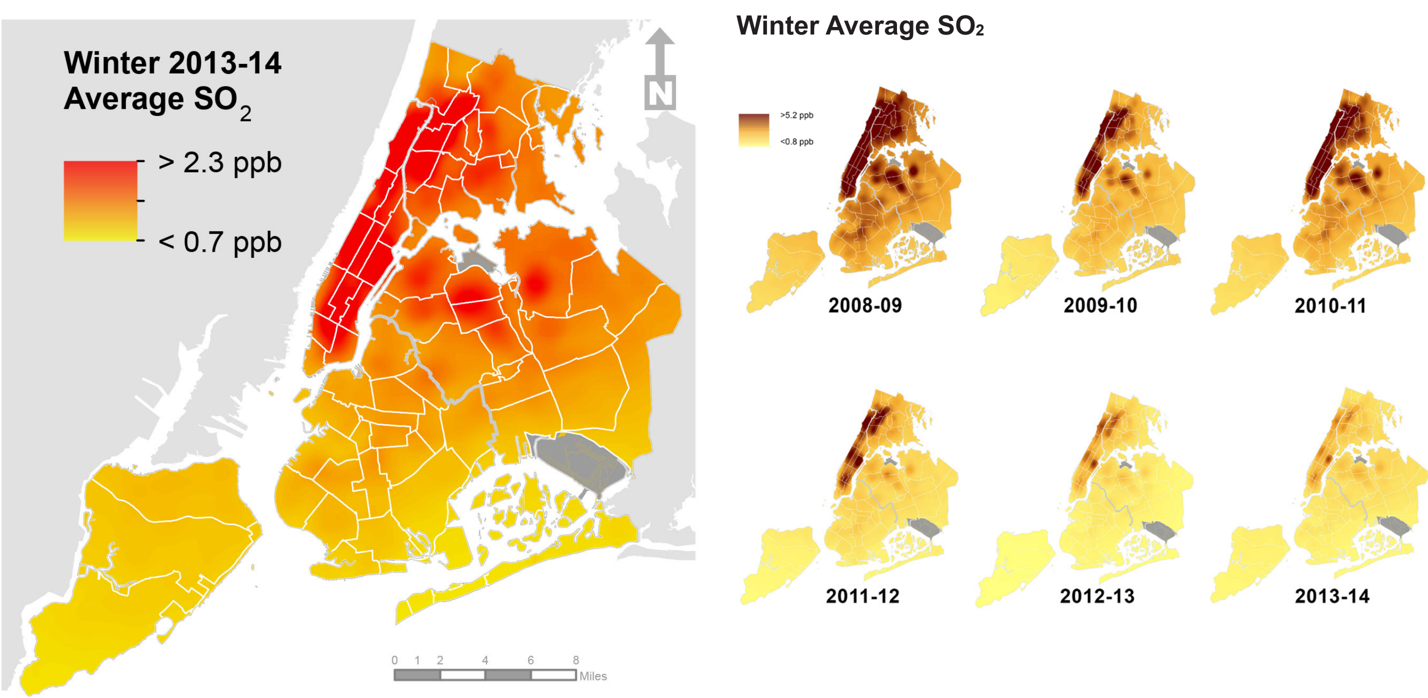


Figure 9: SO_2 concentrations, 2014 wintertime average (left), and 2009-2014 wintertime averages (right)

OZONE

At NYCCAS sites measured in each season, summertime average O_3 levels remained relatively stable across the six years. Since the first summer (2009), where relatively cool temperatures contributed to lower levels of O_3 city-wide, summertime average levels varied minimally year to year (ranging from 29.0 ppb to 31.4 ppb), without a clear trend in levels across this short time period. In the most recent summer (2014), seasonal average O_3 varied from 18.3 to 39.5 ppb across the monitoring sites. Higher levels were consistently measured at sites with lower traffic density and lower NO_2 concentrations, reflecting less removal of ozone from the atmosphere in areas of fewer fresh combustion emissions (Figure 10). Higher levels of ozone were observed in the outer boroughs, downwind from areas of high NO_2 emissions, in outer areas of Queens, Brooklyn, and Staten Island (Figure 11).

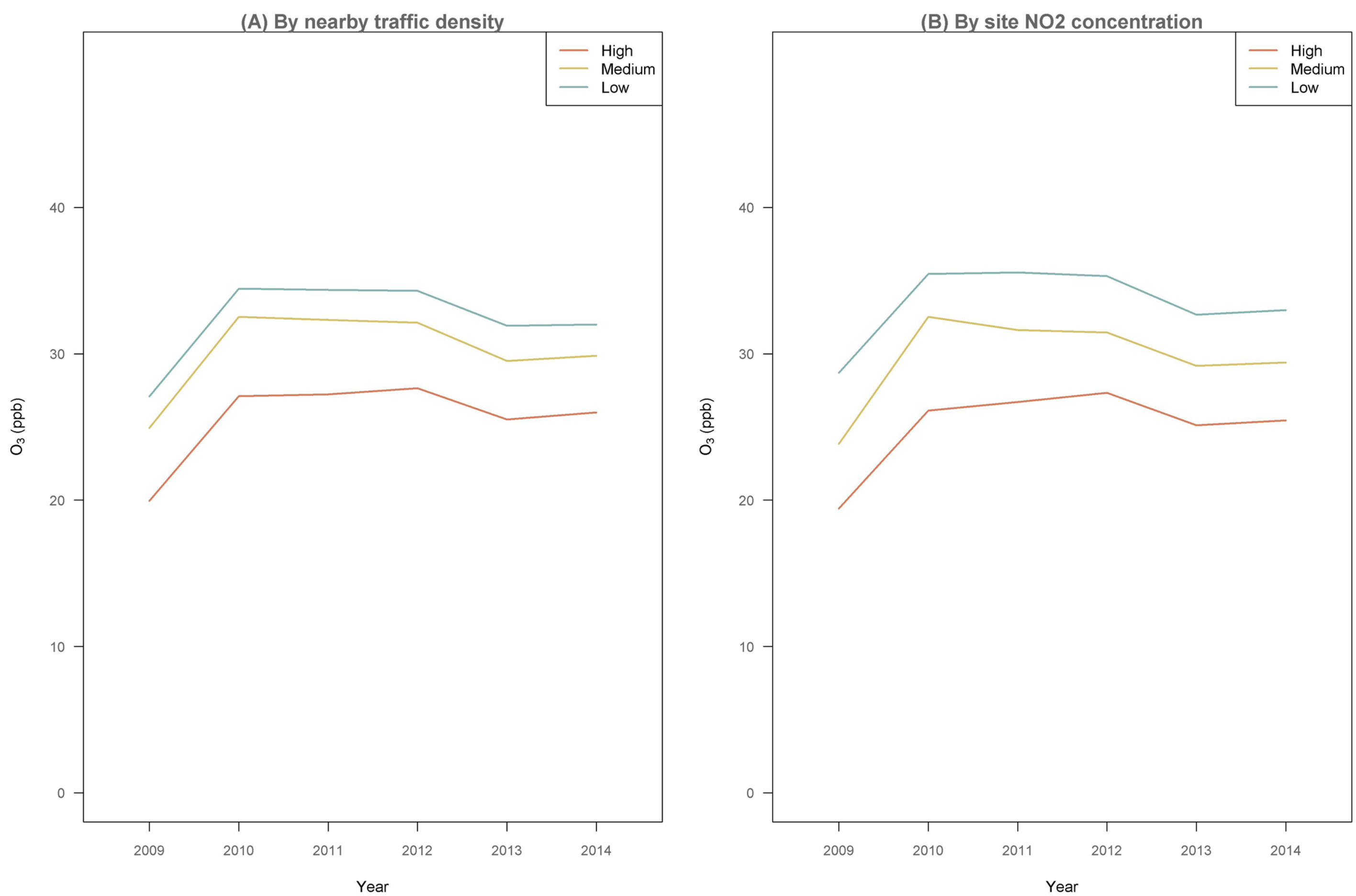


Figure 10: O_3 levels at NYCCAS monitors, by density of nearby traffic density (A) and co-located NO_2 concentration (B)[6]

[6]Traffic density estimated as annual average daily traffic (all types) within 1000 meters of monitoring sites. NO_2 concentrations are based on seasonal average monitored NO_2 levels at the same location. High, Medium, and Low represent one third of sites ranked by source indicator density.

In the LUR model, the most important predictors of O_3 concentrations were, in order of importance:

Indicator	Associated Sources and Interpretation
Level of NO_2 measured at the same location	Nitrogen oxides at elevated concentrations react with ground-level ozone and reduce levels
Tree cover within 50 meters	Reduced levels through reactions of ozone with leaf surfaces.

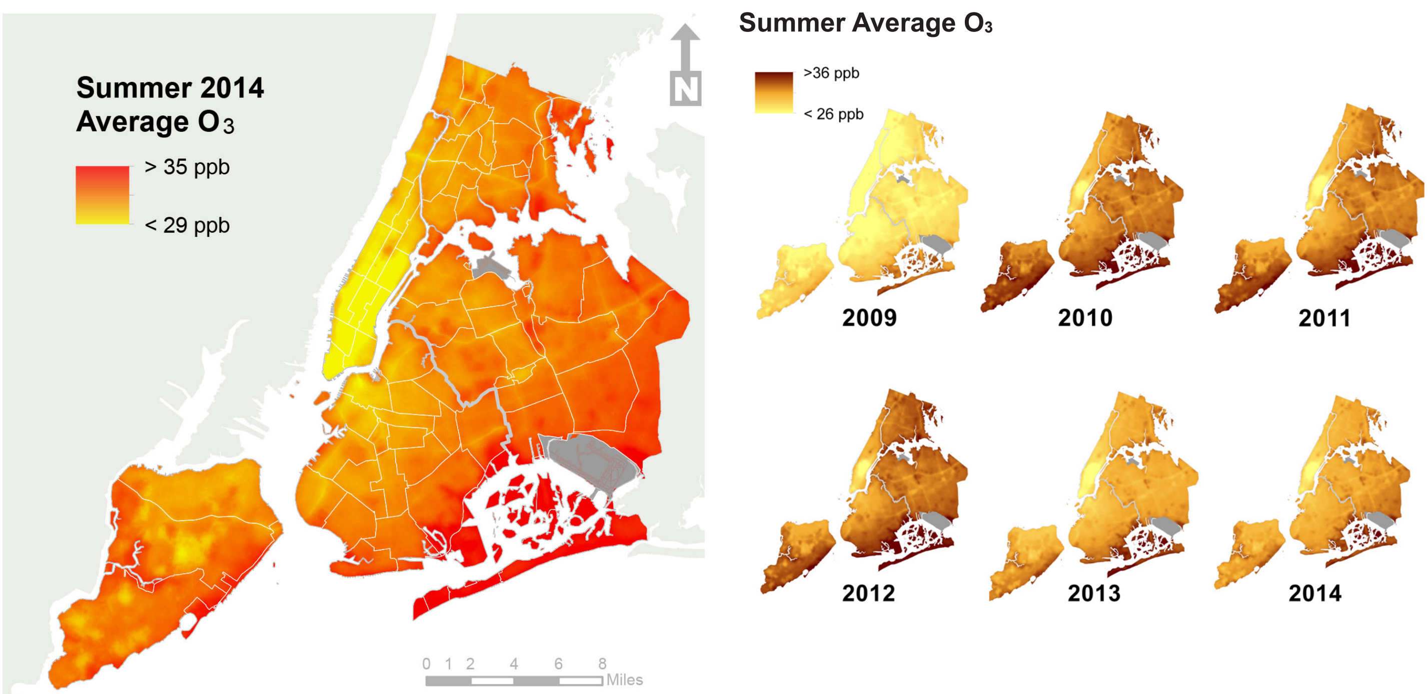


Figure 11: O_3 concentrations, 2014 summertime average (left), and 2009-2014 summertime averages (right)

DISCUSSION

NYCCAS has been an integral part of the city's air quality management efforts, providing policy makers and the public with data on air pollution trends, differences in neighborhood concentrations, and sources of emissions. Much of this information has already been used to design strategies to reduce emissions of harmful pollutants. Six years of data from NYCCAS have documented that despite declining levels of $PM_{2.5}$, SO_2, and NOx citywide, neighborhood differences in average pollution levels persist. The largest improvements in air quality have been observed in some of the City's most polluted neighborhoods. Across the pollutants evaluated in this report, SO_2 has shown the greatest decline, owing to State and Local efforts to phase out high sulfur heating oils through elimination of Nos. 6 and 4 oil and reducing the allowable sulfur content of No. 2 heating oil. With continued phase out of No. 4 heating oil, additional improvements are expected. Air quality improvements and health benefits of eliminating high-sulfur heating oil will occur more rapidly if the phase out No. 4 heating oil boilers occurs before the current 2030 regulatory deadlines. Other major sources of higher levels of pollutants in city neighborhoods include commercial cooking, trucks, buses and motor vehicles. Implementing new control strategies, such as emission controls on commercial char-broilers as required by the new DEP air code, and expanding existing measures will contribute to improved air quality in the future. For more information on NYC air quality initiatives, visit OneNYC.

For neighborhood level air pollution estimates and other environmental, health and sustainability indicators, visit the Environmental & Health Data Portal.

SUPPLEMENTAL MONITORING IN VULNERABLE NEIGHBORHOODS

NYCCAS monitoring locations are located in neighborhoods of varying source density and population density. NYCCAS monitoring locations are also located in neighborhoods of varying socioeconomic status. Communities with higher concentrations of poverty have higher rates of health conditions sensitive to air pollution, making them more vulnerable to harm from a given level of exposure. In the 60 core monitoring sites currently being sampled, the density of monitors per square mile is about 80% higher in the community districts with the highest concentration of poverty compared to more affluent neighborhoods. To further augment monitoring in high poverty neighborhoods and provide more data to check exposure estimates for the city's most vulnerable populations, the NYCCAS team supplemented the monitoring network in 2014 with 15 additional sites, referred to in this report as vulnerable neighborhood (VN) sites. These sites were purposefully placed in neighborhoods with high concentrations of poverty relative to the rest of the city. Within low-income neighborhoods, locations were selected to add monitors in areas with lower than average monitoring density, capture variation in pollution levels, or place monitors near specific sources of interest (Figure 12).

1

NEIGHBORHOOD POVERTY SELECTION
Assess neighborhood poerty and prior monitoring activity

2

MONITORING SITE SELECTION
Chose grid cells within selected neighborhoods that were away from core monitoring sites with varying estimated PM2.5 concentrations or near sources of interest

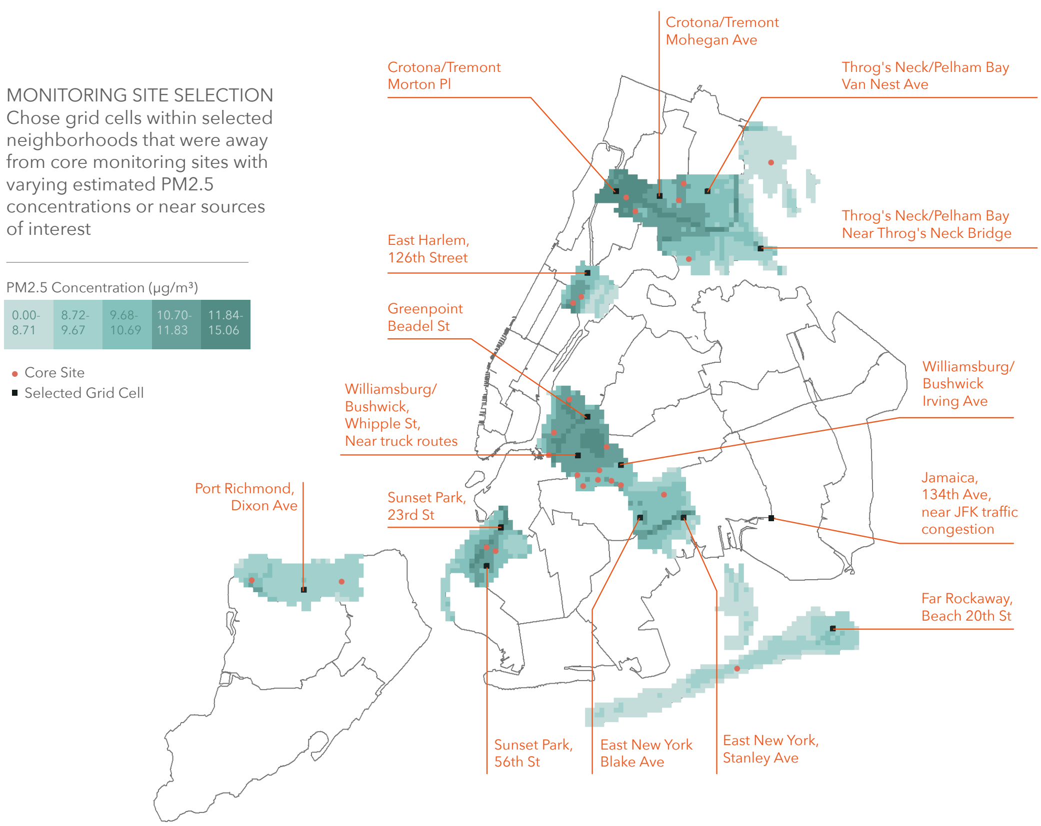


Figure 12: Methods for selecting vulnerable neighborhood sites

In this report we analyze monitoring data at these 15 VN sites that were conducted during three seasons: spring, summer, and fall 2014. To assess how well the model based on the 60 core sites performed in predicting levels at the 15 new locations, we compared the seasonal average modeled estimates to actual levels measured at these locations. We also compared the levels measured at these locations to measurements taken in the same time period throughout the city to evaluate differences in exposures. Monitoring is currently ongoing at these 15 locations.

In comparing $PM_{2.5}$ and NO_2 at the VN sites, we observed small differences between the monitored values and the model predicted estimates, with no statistically significant difference in levels of $PM_{2.5}$ in all seasons, and NO_2 in two of three seasons (Table 1). On average, $PM_{2.5}$ levels over the three season period were only slightly lower (by 0.01 µg/ m^3 lower) than what was predicted by the model at those locations. On average, monitored NO_2 concentrations at the 15 locations, over the three season period, were only 1.1 ppb higher than what was predicted by the model.

Pollutant	Season	Monitored Levels mean (min,max)	Predicted Levels mean (min,max)	Predicted Levels minus Monitored Levels at VN Sites, Difference (percent difference)
$PM_{2.5}$ (µg/m^3)	Spring 2014	8.7 (7.3, 11.3)	8.7 (7.7, 10.5)	-0.0 (-0.5%)
	Summer 2014	8.8 (7.4, 10.4)	9.0 (7.7, 11.2)	0.2 (2.2%)
	Fall 2014	7.6 (6.4, 10.0)	7.5 (6.1, 9.3)	-0.1 (-1.8%)
	Full Period	8.4 (6.4, 11.3)	8.4 (6.1, 11.2)	0.0 (0.1%)
NO_2 (ppb)	Spring 2014	22.0 (16.7, 30.5)	20.0 (16.2, 27.0)	**-2.0 (-9.1%)**
	Summer 2014	16.1 (13.0, 20.7)	15.6 (11.1, 22.5)	-0.5 (-3.3%)
	Fall 2014	19.5 (14.3, 25.8)	18.7 (14.6, 25.4)	-0.8 (-4%)
	Full Period	19.2 (13.0, 30.5)	18.1 (11.1, 27.0)	**-1.1 (-5.7%)**

Table 1: Comparison of monitored values at VN sites to levels predicted by the LUR model at the same locations
*Bold numbers indicate statistically significant differences, based on a paired t-test $p<0.05$ significance

The VN sites, on average, measured $PM_{2.5}$ concentrations that were 5% lower than the city-wide average of the 60 core sites while measured NO_2 concentrations measured at the VN sites were 7% lower than the city-wide average of the 60 core sites (Table 2). Much like other sites citywide, there was variation in the levels measured at the VN sites.

Pollutant	Season	Core Sites, Monitored Levels mean (min,max)	VN Sites Monitored Levels mean (min,max)	Average levels at VN sites minus Core Sites Difference (percent difference)
$PM_{2.5}$ (µg/m³)	Spring 2014	9.2 (6.4, 14.2)	8.7 (7.3, 11.3)	-0.5 (-4.9%)
	Summer 2014	9.3 (6.6, 15.2)	8.8 (7.4, 10.4)	-0.5 (-5.3%)
	Fall 2014	8.1 (5.3, 12.9)	7.6 (6.4, 10.0)	-0.5 (-5.6%)
	Full Period	8.9 (5.3, 15.2)	8.4 (6.4, 11.3)	-0.5 (-5.3%)
NO_2 (ppb)	Spring 2014	22.9 (9.7, 52.4)	22.0 (16.7, 30.5)	-0.9 (-4%)
	Summer 2014	18.0 (5.0, 37.5)	16.1 (13.0, 20.7)	-1.9 (-10.5%)
	Fall 2014	21.1 (9.9, 40.0)	19.5 (14.3, 25.8)	-1.7 (-7.9%)
	Full Period	20.7 (5.0, 52.4)	19.2 (13.0, 30.5)	-1.5 (-7.3%)

Table 2: Comparison of monitored values at VN sites to those at core sites, citywide, during the same time period

These findings show that the LUR models based on the 60 core monitoring sites are useful for predicting $PM_{2.5}$ and NO_2 levels in the new VN sites. In addition, we found, levels of $PM_{2.5}$ and NO_2 at the VN sites were lower than the city on average, although there was variation in levels across the 15 monitoring sites – some higher and some lower than the citywide average. Prior work in NYC has shown that some higher income neighborhoods, especially in Manhattan, tend to have higher $PM_{2.5}$ and NO_2 concentrations, due to increased densities of buildings and traffic. Overall, these findings show that LUR statistical models, based on a measured air pollution concentrations at a systematic sample of locations city-wide, are useful for estimating exposures in unmonitored locations and that data from a single monitor are less useful than LUR estimates to estimate air pollution exposure for a neighborhood.

APPENDIX

MAPS AND SOURCE DESCRIPTIONS

Photo by Iyad Kheirbek

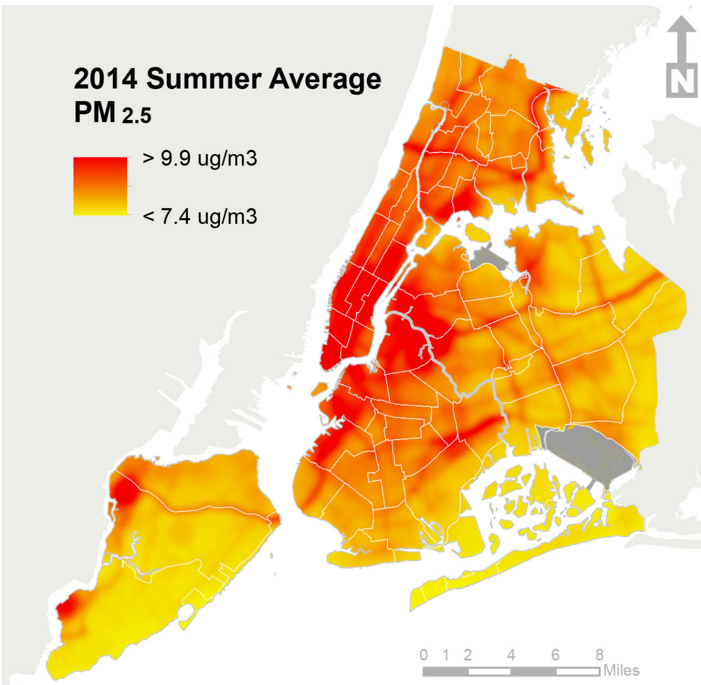
APPENDIX 1 DATA SOURCES FOR EMISSIONS INDICATORS

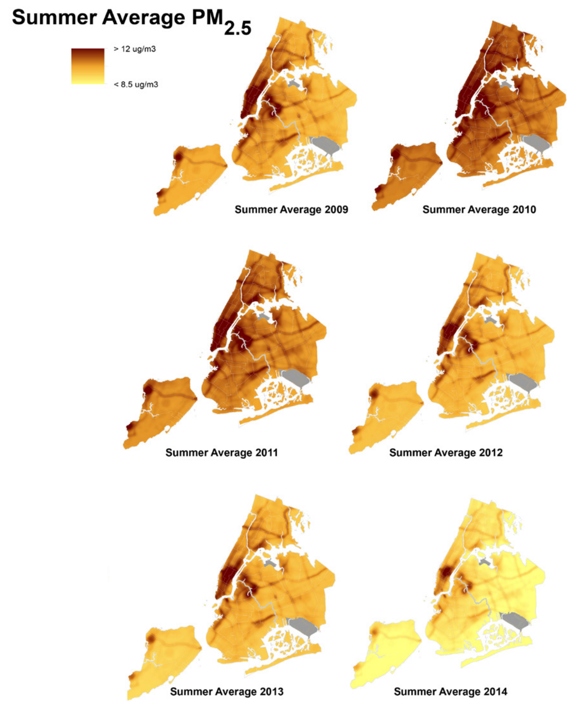
Source Category	Variables Examined (most calculated in buffers of 50 to 1,000 m)	Data Source
Cumulative Traffic Indicators	Unweighted and kernel-weighted traffic density	New York Metropolitan Transportation
		Council (NYMTC) traffic data, 2005; and U.S. Federal Highway Administration Highway
		Performance Monitoring System (HPMS) data, 2007
	Road density	Accident Location Information System (ALIS) road network data, 2008
	Kernel-weighed road density	ALIS network data
	Road density weighted by functional class	ALIS network; MPSI TrafficMetrix ™ data, 1989-2006
	Road density kernel-weighted by functional class	ALIS network; MPSI TrafficMetrix ™ data
	Traffic density weighted by relative emissions rates	NYMTC traffic data; emissions factors from Environmental Protection Agency's AP 42 database
	Number of signaled intersections	NYC Department of Transportation (DOT), 2008
Road-specific Measures	Average daily traffic on nearest major road	NYMTC traffic data
	ADT/ Distance to nearest major road	NYMTC traffic data
	Location on a bus route	NYC DOT
	Distance to nearest road, by functional class	ALIS network; MPSI TrafficMetrix ™ data

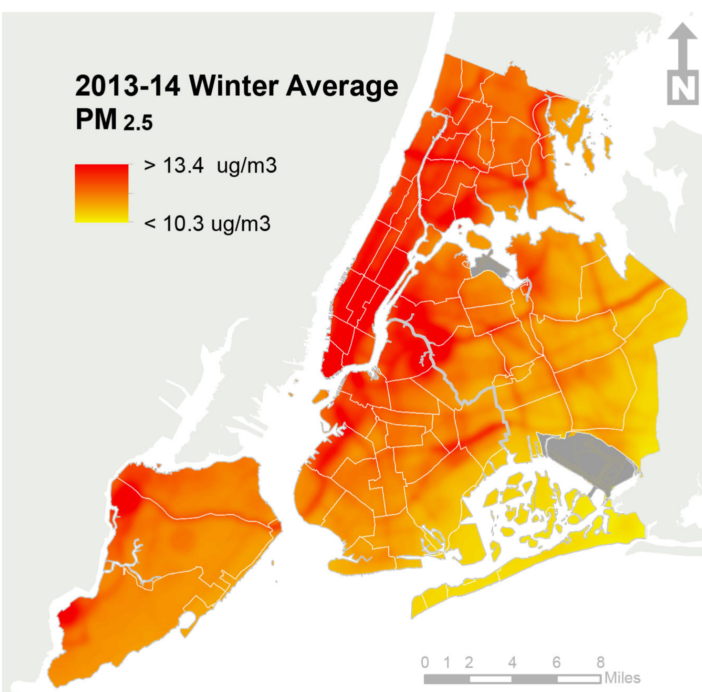
Source Category	Variables Examined (most calculated in buffers of 50 to 1,000 m)	Data Source
Truck/ Diesel-Related Measures	Unweighted traffic on designated truck routes	NYMTC traffic data
	Unweighted density of truck routes	NYMTC traffic data
	Kernel-weighted density of truck routes	NYMTC traffic data
	Distance to nearest truck route	NYMTC traffic data
	Trucks per day on nearest major road	NYMTC traffic data
Population Metrics	Census population density	U.S. Census Bureau 2000 data
	LandScan daytime, nighttime population density	Oak Ridge National Laboratory LandScan™ data, 2006
Built Space	Density of built space (building floor area)	NYC Department of City Planning Primary Land Use Tax Lot Output (PLUTO™) data, 2007
	Density of residential units	PLUTO™ data
	Total residential, factory, garage floor area	PLUTO™ data
	Estimated building boiler emissions for building heat and hot water	PLUTO™ data, EPA AP 42, NYC Department of Environmental Protection (NYC DEP) Registration and Certificate Permit Data, updated annually
	Area of commercial floor area	PLUTO™ data
Land Use	Area of industry and manufacturing	PLUTO™ data
	Area of heavy manufacturing	PLUTO™ data
	Area of gas stations	PLUTO™ data
	Area of tree cover	NYC Department of Parks and Recreation LiDAR data, 2010
	Percent impervious surface	United States Geological Survey, 2006
	Dominant land use type	PLUTO™ data

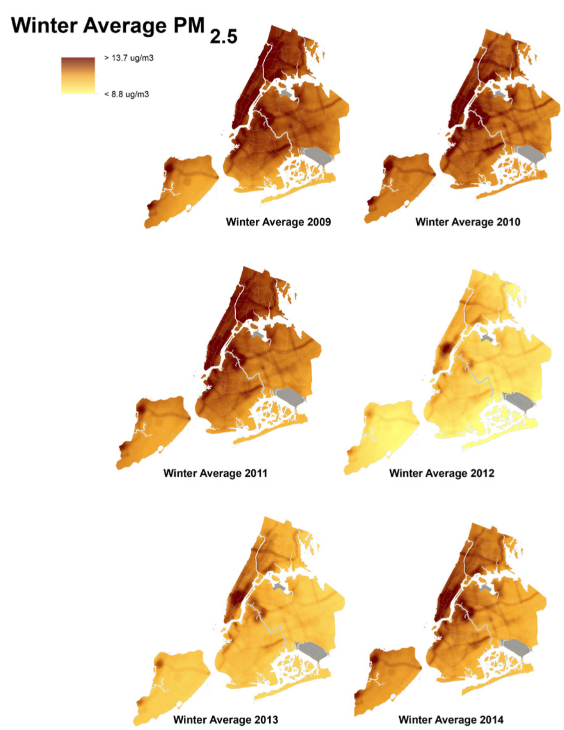
Source Category	Variables Examined (most calculated in buffers of 50 to 1,000 m)	Data Source
Permitted Emissions	Number of DEC permitted combustion sources	NYS Department of Environmental Conservation (DEC) permit data, 2005
	Number of DEP permitted combustion sources	NYC DEP permit data, 2008
	Number of DOB permitted boilers	NYC Department of Buildings (DOB) permit data, 2008
	Number of permitted combustion sources by fuel type (oil 2, 4, 6, natural gas)	DEP permit data, updated every 6 months
	Total BTU by fuel type (oil 2, 4, 6, natural gas)	DEP permit data
	Average BTU by fuel type (oil 2, 4, 6, natural gas)	DEP permit data
Transportation Facilities	Number of bus depots	NYC Department of Citywide Administrative Services, 2008
	Minimum distance to bus depot, school bus depot	NYC Department of Citywide Administrative Services; NYC Department of Education
	Number of school bus depots	NYC Department of Education
	Number of school buses at nearest depot	NYC Department of Education
Distributed Facilities	Number of waste transfer stations	NYC Department of Sanitation inspections
	Minimum distance to waste transfer station, ferry terminal, water treatment facility	NYC Department of Citywide Administrative Services
	Distance to nearest port, airport	NYC Office of Emergency Management (OEM)

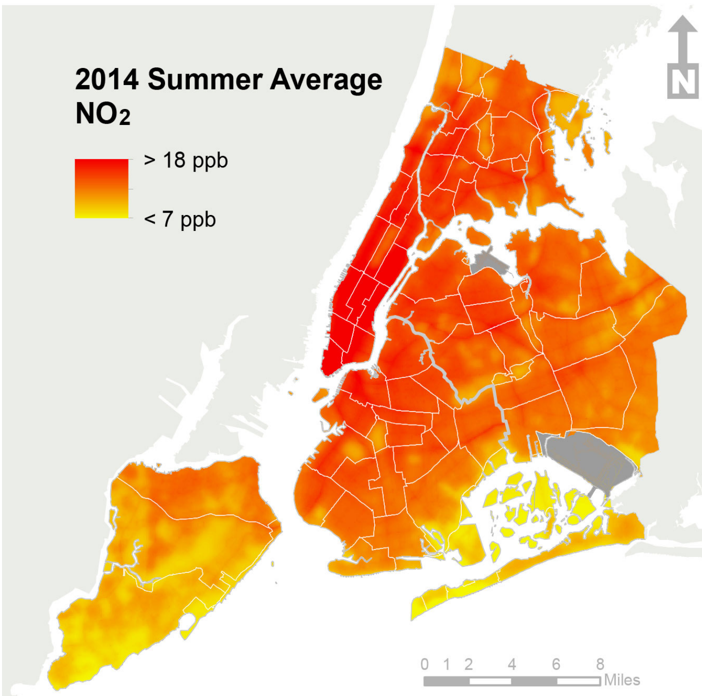
APPENDIX 2
SEASONAL AVERAGE POLLUTANT MAPS, $PM_{2.5}$, NO_2, NO










2014 Summer Average NO_2
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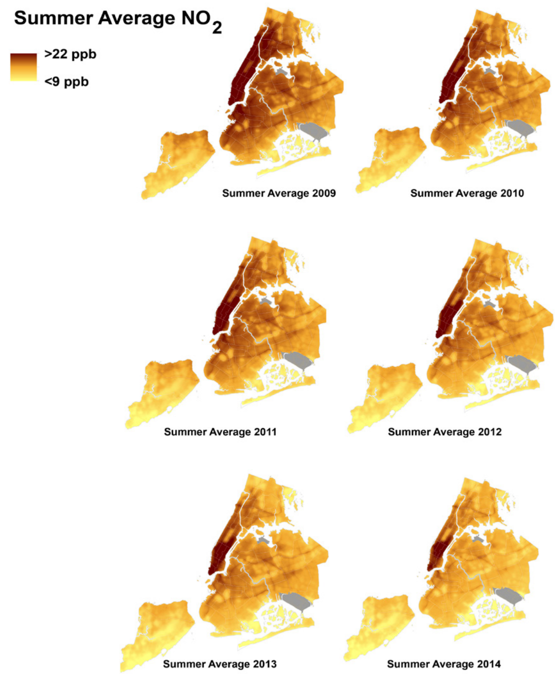
< 7 ppb
N
0 1 2 4 6 8
Miles


Summer Average NO_2
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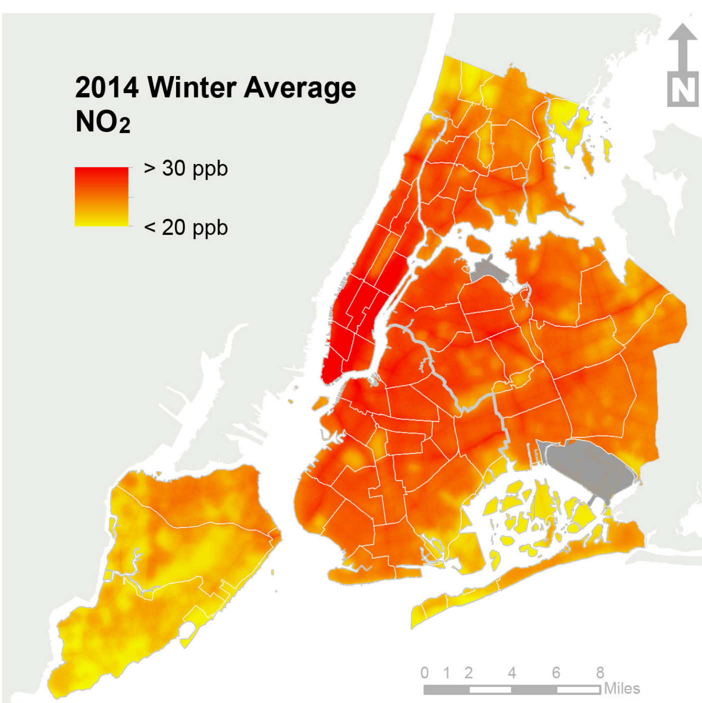
<9 ppb
Summer Average 2009
Summer Average 2010
Summer Average 2011
Summer Average 2012
Summer Average 2013
Summer Average 2014


2014 Winter Average NO_2
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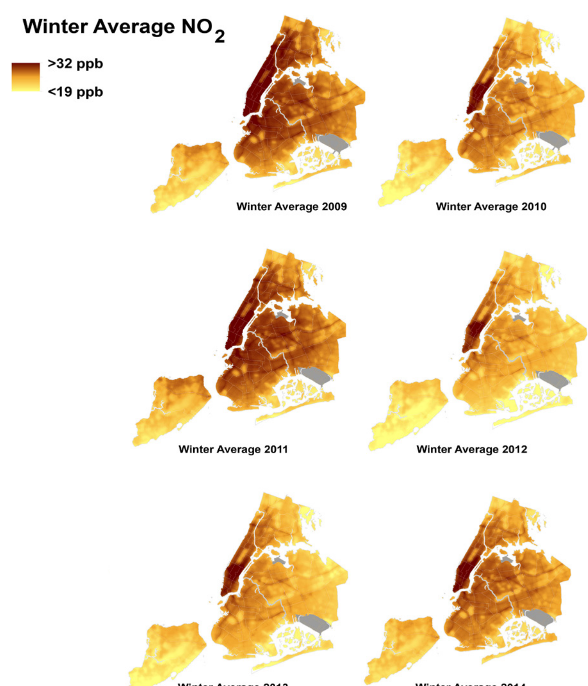
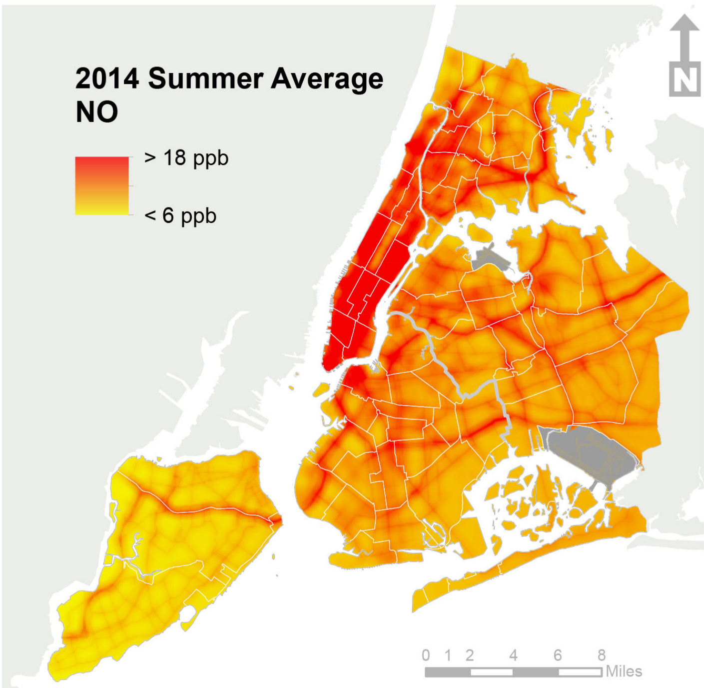
< 20 ppb
N
0 1 2 4 6 8
Miles


Winter Average NO_2
>32 ppb
<19 ppb
Winter Average 2009
Winter Average 2010
Winter Average 2011
Winter Average 2012
Winter Average 2013
Winter Average 2014


2014 Summer Average NO
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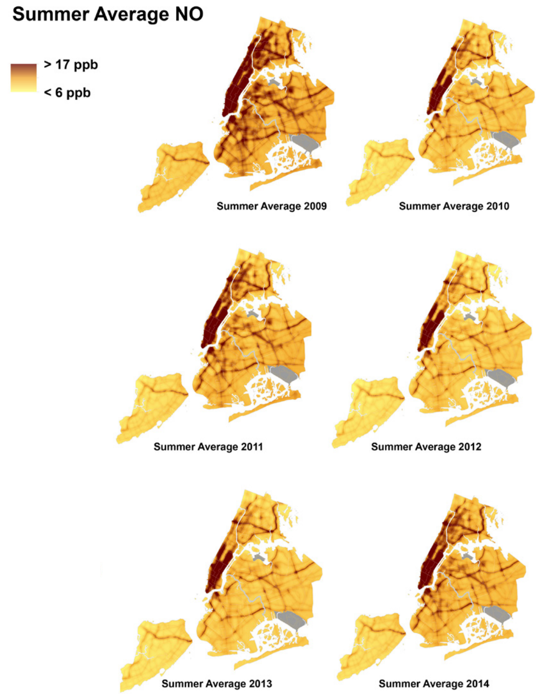
< 6 ppb
N
0 1 2 4 6 8
Miles


Summer Average NO
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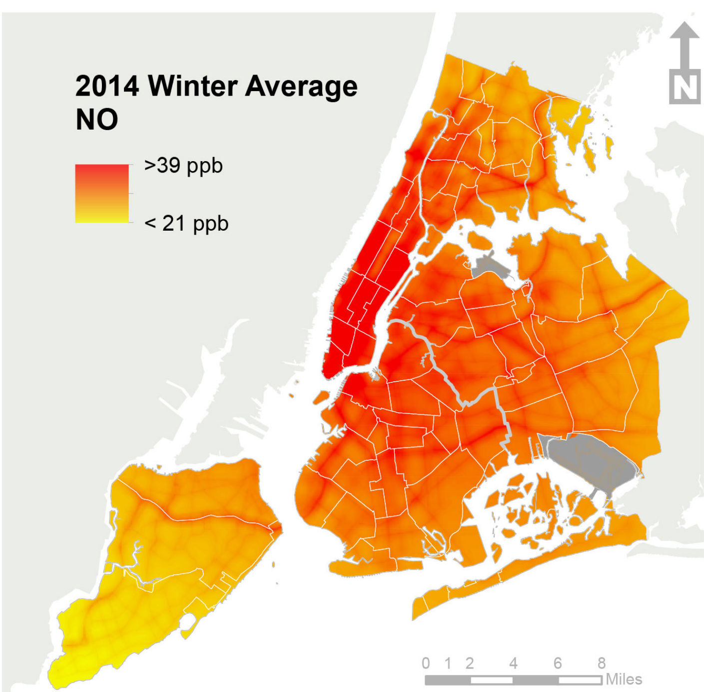
< 6 ppb
Summer Average 2009
Summer Average 2010
Summer Average 2011
Summer Average 2012
Summer Average 2013
Summer Average 2014


2014 Winter Average NO
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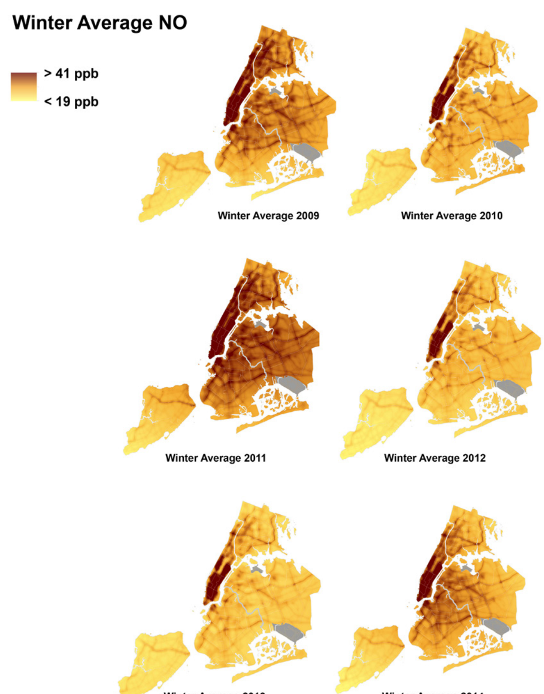
< 21 ppb
N
0 1 2 4 6 8
Miles


Winter Average NO
> 41 ppb
< 19 ppb
Winter Average 2009
Winter Average 2010
Winter Average 2011
Winter Average 2012
Winter Average 2013
Winter Average 2014

APPENDIX 3 COMMUNITY DISTRICT AVERAGE POLLUTANT LEVELS

Table A3-1: Community District Average $PM_{2.5}$ and per-year decline in levels

Borough	Geography	ID	Annual Average 2009	Annual Average 2010	Annual Average 2011	Annual Average 2012	Annual Average 2013	Annual Average 2014	Slope (per year decline)
Manhattan	Washington Heights and Inwood (CD12)	112	11.6	10.7	11.1	9.9	9.5	9.5	-0.44
Bronx	Kingsbridge Heights and Bedford (CD7)	207	11.5	10.7	11.1	9.8	9.4	9.5	-0.43
Bronx	Fordham and University Heights (CD5)	205	12.1	11.4	11.7	10.5	10.1	10.1	-0.43
Bronx	Riverdale and Fieldston (CD8)	208	11.0	10.1	10.7	9.3	8.9	9.0	-0.43
Bronx	Highbridge and Concourse (CD4)	204	12.0	11.2	11.6	10.4	10.0	10.0	-0.42
Bronx	Belmont and East Tremont (CD6)	206	11.5	10.7	11.2	9.9	9.5	9.6	-0.41
Bronx	Morrisania and Crotona (CD3)	203	11.4	10.6	11.1	9.9	9.4	9.5	-0.41
Manhattan	Midtown (CD5)	105	16.1	15.5	14.8	14.2	14.3	14.2	-0.39
Manhattan	Central Harlem (CD10)	110	11.6	10.6	11.1	9.9	9.6	9.7	-0.39
Manhattan	Morningside Heights and Hamilton Heights (CD9)	109	11.7	10.7	11.2	10.1	9.8	9.8	-0.38
Bronx	Parkchester and Soundview (CD9)	209	10.8	10.0	10.7	9.4	8.9	9.1	-0.37
Brooklyn	South Crown Heights and Lefferts Gardens (CD9)	309	10.6	9.9	10.2	9.1	8.6	9.0	-0.37
Bronx	Mott Haven and Melrose (CD1)	201	11.9	10.9	11.6	10.4	10.0	10.1	-0.37
Brooklyn	Crown Heights and Prospect Heights (CD8)	308	10.8	10.0	10.4	9.2	8.8	9.2	-0.37
Brooklyn	Brownsville (CD16)	316	10.8	10.0	10.3	9.1	8.8	9.2	-0.37
Queens	Rego Park and Forest Hills (CD6)	406	10.6	9.8	10.1	9.1	8.7	8.9	-0.37
Bronx	Morris Park and Bronxdale (CD11)	211	10.6	9.7	10.4	9.2	8.7	8.9	-0.36
Bronx	Williamsbridge and Baychester (CD12)	212	10.6	9.6	10.4	9.0	8.7	8.9	-0.36
Manhattan	Financial District (CD1)	101	13.1	12.1	12.3	11.3	11.1	11.4	-0.36
Queens	Kew Gardens and Woodhaven (CD9)	409	10.3	9.5	9.7	8.6	8.4	8.7	-0.35
Queens	Hillcrest and Fresh Meadows (CD8)	408	10.0	9.3	9.7	8.6	8.2	8.4	-0.35
Brooklyn	East Flatbush (CD17)	317	10.6	9.9	10.2	9.1	8.7	9.1	-0.35
Brooklyn	Fort Greene and Brooklyn Heights (CD2)	302	11.6	10.5	11.1	9.9	9.5	10.0	-0.35

Borough	Geography	ID	Annual Average 2009	Annual Average 2010	Annual Average 2011	Annual Average 2012	Annual Average 2013	Annual Average 2014	Slope (per year decline)
Manhattan	Upper West Side (CD7)	107	12.2	11.0	11.5	10.4	10.3	10.4	-0.35
Queens	South Ozone Park and Howard Beach (CD10)	410	9.8	9.0	9.2	8.1	8.0	8.2	-0.35
Brooklyn	Bedford Stuyvesant (CD3)	303	10.8	9.9	10.4	9.2	8.8	9.3	-0.34
Bronx	Hunts Point and Longwood (CD2)	202	11.6	10.7	11.5	10.3	9.8	10.0	-0.34
Manhattan	Upper East Side (CD8)	108	12.9	11.9	12.1	11.2	11.1	11.2	-0.34
Bronx	Throgs Neck and Co-op City (CD10)	210	10.5	9.5	10.4	9.1	8.7	8.9	-0.33
Manhattan	East Harlem (CD11)	111	11.5	10.4	11.1	10.0	9.7	9.8	-0.33
Brooklyn	Park Slope and Carroll Gardens (CD6)	306	11.4	10.4	11.1	9.9	9.4	9.9	-0.33
Queens	Flushing and Whitestone (CD7)	407	10.2	9.4	10.1	8.9	8.4	8.7	-0.33
Manhattan	Stuyvesant Town and Turtle Bay (CD6)	106	14.1	13.1	13.1	12.3	12.3	12.4	-0.33
Brooklyn	Bushwick (CD4)	304	10.8	9.8	10.3	9.2	8.8	9.3	-0.33
Brooklyn	East New York and Starrett City (CD5)	305	10.5	9.7	10.0	8.9	8.7	9.0	-0.33
Brooklyn	Sunset Park (CD7)	307	11.1	10.3	10.9	9.7	9.2	9.7	-0.33
Queens	Jackson Heights (CD3)	403	10.3	9.2	9.9	8.8	8.4	8.7	-0.33
Staten Island	Tottenville and Great Kills (CD3)	503	9.7	8.8	9.3	8.3	7.8	8.2	-0.33
Brooklyn	Flatbush and Midwood (CD14)	314	10.3	9.7	10.1	8.9	8.6	8.9	-0.33
Brooklyn	Borough Park (CD12)	312	10.3	9.6	10.1	8.9	8.5	8.9	-0.33
Queens	Elmhurst and Corona (CD4)	404	10.7	9.8	10.3	9.2	8.9	9.2	-0.32
New York City	New York City	1	10.4	9.5	10.1	9.0	8.6	8.9	-0.32
Queens	Ridgewood and Maspeth (CD5)	405	10.7	9.7	10.2	9.1	8.8	9.2	-0.32
Queens	Jamaica and Hollis (CD12)	412	9.9	9.2	9.5	8.4	8.3	8.4	-0.32
Brooklyn	Bay Ridge and Dyker Heights (CD10)	310	10.2	9.4	10.0	8.8	8.4	8.8	-0.32
Manhattan	Greenwich Village and Soho (CD2)	102	12.8	11.6	12.1	11.1	10.9	11.2	-0.32
Queens	Bayside and Little Neck (CD11)	411	9.7	9.0	9.7	8.5	8.1	8.3	-0.31
Manhattan	Lower East Side and Chinatown (CD3)	103	11.8	10.6	11.3	10.1	9.9	10.3	-0.31
Staten Island	St. George and Stapleton (CD1)	501	10.0	8.9	9.6	8.4	8.1	8.6	-0.30
Manhattan	Clinton and Chelsea (CD4)	104	13.2	11.9	12.4	11.4	11.4	11.6	-0.30
Queens	Queens Village (CD13)	413	9.4	8.7	9.2	8.1	7.9	8.0	-0.30
Brooklyn	Flatlands and Canarsie (CD18)	318	9.8	9.1	9.5	8.3	8.2	8.5	-0.30
Queens	Long Island City and Astoria (CD1)	401	10.7	9.4	10.4	9.2	8.9	9.2	-0.29
Brooklyn	Bensonhurst (CD11)	311	9.8	9.2	9.7	8.6	8.2	8.6	-0.29
Brooklyn	Greenpoint and Williamsburg (CD1)	301	12.0	10.7	11.6	10.4	10.1	10.6	-0.29
Staten Island	South Beach and Willowbrook (CD2)	502	9.8	8.8	9.5	8.3	8.1	8.5	-0.28
Queens	Woodside and Sunnyside (CD2)	402	11.9	10.6	11.5	10.3	10.1	10.5	-0.28
Brooklyn	Sheepshead Bay (CD15)	315	9.6	8.9	9.5	8.3	8.1	8.4	-0.27
Brooklyn	Coney Island (CD13)	313	9.4	8.8	9.4	8.2	8.0	8.3	-0.26
Queens	Rockaway and Broad Channel (CD14)	414	8.8	8.0	8.4	7.4	7.6	7.7	-0.22

Table A3-1: Community District Average NO_2 and per-year decline in levels

Borough	Geography	ID	Annual Average 2009	Annual Average 2010	Annual Average 2011	Annual Average 2012	Annual Average 2013	Annual Average 2014	Slope (per year decline)
Manhattan	Midtown (CD5)	105	46.8	42.1	41.8	40.0	38.7	37.1	-1.73
Manhattan	Financial District (CD1)	101	36.6	33.4	33.5	31.1	30.3	28.9	-1.43
Manhattan	Stuyvesant Town and Turtle Bay (CD6)	106	39.9	36.2	36.4	34.5	33.4	32.2	-1.39
Manhattan	Morningside Heights and Hamilton Heights (CD9)	109	31.0	27.6	28.1	25.5	25.2	23.6	-1.34
Manhattan	Washington Heights and Inwood (CD12)	112	27.9	24.7	25.0	22.6	22.3	20.6	-1.32
Manhattan	Central Harlem (CD10)	110	31.2	27.9	28.3	25.9	25.4	24.0	-1.31
Bronx	Highbridge and Concourse (CD4)	204	29.7	26.6	26.9	24.5	24.0	22.7	-1.29
Bronx	Fordham and University Heights (CD5)	205	29.6	26.5	26.8	24.6	23.9	22.7	-1.27
Manhattan	Clinton and Chelsea (CD4)	104	36.3	32.9	33.5	31.4	30.6	29.2	-1.27
Manhattan	Greenwich Village and Soho (CD2)	102	34.8	31.8	32.3	30.1	29.3	28.1	-1.23
Manhattan	Upper East Side (CD8)	108	34.5	31.2	31.7	29.6	28.7	27.8	-1.23
Manhattan	Upper West Side (CD7)	107	31.9	28.6	29.3	27.1	26.5	25.1	-1.21
Bronx	Morrisania and Crotona (CD3)	203	27.7	25.0	25.3	23.0	22.3	21.6	-1.17
Brooklyn	Fort Greene and Brooklyn Heights (CD2)	302	29.3	27.1	27.4	24.8	24.2	23.4	-1.17
Brooklyn	Park Slope and Carroll Gardens (CD6)	306	27.7	25.9	26.0	23.3	22.7	22.0	-1.17
Manhattan	Lower East Side and Chinatown (CD3)	103	31.8	29.2	29.7	27.4	26.6	25.7	-1.16
Manhattan	East Harlem (CD11)	111	29.8	27.0	27.6	25.2	24.7	23.6	-1.15
Bronx	Mott Haven and Melrose (CD1)	201	28.1	25.5	25.9	23.5	22.9	22.1	-1.15
Brooklyn	Crown Heights and Prospect Heights (CD8)	308	27.8	25.9	26.0	23.4	22.8	22.3	-1.13
Brooklyn	Sunset Park (CD7)	307	25.5	24.0	24.0	21.2	20.7	20.3	-1.11
Bronx	Kingsbridge Heights and Bedford (CD7)	207	26.7	23.8	24.2	22.5	21.5	20.7	-1.10

Borough	Geography	ID	Annual Average 2009	Annual Average 2010	Annual Average 2011	Annual Average 2012	Annual Average 2013	Annual Average 2014	Slope (per year decline)
Brooklyn	South Crown Heights and Lefferts Gardens (CD9)	309	27.0	25.3	25.2	22.7	22.1	21.7	-1.10
Brooklyn	Bedford Stuyvesant (CD3)	303	27.6	25.7	25.9	23.5	22.8	22.2	-1.09
Bronx	Belmont and East Tremont (CD6)	206	27.1	24.4	24.8	22.8	21.9	21.4	-1.09
Bronx	Riverdale and Fieldston (CD8)	208	23.2	20.1	20.8	19.1	18.2	17.1	-1.08
Bronx	Hunts Point and Longwood (CD2)	202	26.1	23.9	24.3	22.1	21.3	21.0	-1.01
Brooklyn	Borough Park (CD12)	312	25.2	23.8	23.6	21.1	20.5	20.6	-1.01
Brooklyn	East Flatbush (CD17)	317	25.1	23.6	23.6	21.3	20.7	20.5	-0.97
Brooklyn	Flatbush and Midwood (CD14)	314	24.4	23.0	22.9	20.5	19.9	20.0	-0.96
Brooklyn	Brownsville (CD16)	316	25.6	24.0	24.2	21.9	21.4	20.9	-0.96
Brooklyn	Bushwick (CD4)	304	25.9	24.2	24.7	22.4	21.7	21.2	-0.95
Brooklyn	Greenpoint and Williamsburg (CD1)	301	27.0	25.2	25.9	23.6	22.9	22.4	-0.92
Bronx	Parkchester and Soundview (CD9)	209	24.6	22.6	23.0	21.1	19.9	20.2	-0.91
Brooklyn	Bay Ridge and Dyker Heights (CD10)	310	23.6	22.4	22.6	20.1	19.5	19.6	-0.89
Queens	Elmhurst and Corona (CD4)	404	26.9	25.3	25.9	23.7	22.8	22.8	-0.86
Queens	Rego Park and Forest Hills (CD6)	406	25.0	23.5	24.1	21.8	21.1	20.9	-0.86
Queens	Long Island City and Astoria (CD1)	401	25.4	23.5	24.4	22.2	21.4	21.2	-0.84
Brooklyn	East New York and Starrett City (CD5)	305	23.4	22.0	22.4	20.2	19.8	19.3	-0.84
Queens	Kew Gardens and Woodhaven (CD9)	409	24.1	22.8	23.3	21.0	20.6	20.1	-0.83
Queens	Ridgewood and Maspeth (CD5)	405	24.1	22.6	23.3	21.1	20.4	20.1	-0.82
Queens	Jackson Heights (CD3)	403	25.6	24.0	24.7	22.6	21.6	21.7	-0.82
Queens	Woodside and Sunnyside (CD2)	402	25.9	24.1	25.1	23.0	22.1	21.9	-0.80
Queens	Hillcrest and Fresh Meadows (CD8)	408	22.4	21.3	21.7	19.4	18.7	18.8	-0.80
Bronx	Morris Park and Bronxdale (CD11)	211	23.4	21.2	21.8	20.4	19.0	19.4	-0.80
Brooklyn	Bensonhurst (CD11)	311	23.0	21.9	21.9	19.7	19.0	19.7	-0.78
Queens	Flushing and Whitestone (CD7)	407	22.7	21.5	21.9	19.8	18.7	19.4	-0.77

Borough	Geography	ID	Annual Average 2009	Annual Average 2010	Annual Average 2011	Annual Average 2012	Annual Average 2013	Annual Average 2014	Slope (per year decline)
Queens	South Ozone Park and Howard Beach (CD10)	410	22.2	21.0	21.5	19.3	19.0	18.6	-0.75
Queens	Jamaica and Hollis (CD12)	412	22.3	21.3	21.6	19.4	19.1	18.9	-0.74
Staten Island	St. George and Stapleton (CD1)	501	20.7	19.3	20.5	18.1	17.6	17.1	-0.73
Brooklyn	Flatlands and Canarsie (CD18)	318	20.3	19.2	19.2	17.3	16.7	17.1	-0.73
Bronx	Williamsbridge and Baychester (CD12)	212	22.1	19.7	20.6	19.5	18.0	18.3	-0.72
Queens	Bayside and Little Neck (CD11)	411	20.5	19.6	19.9	17.9	16.8	17.8	-0.68
Bronx	Throgs Neck and Co-op City (CD10)	210	21.3	19.8	20.4	19.0	17.4	18.5	-0.65
Brooklyn	Sheepshead Bay (CD15)	315	20.4	19.4	19.4	17.6	16.8	18.0	-0.62
Queens	Queens Village (CD13)	413	19.9	19.1	19.3	17.4	16.9	17.3	-0.61
Staten Island	South Beach and Willowbrook (CD2)	502	16.5	15.2	16.3	14.5	13.8	14.0	-0.53
Brooklyn	Coney Island (CD13)	313	18.4	17.6	17.7	16.0	15.1	16.6	-0.52
Staten Island	Tottenville and Great Kills (CD3)	503	14.7	13.0	13.3	12.4	11.4	12.5	-0.48
Queens	Rockaway and Broad Channel (CD14)	414	14.6	13.9	14.2	13.0	12.5	13.7	-0.28

Table A3-3: Community District Average NO and per-year decline in levels

Borough	Geography	ID	Annual Average 2008-09	Annual Average 2009-10	Annual Average 2010-11	Annual Average 2011-12	Annual Average 2012-13	Annual Average 2013-14	Slope (per year decline)
Manhattan	Greenwich Village and Soho (CD2)	102	52.7	46.4	50.7	41.7	37.2	42.3	-2.53
Manhattan	Upper East Side (CD8)	108	51.8	46.0	50.0	42.2	37.7	41.3	-2.43
Manhattan	Midtown (CD5)	105	57.7	52.1	56.0	48.1	43.4	47.8	-2.39
Manhattan	Upper West Side (CD7)	107	46.6	40.9	44.6	37.4	33.2	37.3	-2.19
Manhattan	Stuyvesant Town and Turtle Bay (CD6)	106	49.3	44.7	48.2	41.2	37.4	42.3	-1.83
Manhattan	Lower East Side and Chinatown (CD3)	103	40.9	36.0	39.6	31.9	28.7	34.4	-1.76
Manhattan	Clinton and Chelsea (CD4)	104	44.2	39.1	42.7	35.7	32.1	37.5	-1.75
Bronx	Kingsbridge Heights and Bedford (CD7)	207	31.1	26.1	28.4	23.3	20.8	23.6	-1.67
Bronx	Fordham and University Heights (CD5)	205	34.2	29.2	31.6	26.3	23.7	27.1	-1.63
Manhattan	Central Harlem (CD10)	110	33.6	28.3	31.5	25.3	22.4	26.9	-1.63
Manhattan	Morningside Heights and Hamilton Heights (CD9)	109	34.1	29.0	31.9	26.0	23.0	27.5	-1.63
Manhattan	Washington Heights and Inwood (CD12)	112	32.3	27.2	29.6	24.4	21.7	25.5	-1.60
Bronx	Highbridge and Concourse (CD4)	204	32.3	27.7	30.2	24.9	22.2	26.0	-1.51
Bronx	Belmont and East Tremont (CD6)	206	29.7	25.0	27.5	22.4	20.2	23.4	-1.45
Manhattan	East Harlem (CD11)	111	33.4	28.9	31.9	26.2	23.5	28.3	-1.35
Bronx	Riverdale and Fieldston (CD8)	208	24.4	19.6	21.5	17.1	15.1	18.5	-1.35
Bronx	Morrisania and Crotona (CD3)	203	27.6	23.2	25.8	20.6	18.5	22.1	-1.35
Manhattan	Financial District (CD1)	101	39.5	35.6	38.7	32.3	29.4	35.2	-1.33
Brooklyn	Crown Heights and Prospect Heights (CD8)	308	28.3	25.3	27.9	21.6	18.9	24.1	-1.32
Brooklyn	Bushwick (CD4)	304	26.2	23.3	25.8	19.5	16.9	22.2	-1.30
Queens	Bayside and Little Neck (CD11)	411	22.7	20.5	23.2	18.1	16.5	17.3	-1.25
Queens	Rego Park and Forest Hills (CD6)	406	27.5	24.9	27.3	21.5	19.4	23.2	-1.25
Bronx	Williamsbridge and Baychester (CD12)	212	23.1	18.9	20.9	16.6	15.0	17.7	-1.25
Queens	Hillcrest and Fresh Meadows (CD8)	408	24.0	21.8	24.3	18.9	17.1	19.2	-1.24
Bronx	Morris Park and Bronxdale (CD11)	211	23.7	19.8	22.0	17.4	15.8	18.4	-1.24
Bronx	Parkchester and Soundview (CD9)	209	25.8	22.2	24.6	19.8	17.9	20.9	-1.21
Queens	Flushing and Whitestone (CD7)	407	23.1	20.4	23.0	17.8	16.0	18.3	-1.21
Bronx	Mott Haven and Melrose (CD1)	201	28.4	24.3	27.0	21.8	19.5	23.9	-1.20
Queens	Jamaica and Hollis (CD12)	412	23.0	21.3	23.7	18.5	16.8	18.3	-1.20
Bronx	Hunts Point and Longwood (CD2)	202	26.1	22.2	24.8	19.8	17.7	21.4	-1.20
Queens	Queens Village (CD13)	413	21.3	19.9	22.4	17.6	16.0	16.2	-1.18

Borough	Geography	ID	Annual Average 2008-09	Annual Average 2009-10	Annual Average 2010-11	Annual Average 2011-12	Annual Average 2012-13	Annual Average 2013-14	Slope (per year decline)
Queens	Kew Gardens and Woodhaven (CD9)	409	24.5	22.3	24.6	19.0	17.0	20.6	-1.17
Bronx	Throgs Neck and Co-op City (CD10)	210	24.0	20.7	23.1	18.4	16.9	19.1	-1.16
Queens	Elmhurst and Corona (CD4)	404	26.7	23.8	26.4	20.6	18.5	22.9	-1.16
Brooklyn	Bedford Stuyvesant (CD3)	303	25.7	22.9	25.4	19.4	16.9	22.5	-1.15
Queens	Jackson Heights (CD3)	403	24.9	21.8	24.5	18.9	16.8	21.1	-1.13
Brooklyn	Greenpoint and Williamsburg (CD1)	301	27.7	24.5	27.2	21.1	18.6	24.6	-1.12
Brooklyn	Brownsville (CD16)	316	24.4	22.2	24.4	18.8	16.4	21.2	-1.11
Queens	Long Island City and Astoria (CD1)	401	24.7	21.2	24.0	18.5	16.3	21.3	-1.08
Queens	Ridgewood and Maspeth (CD5)	405	23.9	21.4	23.7	18.0	15.9	20.9	-1.07
Brooklyn	South Crown Heights and Lefferts Gardens (CD9)	309	26.7	24.3	26.8	21.1	18.9	23.8	-1.05
Queens	South Ozone Park and Howard Beach (CD10)	410	22.4	20.8	22.8	17.7	15.9	19.0	-1.04
Brooklyn	Fort Greene and Brooklyn Heights (CD2)	302	30.0	27.0	29.7	23.8	21.4	27.3	-1.04
Brooklyn	East New York and Starrett City (CD5)	305	23.8	21.9	24.0	18.6	16.6	20.8	-1.03
Brooklyn	Park Slope and Carroll Gardens (CD6)	306	25.9	23.2	25.9	20.2	17.7	23.2	-1.03
Queens	Woodside and Sunnyside (CD2)	402	27.1	24.0	26.6	20.9	18.7	24.3	-1.02
Brooklyn	East Flatbush (CD17)	317	24.3	22.4	24.7	19.5	17.5	21.9	-0.92
Brooklyn	Flatbush and Midwood (CD14)	314	24.4	22.7	25.2	20.3	18.3	22.1	-0.85
Brooklyn	Sunset Park (CD7)	307	23.6	21.4	24.1	19.0	16.8	21.5	-0.84
Brooklyn	Borough Park (CD12)	312	21.6	19.9	22.6	17.9	16.0	19.8	-0.74
Queens	Rockaway and Broad Channel (CD14)	414	18.2	18.0	20.3	16.8	15.3	15.5	-0.71
Brooklyn	Flatlands and Canarsie (CD18)	318	19.7	18.6	20.8	16.4	14.8	18.1	-0.66
Brooklyn	Bay Ridge and Dyker Heights (CD10)	310	21.1	19.4	22.3	17.9	16.0	19.5	-0.66
Brooklyn	Bensonhurst (CD11)	311	20.0	18.7	21.4	17.4	15.5	18.4	-0.61
Brooklyn	Sheepshead Bay (CD15)	315	19.2	18.5	21.0	17.3	15.6	17.8	-0.56
Staten Island	Tottenville and Great Kills (CD3)	503	13.0	11.2	12.7	12.5	10.7	9.8	-0.50
Staten Island	St. George and Stapleton (CD1)	501	16.8	14.7	17.3	14.2	12.3	15.4	-0.49
Brooklyn	Coney Island (CD13)	313	17.3	16.6	19.2	16.1	14.4	16.1	-0.44
Staten Island	South Beach and Willowbrook (CD2)	502	14.7	12.8	15.1	13.2	11.3	12.9	-0.43

Table A3-4: Community District Average SO_2 and per-year decline in levels

Borough	Geography	ID	Winter 2008-09	Winter 2009-10	Winter 2010-11	Winter 2011-12	Winter 2012-13	Winter 2013-14	Slope (per year decline)
Bronx	Fordham and University Heights (CD5)	205	12.7	8.2	10.5	6.8	4.5	3.8	-1.69
Manhattan	Upper East Side (CD8)	108	12.1	8.5	10.4	6.3	4.1	3.8	-1.68
Bronx	Kingsbridge Heights and Bedford (CD7)	207	11.8	7.5	9.5	6.3	4.0	3.3	-1.61
Manhattan	Washington Heights and Inwood (CD12)	112	11.4	7.5	9.5	6.3	4.3	3.4	-1.51
Manhattan	Upper West Side (CD7)	107	11.0	7.6	9.4	6.0	4.0	3.5	-1.48
Manhattan	Midtown (CD5)	105	10.3	7.0	8.8	5.3	3.2	3.3	-1.43
Bronx	Highbridge and Concourse (CD4)	204	10.4	6.9	8.8	5.5	3.9	3.2	-1.38
Manhattan	Stuyvesant Town and Turtle Bay (CD6)	106	9.2	6.3	7.9	4.6	2.8	3.0	-1.28
Manhattan	Morningside Heights and Hamilton Heights (CD9)	109	9.3	6.3	7.9	5.1	3.5	2.9	-1.23
Manhattan	Greenwich Village and Soho (CD2)	102	8.7	5.7	7.3	4.3	2.4	2.7	-1.23
Bronx	Belmont and East Tremont (CD6)	206	8.2	5.3	6.8	4.3	2.8	2.5	-1.10
Manhattan	Central Harlem (CD10)	110	8.2	5.6	7.0	4.4	3.1	2.7	-1.07
Manhattan	Lower East Side and Chinatown (CD3)	103	7.0	4.6	5.9	3.3	1.8	2.2	-1.00
Manhattan	Clinton and Chelsea (CD4)	104	7.3	4.9	6.2	3.8	2.3	2.4	-0.99
Bronx	Morrisania and Crotona (CD3)	203	7.0	4.7	6.0	3.6	2.4	2.2	-0.95
Bronx	Riverdale and Fieldston (CD8)	208	6.7	4.2	5.4	3.8	2.3	1.7	-0.92
Manhattan	East Harlem (CD11)	111	7.0	4.8	6.0	3.7	2.5	2.4	-0.92
Queens	Elmhurst and Corona (CD4)	404	6.3	4.5	5.6	2.8	1.8	2.4	-0.87
Queens	Jackson Heights (CD3)	403	6.1	4.3	5.4	2.8	1.8	2.3	-0.83
Bronx	Morris Park and Bronxdale (CD11)	211	5.9	3.8	4.8	3.0	1.8	1.9	-0.79
Bronx	Williamsbridge and Baychester (CD12)	212	5.8	3.6	4.5	3.0	1.7	1.7	-0.79
Brooklyn	South Crown Heights and Lefferts Gardens (CD9)	309	5.0	3.4	4.2	2.0	1.1	1.3	-0.79
Queens	Rego Park and Forest Hills (CD6)	406	5.3	3.8	4.7	2.3	1.3	1.8	-0.78
Bronx	Parkchester and Soundview (CD9)	209	5.9	3.9	4.9	2.9	1.9	2.1	-0.77
Brooklyn	Flatbush and Midwood (CD14)	314	4.7	3.1	3.8	1.8	1.0	1.1	-0.75
Bronx	Mott Haven and Melrose (CD1)	201	5.7	3.9	4.9	3.0	2.1	2.0	-0.74
Brooklyn	Crown Heights and Prospect Heights (CD8)	308	4.8	3.2	4.0	2.0	1.1	1.3	-0.74
Brooklyn	Bedford Stuyvesant (CD3)	303	4.7	3.2	4.0	2.0	1.2	1.4	-0.70
Brooklyn	East Flatbush (CD17)	317	4.4	3.0	3.6	1.7	1.0	1.1	-0.70
Manhattan	Financial District (CD1)	101	4.8	3.0	4.0	2.3	1.2	1.4	-0.69
Brooklyn	Borough Park (CD12)	312	4.4	2.8	3.6	1.7	0.9	1.1	-0.69
Brooklyn	Bushwick (CD4)	304	4.7	3.3	4.1	2.0	1.3	1.5	-0.69

Borough	Geography	ID	Winter 2008-09	Winter 2009-10	Winter 2010-11	Winter 2011-12	Winter 2012-13	Winter 2013-14	Slope (per year decline)
Bronx	Hunts Point and Longwood (CD2)	202	5.1	3.5	4.4	2.5	1.7	1.8	-0.68
Brooklyn	Fort Greene and Brooklyn Heights (CD2)	302	4.4	2.9	3.7	1.9	1.0	1.2	-0.67
Brooklyn	Brownsville (CD16)	316	4.3	3.1	3.7	1.7	1.1	1.2	-0.67
Queens	Long Island City and Astoria (CD1)	401	5.0	3.6	4.5	2.5	1.7	1.9	-0.66
Queens	Woodside and Sunnyside (CD2)	402	4.8	3.4	4.3	2.3	1.5	1.7	-0.66
Queens	Kew Gardens and Woodhaven (CD9)	409	4.2	3.1	3.7	1.8	1.1	1.4	-0.63
Brooklyn	Greenpoint and Williamsburg (CD1)	301	4.3	3.0	3.7	2.0	1.2	1.4	-0.62
Queens	Ridgewood and Maspeth (CD5)	405	4.1	2.9	3.6	1.8	1.1	1.4	-0.59
Brooklyn	East New York and Starrett City (CD5)	305	3.8	2.8	3.3	1.5	1.0	1.1	-0.59
Brooklyn	Park Slope and Carroll Gardens (CD6)	306	3.9	2.5	3.2	1.6	0.8	1.1	-0.59
Queens	Flushing and Whitestone (CD7)	407	4.5	3.0	3.9	2.0	1.2	1.9	-0.58
Bronx	Throgs Neck and Co-op City (CD10)	210	4.4	2.8	3.6	2.1	1.2	1.6	-0.58
Brooklyn	Sunset Park (CD7)	307	3.8	2.3	3.1	1.5	0.8	1.0	-0.57
Queens	Hillcrest and Fresh Meadows (CD8)	408	4.0	2.8	3.4	1.7	0.9	1.5	-0.57
Brooklyn	Bensonhurst (CD11)	311	3.6	2.4	2.9	1.3	0.8	1.0	-0.55
Brooklyn	Sheepshead Bay (CD15)	315	3.3	2.3	2.7	1.2	0.7	0.8	-0.54
Queens	South Ozone Park and Howard Beach (CD10)	410	3.4	2.5	2.9	1.4	0.8	1.1	-0.52
Queens	Jamaica and Hollis (CD12)	412	3.4	2.5	2.9	1.4	0.7	1.2	-0.51
Brooklyn	Bay Ridge and Dyker Heights (CD10)	310	3.4	2.1	2.8	1.3	0.7	1.0	-0.51
Brooklyn	Flatlands and Canarsie (CD18)	318	3.2	2.3	2.7	1.2	0.8	0.9	-0.50
Queens	Bayside and Little Neck (CD11)	411	3.7	2.4	3.1	1.6	0.8	1.5	-0.49
Brooklyn	Coney Island (CD13)	313	2.9	2.0	2.4	1.0	0.6	0.8	-0.46
Queens	Queens Village (CD13)	413	3.1	2.2	2.5	1.3	0.6	1.1	-0.46
Queens	Rockaway and Broad Channel (CD14)	414	2.4	1.9	1.9	0.9	0.5	0.6	-0.41
Staten Island	St. George and Stapleton (CD1)	501	2.6	1.4	2.1	1.0	0.5	1.0	-0.34
Staten Island	South Beach and Willowbrook (CD2)	502	2.2	1.2	1.8	0.8	0.4	0.9	-0.28
Staten Island	Tottenville and Great Kills (CD3)	503	1.8	1.0	1.5	0.6	0.4	0.7	-0.23

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