Diesel Emissions Impact on Air Quality Surrounding San Pedro Ports Area

UCLA Environmental Science Practicum 2018-2019

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Table of Contents

1. Abstract

The San Pedro Bay Ports contribute significantly to the suboptimal air quality that residents are exposed to in communities around the port. This can be attributed to the ports' utilization of fossil fuels in their large scale daily operations. A major contributor of poor air quality is diesel truck exhaust. Diesel trucks emit a wide range of pollutants but among the most detrimental are nitrogen oxides and particulate matter measuring 2.5 micrometers or less in diameter ($PM_{2.5}$). While existing programs such as the Clean Air Action Plan (CAAP) utilize monitoring stations to measure ambient air pollutant concentrations, attributing the portion of pollutants directly related to diesel trucks comes with a variety of challenges. Our project seeks to predict the portion of these pollutants related to diesel trucks by using AERMOD, an air pollutant dispersion model. Using existing meteorological data, terrain data, and approximate truck counts operating within the port, we predict nitrogen oxides and $PM_{2.5}$ concentrations that would be directly associated to diesel truck exhaust. Emissions data from six monitoring stations located within the Los Angeles and Long Beach Port Area were used as validation for the AERMOD model and as an observational assessment of the air quality level in the San Pedro Port area. Moreover, we visited an intersection in the Wilmington area in the hopes of corroborating our field data with our AERMOD and CAAP data. Although the sensor only measured particulate matter, we found that over three site visits, there was no clear pattern that emerged and that each day presented variability in concentration levels. Through AERMOD, we found that emission levels were highest in the winter months and lowest during the summer months. Additionally, morning (7am-10am) and late night (8pm-11pm) hours had the highest levels of emissions on an average day.

2. Introduction

California continues to make major strides in enacting progressive legislation concerning fossil fuel combustion and climate change mitigation. However, nonstationary sources such as diesel fleet trucks remain a challenge for air quality. Historically, diesel fleet truck regulations have been difficult to develop due to the cost advantages of heavy-duty diesel engines in addition to their longer than assumed life span (Morriss, Yandle, & Dorchak, 2004). The Los Angeles Port handles 18% of the nation's containerized cargo, making it one of the most economically productive ports across the nation, and in some instances, across the world (Port 101 | About the Port of Los Angeles | Port of Los Angeles,2017). Diesel trucks that transport cargo to and from the port release 400,000 tons of air pollutants annually such as particulate matter, nitrogen oxides, sulfur oxides, methane, and carbon dioxide (Air Emissions Inventory | Air Quality | Port of Los Angeles, 2017).While there are attempts to transition to zero emission technology and production processes, the port remains one of the dominant sources of regional air pollution (Mongelluzzo, 2017). Given the scale of operations, the environmental impacts associated with the port's activities are especially detrimental to the surrounding communities, many of which consist of low-income people of color (California Cleaner Freight Coalition, 2019). In addition to being established as carcinogenic, diesel exhaust has been widely studied and proven to damage the cardiovascular and respiratory systems (American Cancer Society, 2019). These concerns are amplified among communities in close proximity to truck routes. Wilmington in particular is of special interest due to the compounding environmental hazards associated with additional polluting sources in the area, such as oil refineries and the port complex.

The purpose of our project is to gather air quality data, infer air quality at locations without data via dispersal modeling, and develop an accessible visual representation of hyperlocal air pollution levels around the port.

Our project focuses on predicting and measuring particulate matter and nitrogen oxides emitted from diesel trucks. By concentrating on a region heavily involved with port operations, particulate matter and nitrogen oxides dispersion can be closely analyzed in order to provide further insight on the consequences associated with diesel truck emissions. Our goal is to reach a reasonable conclusion regarding the impact of diesel truck exhaust on ambient air quality.

3. Methodology

The goal of this research project is to use a high resolution dispersion model to predict pollutant concentrations in hotspots around the San Pedro Bay Ports. We are specifically interested in the dispersion of particulate matter ($PM_{2.5}$) and nitrogen oxides (NO_x) due to the abundance of these pollutants in diesel exhaust. AERMOD is an atmospheric air dispersion modeling system that uses two data preprocessors: AERMET, a meteorological data processor and AERMAP, a terrain data processor. Using meteorological data, terrain data, diesel truck counts, and emissions factors, AERMOD generates hyperlocal NO_x and $PM_{2.5}$ concentrations found in diesel truck exhaust. Real time, eye-level ambient pollutant concentrations were also gathered using an air quality sensor. Measurements from these sensors will serve to gauge the level of emissions from AERMOD from a firsthand perspective. Finally, AERMOD results and real time ambient pollutant concentrations will be used to analyze air quality data relative to what is measured by the six monitoring stations around the San Pedro Bay Ports.

3.1 Air Pollutant Monitoring

The surrounding communities of the San Pedro Bay Ports is greatly impacted by pollutant emissions (May et.al, 2009). There are several different air monitoring stations from the San Pedro Port that measure these emissions. However, readings from these stations provide limited points of measurements of air quality of the immediate area around the station. Therefore, real time, eye level pollutant concentrations for the Wilmington area provide a more robust reading of the air quality Wilmington residents are exposed to on a daily basis, as opposed to further-field point measurements. The intersection at North Avalon Street and West Anaheim Street was the location we chose for air quality monitoring due to its proximity to key points of interest. This intersection corresponds to government designated truck routes and is also in close proximity to areas where the population is vulnerable to the health effects associated with exposure to diesel exhaust (CalTrans | Truck Routes, 2006). Within a 5-mile radius there are not only schools such as the George De La Torre Jr. elementary school but also health centers, one of which is the Wilmington Urgent Care and Family Clinic. While other intersections such as Watson Ave and East L Street were also of interest, the area encompassed by the W Anaheim and N Avalon intersection is influenced by fewer major polluting sources unrelated to the port. For example, the ambient air pollutant concentrations at the intersection of Watson Ave and East L Street would include readings from sources such as metal disposal and recycling stations, which contribute to detrimental air quality. Controlling for confounding variables that contribute to ambient air pollution concentrations comes with many challenges. Therefore, W Anaheim and N Avalon was the most viable location given our circumstances and limitations.

The air quality monitor chosen was the IQAir sensor. It was used to measure particulate matter (2.5 microns) concentrations since it could not read for nitrogen oxide and sensors that could read for NO_x were too expensive since it is difficult to measure. We conducted three site visits in an attempt to account for differences in ambient pollutant concentrations due to varying daily activities. During our visits we encountered prolonged periods of roadway construction and changes in city bus routes, all of which can affect the ambient pollutant concentration readings. Each site visit and reading were then consolidated to allow comparison to existing air quality measurements.

3.2 AERMOD

The model of choice used to calculate the dispersion of $PM_{2.5}$ and NOx is AERMOD, the EPA preferred dispersion model. AERMOD is a Gaussian steady state plume air dispersion model in which the results are time-independent. AERMOD allows us to generate predictions of the dispersion of $PM_{2.5}$ and NO_x within the atmosphere based on a specific point in time. Its primary usage is to model nearfield impacts in complex terrain based on a planetary boundary layer model (US EPA, 2016). Using input data such as wind speeds, temperatures, and emission factors, AERMOD calculates the spatial distribution of a pollutant at a given source.

A user interface, AERMOD View, was utilized to create the air dispersion plume of $PM_{2.5}$ and NO_x emissions from diesel trucks with the help of AERMET and AERMAP processes.

After running AERMOD, the projected model will be compared with hourly data in order to analyze the contribution of diesel truck exhaust to the detrimental air quality in the exposed community.

3.3 AERMOD Input Data

3.3a. AERMET

AERMET is a meteorological preprocessor within AERMOD which takes in temperature, wind speed, and wind direction as inputs and processes it using a meteorological model (AERMOD Table 1, 2019). We utilized meteorological data from the South Coast Air

Quality Monitoring District (SCAQMD) at the Long Beach Airport station provided at a resolution of hourly averages from 2012 to 2016 (AERMOD Table 1, 2019). This station was chosen because it contains data from 2012 to 2016 at an hourly resolution, replicating the location of meteorological data from the exposure study conducted (Wu et al., 2009).

3.3b. AERMAP

AERMAP is a terrain data preprocessor that takes in digital elevation model data as an input. We utilized a 90 meter resolution digital elevation model from USGS.

3.4 Diesel Truck Counts and Emissions Factors

In order to isolate emissions directly related to diesel trucks operating in conjunction with the Los Angeles port, model runs were carried out using only diesel truck counts and emission factors related to diesel trucks. Annual Average Daily Traffic (AADT) volumes on heavy duty diesel trucks on six different freeways surrounding the Wilmington area was provided via the CalTrans Traffic Census Program (Traffic Census Program, 2017). These freeways were the 1, 103, 110, 47, 405, and 710. In order to analyze the amount of $PM_{2.5}$ and NO_x attributed to diesel trucks, the assumption was made that the AADT volumes on each freeway were unique truck counts that did not travel from one freeway to another. Furthermore, each diesel truck count provided by the California Department of Transportation is assumed to be made of identical heavy-duty diesel truck models in order to develop emission rates. A shapefile from the Caltrans GIS Data Library provided point GIS datasets of truck traffic volumes from 2017 (Caltrans GIS Data Library, 2017). The AADT from the particular freeways of interest was extracted by examining the attribute table of each point on the freeways via ArcGIS.

Emission factors, utilized to represent the amount of pollutants released with a particular activity, are essential for calculating an emissions inventory representing the amount of $PM_{2.5}$ and NO_x released into the atmosphere from the operation of diesel trucks on the freeways. The EPA provides an emission factor of 0.202 ug/m^3 for $PM_{2.5}$ and 8.613 ug/m^3 for NO_x for heavy-duty diesel vehicles (HDDV) (US EPA, 2008). These emission factors are averages for the entire in-use fleet as of July 2008 according to the EPA, with older diesel trucks having higher emission factors and more advanced diesel trucks with newer equipment having lower emission factors.

3.5 Model Runs

Using AERMOD View, a GUI for the modeling process, we were able to display a plume dispersion model taking into account an input of factors and data: meteorological data consisting of upper and surface wind patterns, a digital elevation model, and emission rates from the average number of trucks on a freeway in an hour. The AADT was averaged from a daily traffic volume to an hourly traffic volume. An average truck speed of 55 mph on a freeway was utilized in order to associate the emission factors with an emission activity (US DOE, 2011). The freeways were treated as area sources, and thus, an estimated width across the entire freeway taken via Google Maps was multiplied by the source length in order to account for the freeway area. A Cartesian grid receptor network was created in AERMOD. The grid receptor network designates specific locations for the generation of pollutant concentrations. We chose a 200 x 200 meter resolution in order to produce a high enough resolution model within a sensible time frame. Running a receptor grid network of a resolution such as 30 x 30 would involve processing a substantial amount of data points. Therefore, this gridded receptor network established the model's resolution at 200 x 200 meters. The dispersion model is a snapshot of the dispersed pollutant for a one hour average concentration in micrograms per meters cubed ($\mu g/m^3$).

3.6 Clean Air Action Plan

Hourly data concerning $PM_{2.5}$ and NO_x pollutants were compiled using monitoring station data based on the Clean Air Action Plan. This data will be used to validate our AERMOD data and act as a secondary depiction of emissions in the Los Angeles and Long Beach Port Areas. It should be noted, however, that the area measured is limited in extent, which constrains the accuracy of the monitoring stations. The monitoring stations are based in the Inner Harbor area, near West Long Beach and the Outer Harbor area on the Navy Mole. The Port of Los Angeles' stations are located in the Outer Harbor area at Berth 47, by the Terminal Island Treatment Plant, within the San Pedro community, and within the Wilmington community ("About the Plan"). Emission statistics from the Clean Air Action Plan Data were calculated using Microsoft Excel and MATLAB.

4. Results

4.1 IQAir Sensor

After three site visits to the W Anaheim and N Avalon intersection in Wilmington, we noticed some interesting patterns that emerged from the results. All of the raw data collected by the sensor, which showcases minute-by-minute particulate matter concentration data, was consolidated from the three sites and developed into a plot shown in Figure 1. The team tried to conduct site visits at the same time each morning to keep the data consistent and reduce the number of confounding variables present.

From our first site visit on Friday, March 8 the IQAir measured a range of 1-11 ug/m^3 of $PM_{2.5}$, with an average of about 2.75 ug/m^3 over a span of 35 minutes. Figure 1 shows that although there was a spike in concentration levels towards the end of the visit, this data showed the most consistency in ambient $PM_{2.5}$ concentrations of all three site visits. One important note is that for this first visit, we happened to stand next to a bus stop and the $PM_{2.5}$ concentration levels would increase dramatically every time a bus stopped right next to our sensors. The concentrations would then subsequently drop by a significant amount when the bus moved. For this reason, we continued the next two site visits across the street but still at the intersection of Anaheim and Avalon.

On our second visit on Thursday, April 4th, the IQAir measured a wider range of concentrations of $PM_{2.5}$ with 1 ug/m^3 being the lowest and 28 ug/m^3 being the highest over a span of sixty minutes. The average concentration was 1.66 ug/m^3. As can be seen from Figure 1, the concentration stayed relatively constant with the exception of one particularly large increase in the data. Although we had moved from the bus stop, no observation of an influencing factor was visible to correlate with this surge in our data so it may have been due to the quality of the IQAir sensor.

On our final site visit on Friday, April 12 the concentrations were much higher, with a range of 15-33 ug/m^3 and an average of 18.67 ug/m^3 over a span of 51 minutes. As can be seen from Figure 1, the concentrations also varied much more than the previous two site visits, with a greater number of, and larger, spikes in $PM_{2.5}$ concentrations. It is also uncertain what may have been different that day that caused a much higher average concentration of $PM_{2.5}$ in the air. Factors such as an increased number of diesel trucks, changes in meteorology, greater traffic congestion, and intensification of industrial processes, among others, may have caused this effect.

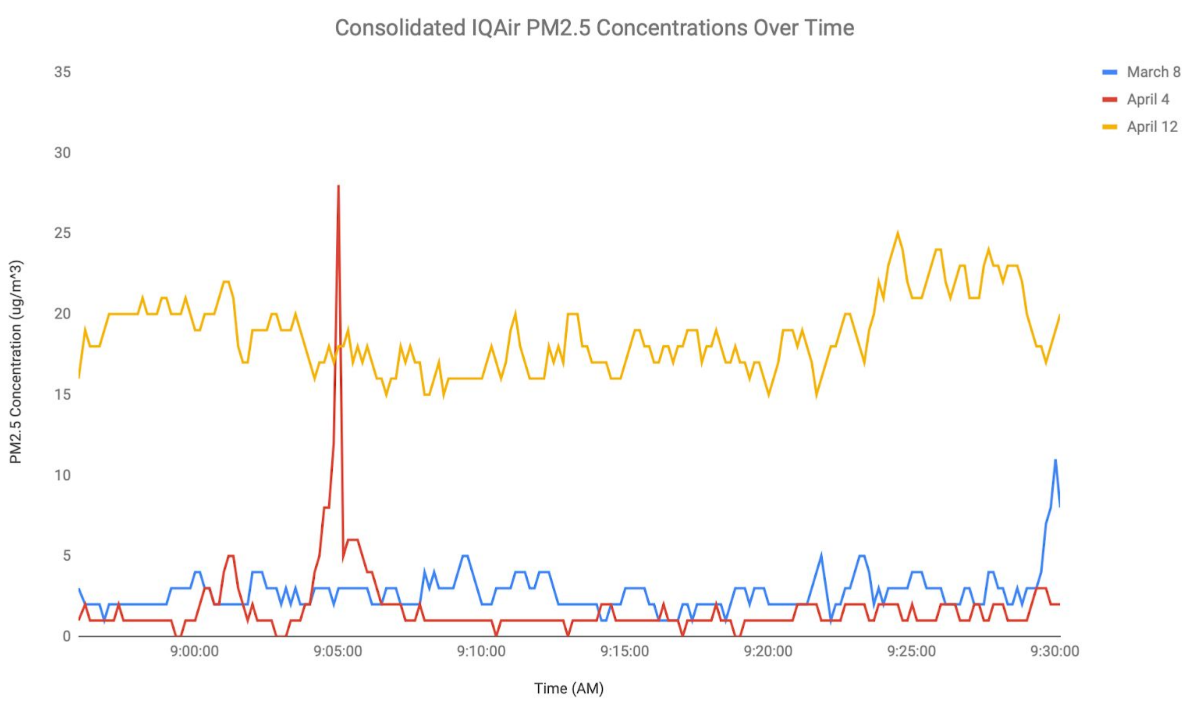

Figure 1. IQAir $PM_{2.5}$ concentrations from 8:55 AM to 9:30 AM for three site visits.

4.2 Clean Air Action Plan Results

Data from the six monitoring stations were analyzed as well. Emissions for every hour between January 1st, 2012 and December 31st, 2016 were taken and averaged using Microsoft Excel. The mean emissions level for particulates across all hours of our data was 14.1 ug/m^3 and the mean emissions level for NO_x was 0.017 ppm. On average, 7:00 pm had the highest concentration of particulates and 7:00 am had the highest concentration of NO_x. For both pollutants, January had the highest concentration. Conversely, June had the lowest concentration of pollutants. Below are graphs that depict the change in the average concentration of emissions per pollutant over time.

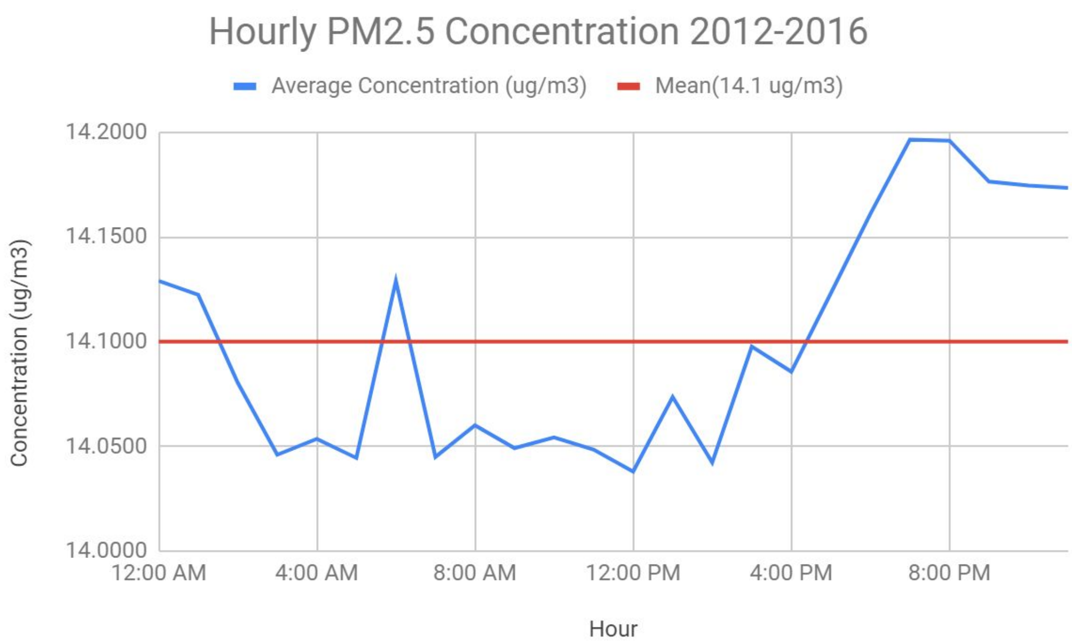

Figure 2. CAAP monitoring station data. $PM_{2.5}$ concentrations are averaged on an hourly basis between 2012-2016.

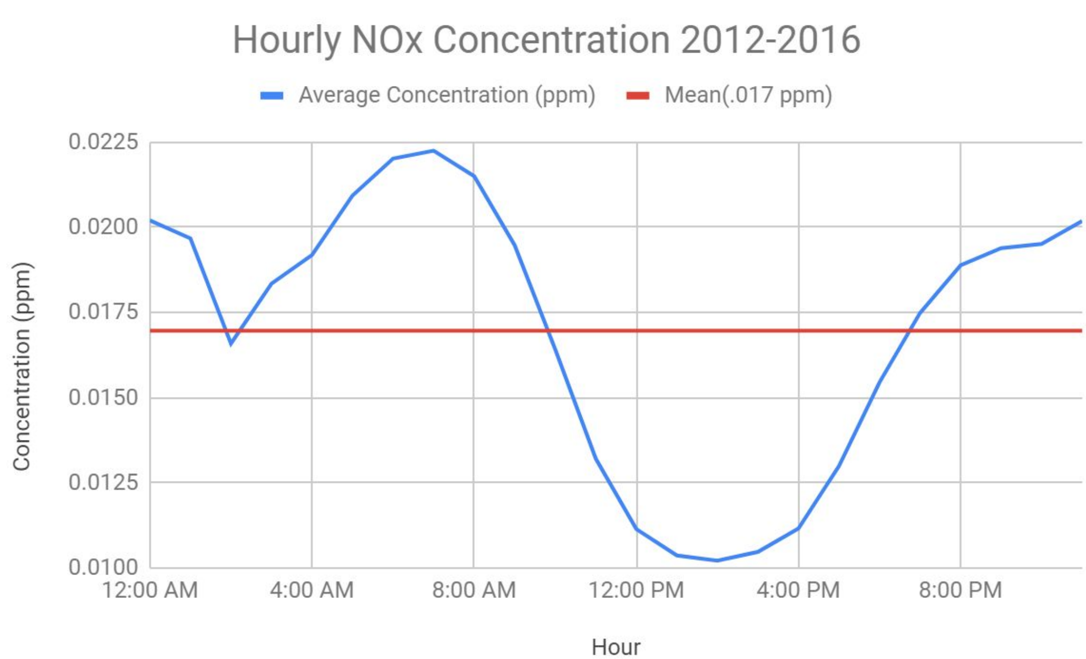

Figure 3. CAAP monitoring station data. NO_x concentrations are averaged on an hourly basis between 2012-2016.

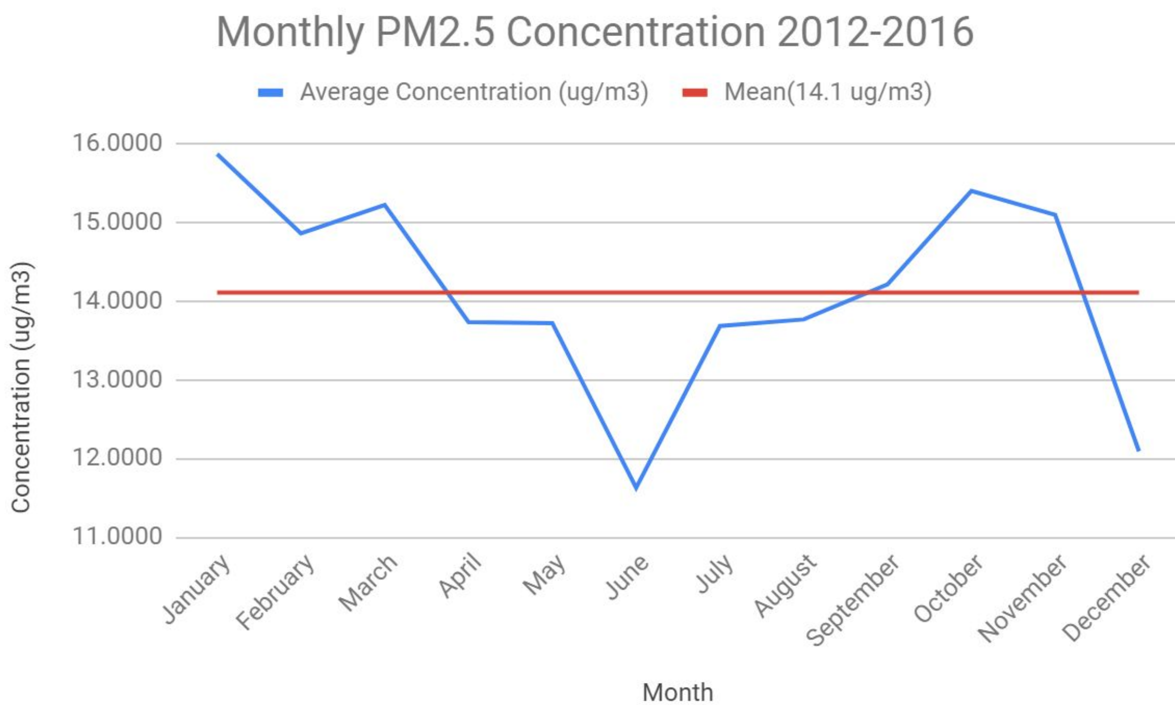

Figure 4. CAAP monitoring station data. $PM_{2.5}$ concentrations are averaged on a monthly basis between 2012-2016.

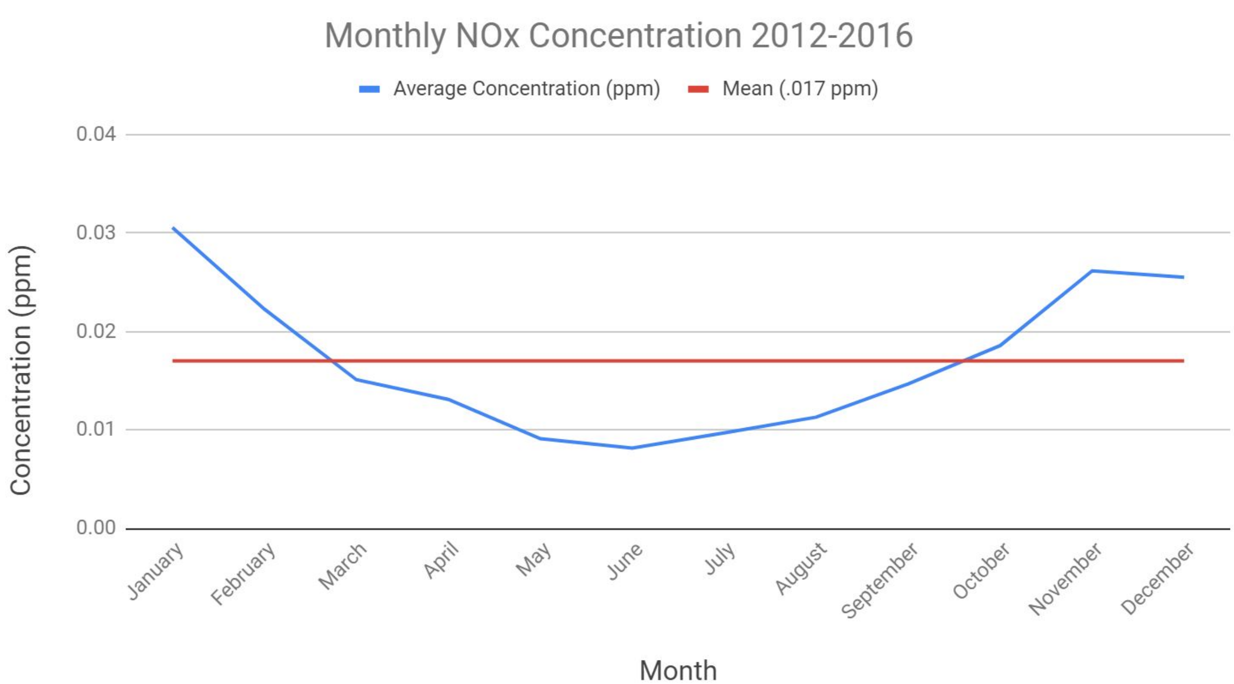

Figure 5. CAAP monitoring station data. NO_x concentrations are averaged on a monthly basis between 2012-2016

4.3 AERMOD

The daily $PM_{2.5}$ concentration across 2016 calculated with AERMOD had an average of 8.9 ug/m^3 (Figure 6). A model of the dispersion of the pollutant over the Wilmington area shows the highest concentration to be over the southern side of the 710 Freeway followed by the 47 Freeway (Figure 7, 8). Seasonal variations of $PM_{2.5}$ concentrations range from 6.5 to 9.9 ug/m^3 with winter having the highest average concentration and summer having the lowest average concentration (Figure 9, 10, 13, 14). Spring and autumn seasons fall in the middle with mean concentrations of 8.2 and 9.1 ug/m^3 (Figure 11, 12, 15, 16).

The daily NOx concentration across the year of 2016 found by AERMOD had an average of 63.71 ug/m^3 (Figure 17). Seasonal variations of NOx ranged from 45.27 to 65.49 ug/m^3, with winter having the highest concentration and summer having the lowest concentration (Figures 18, 19, 22, 23). As seen with $PM_{2.5}$, Spring and Autumn seasons fall in the middle with mean concentrations of 55.58 and 63.39 (Figures 20, 21, 24, 25).

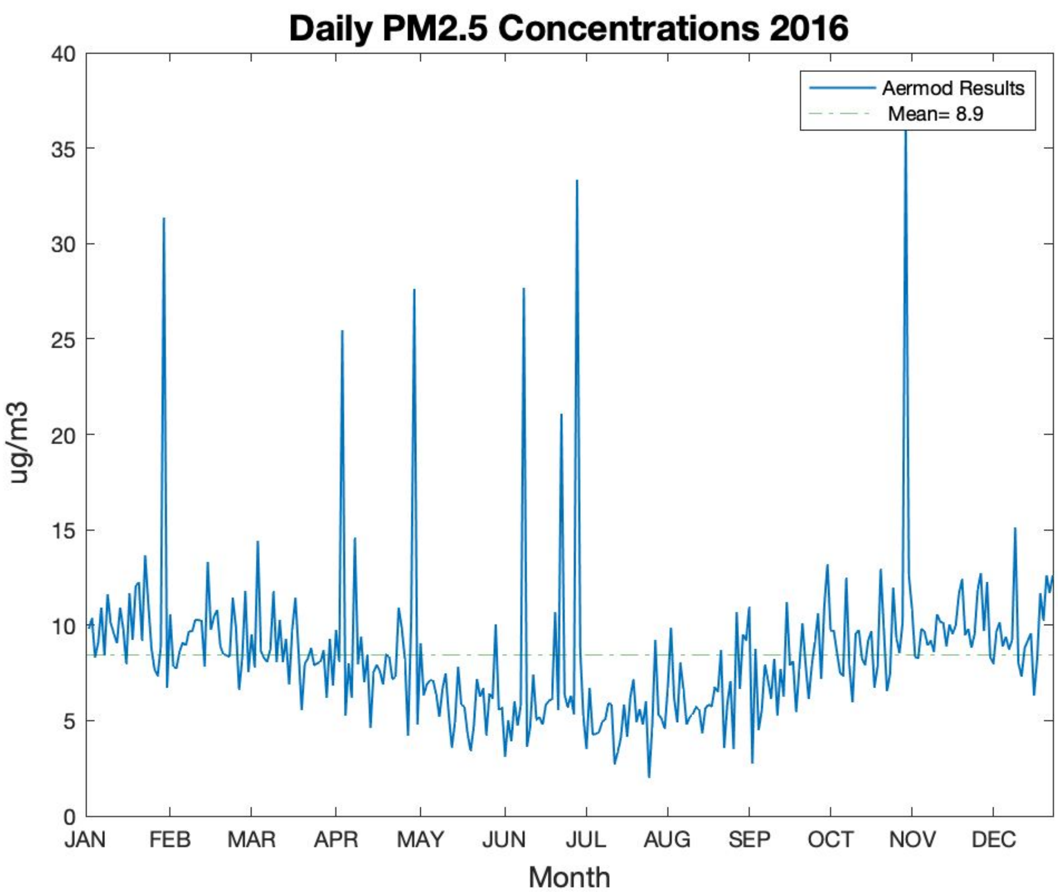

Figure 6. Daily $PM_{2.5}$ concentrations (ug/m^3) for the year 2016. Mean: 8.9 ug/m^3

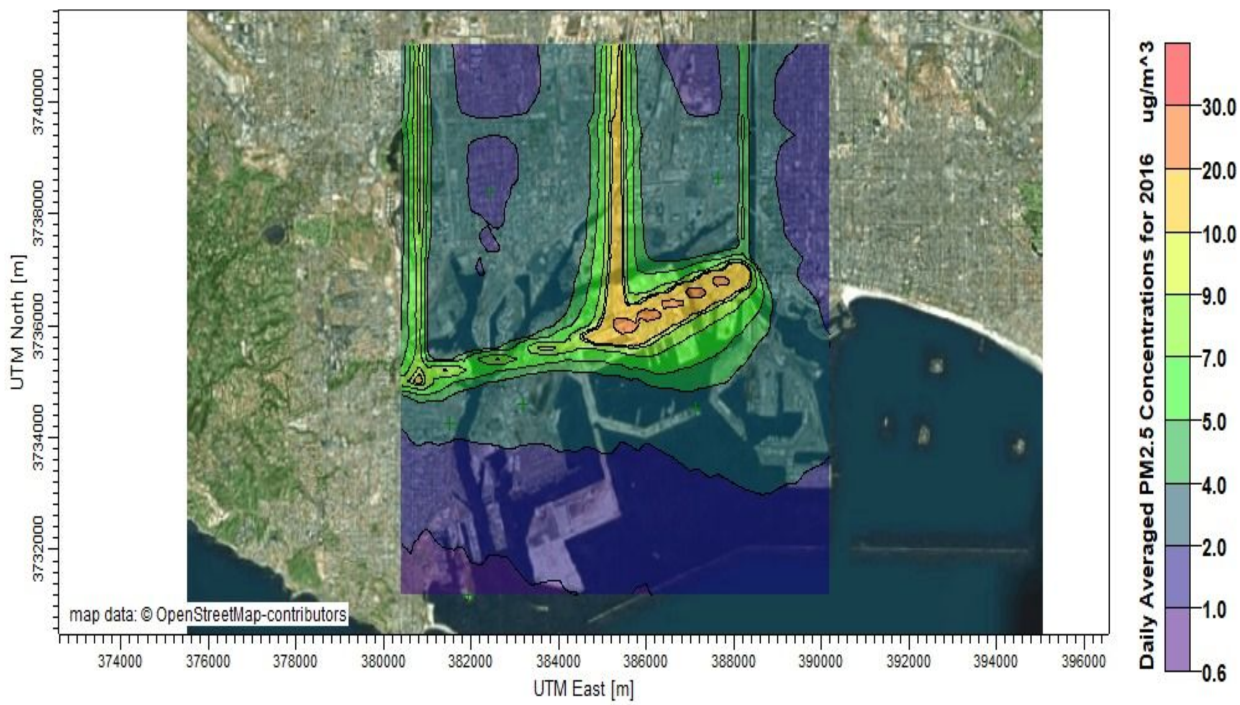

Figure *7.Annual mean* plume dispersion of $PM_{2.5}$ over Wilmington site area.

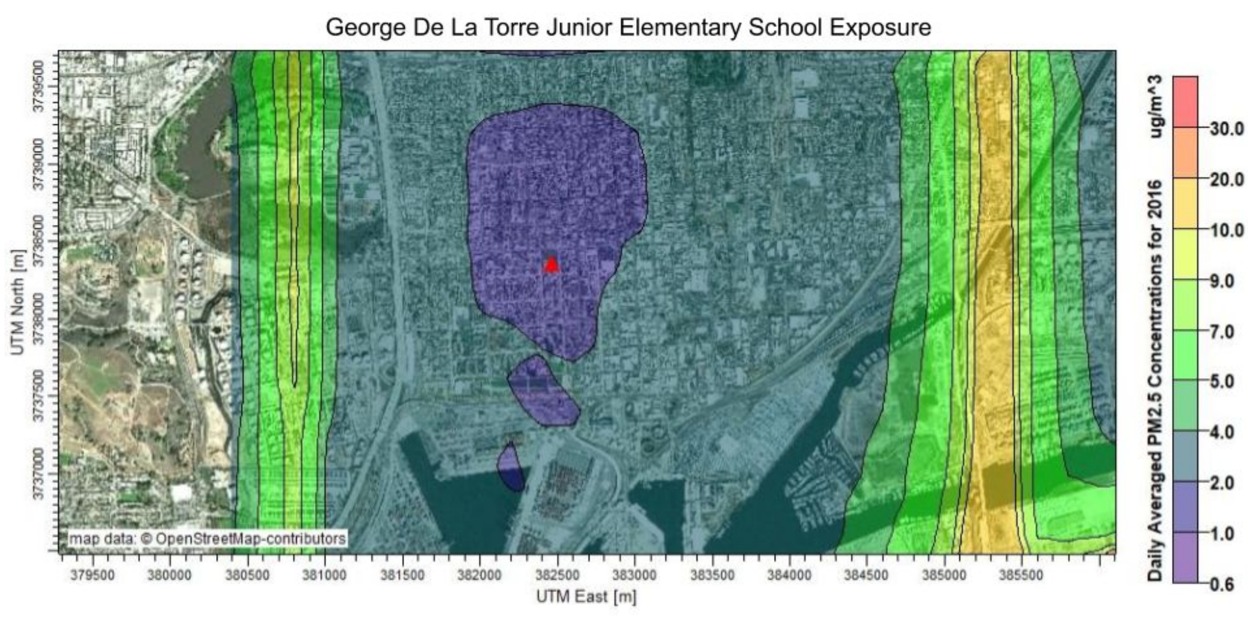

Figure 8*.* Zoomed-in version to show the exposure level of George De La Torre Junior Elementary School (shown with red triangle).

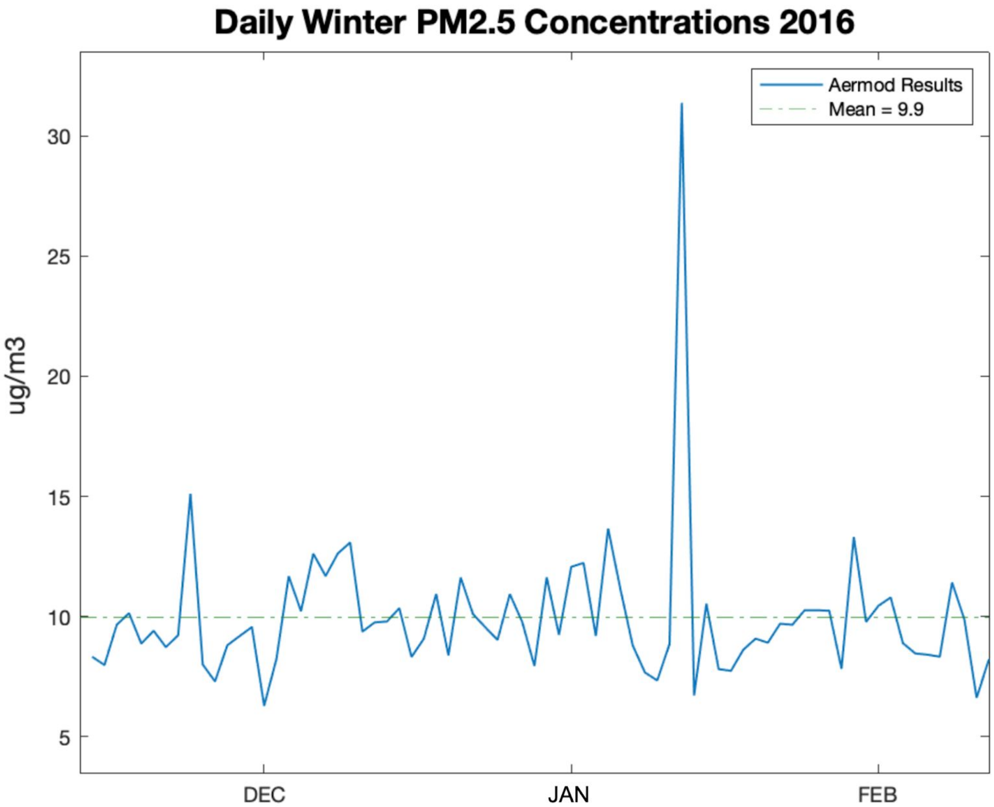

Figure 9. Seasonal daily $PM_{2.5}$ concentrations (ug/m^3) for Winter 2016. Mean: 9.9 ug/m^3

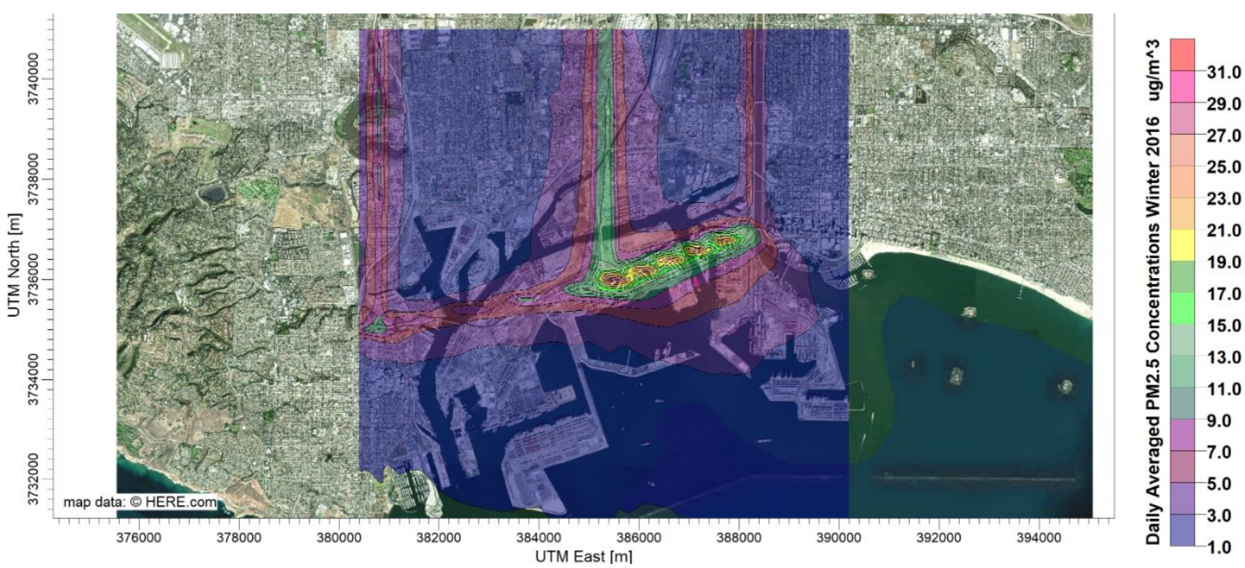

Figure 10. Spatial distribution of seasonal daily $PM_{2.5}$ concentrations (ug/m^3) for Winter 2016. Mean: 9.9 ug/m^3

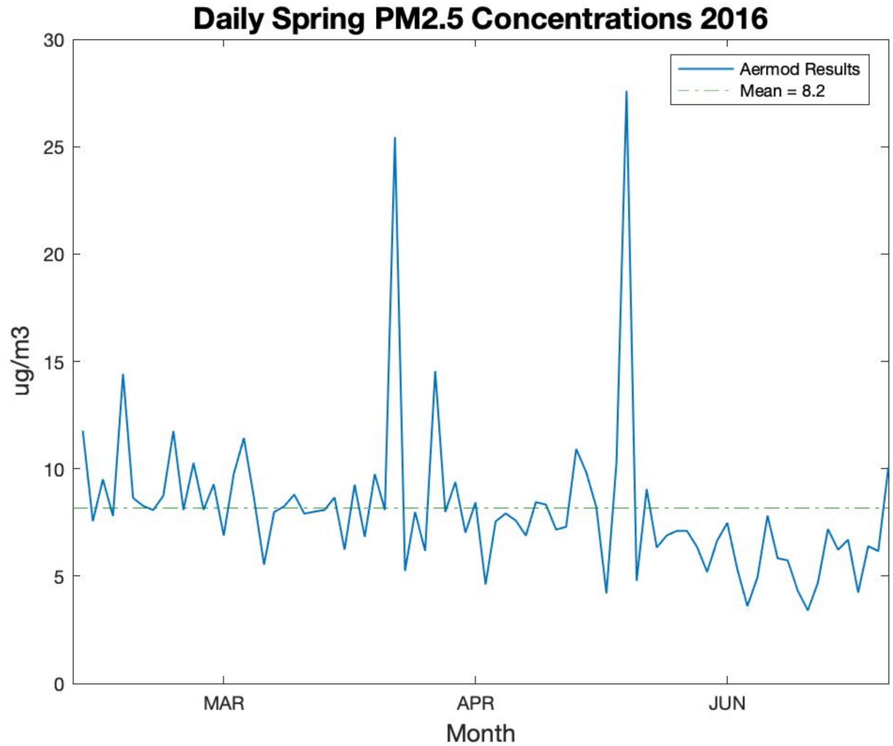

Figure 11. Seasonal daily $PM_{2.5}$ concentrations (ug/m^3) for Spring 2016. Mean: 8.2 ug/m^3

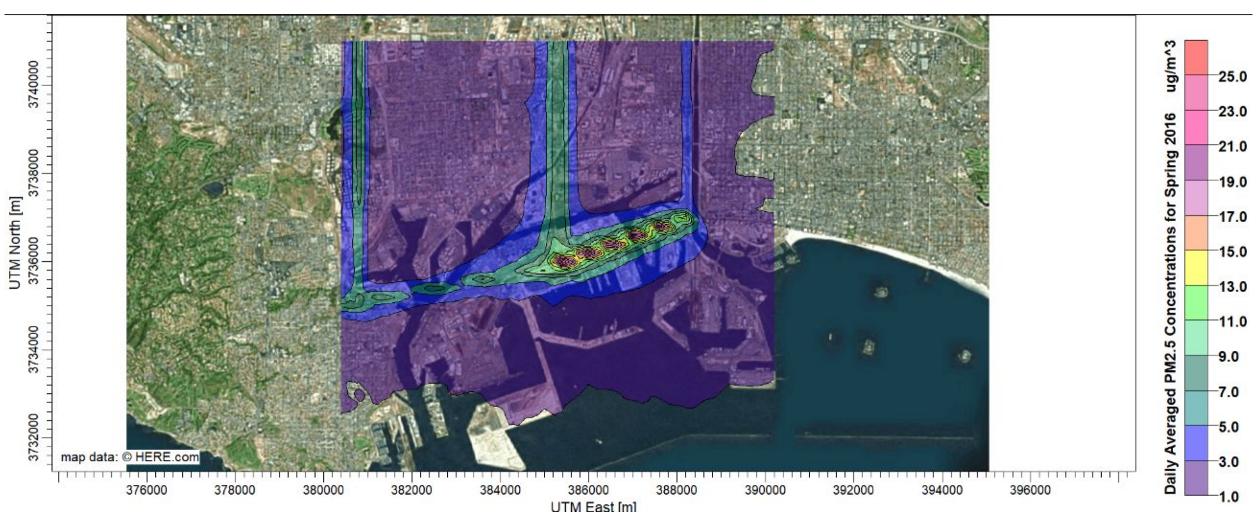

Figure 12. Spatial distribution of seasonal daily $PM_{2.5}$ concentrations (ug/m^3) for Spring 2016. Mean: 8.2 ug/m^3

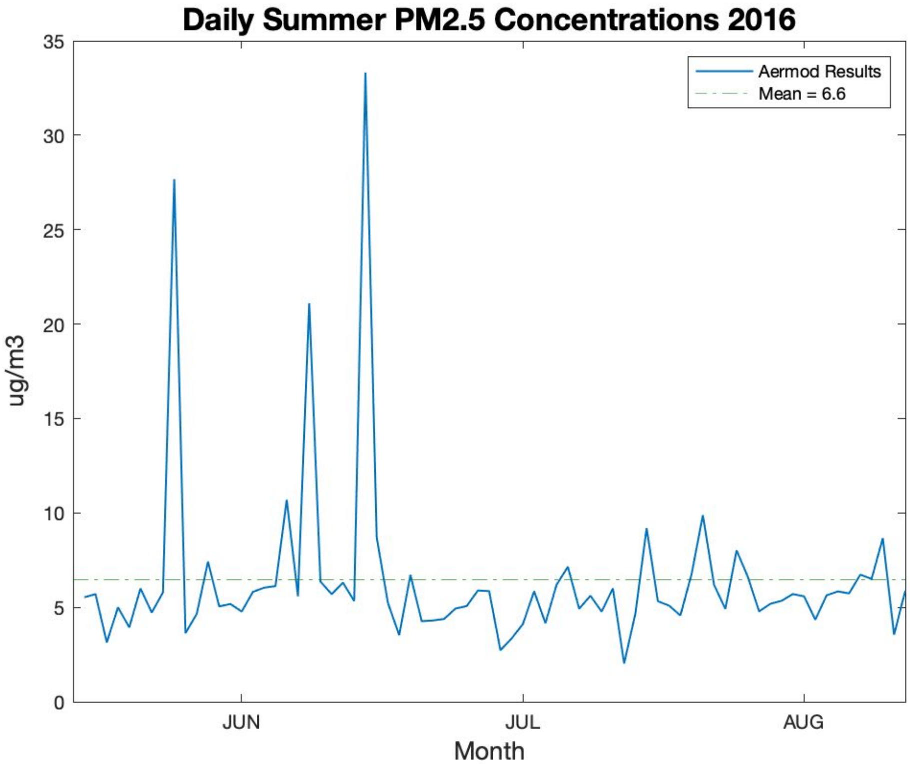

Figure 13. Seasonal daily $PM_{2.5}$ concentrations (ug/m^3) for Summer 2016. Mean: 6.6 ug/m^3

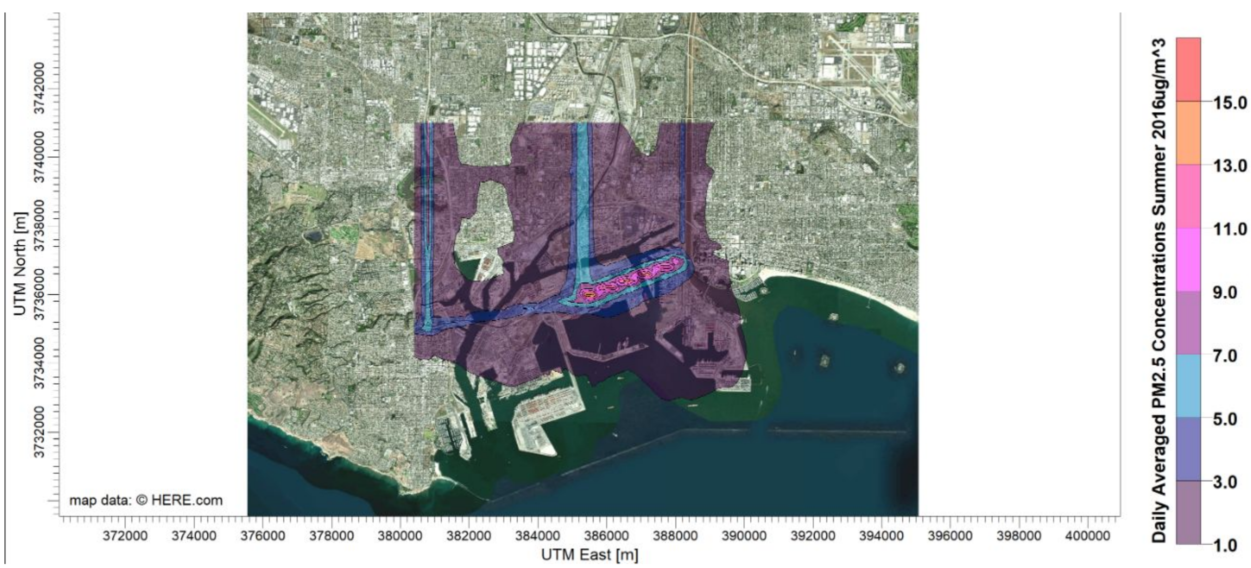

Figure 14. Spatial distribution of seasonal daily $PM_{2.5}$ concentrations (ug/m^3) for Summer 2016. Mean: 6.6 ug/m^3

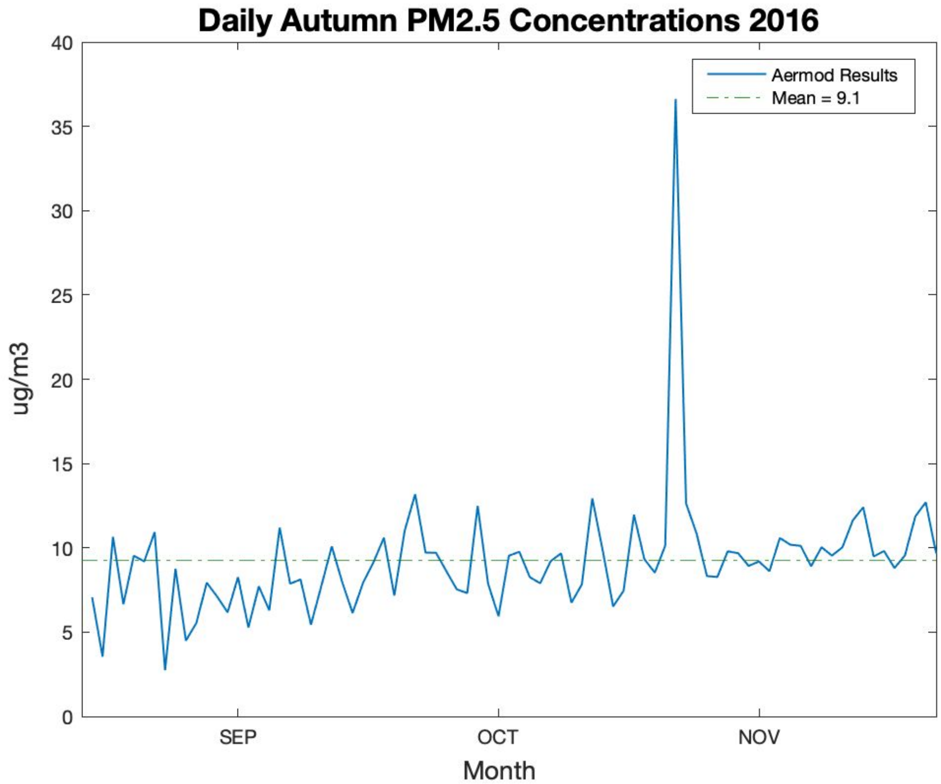

Figure 15. Seasonal daily $PM_{2.5}$ concentrations (ug/m^3) for Autumn 2016. Mean: 9.1 ug/m^3

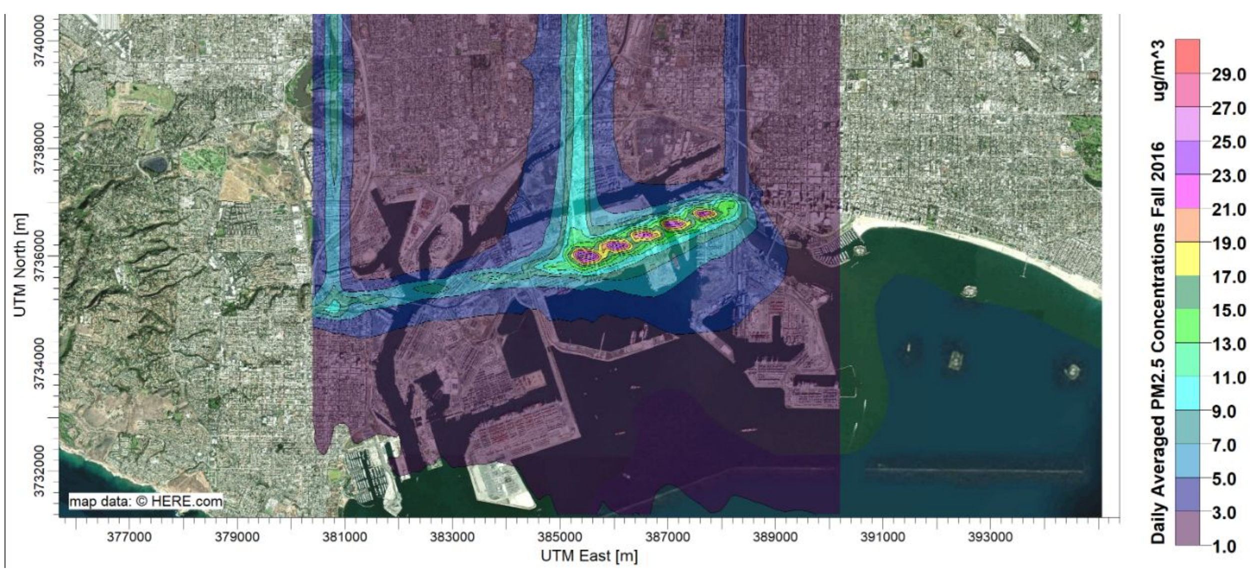

Figure 16. Spatial distribution of seasonal daily $PM_{2.5}$ concentrations (ug/m^3) for Autumn 2016. Mean: 9.1 ug/m^3

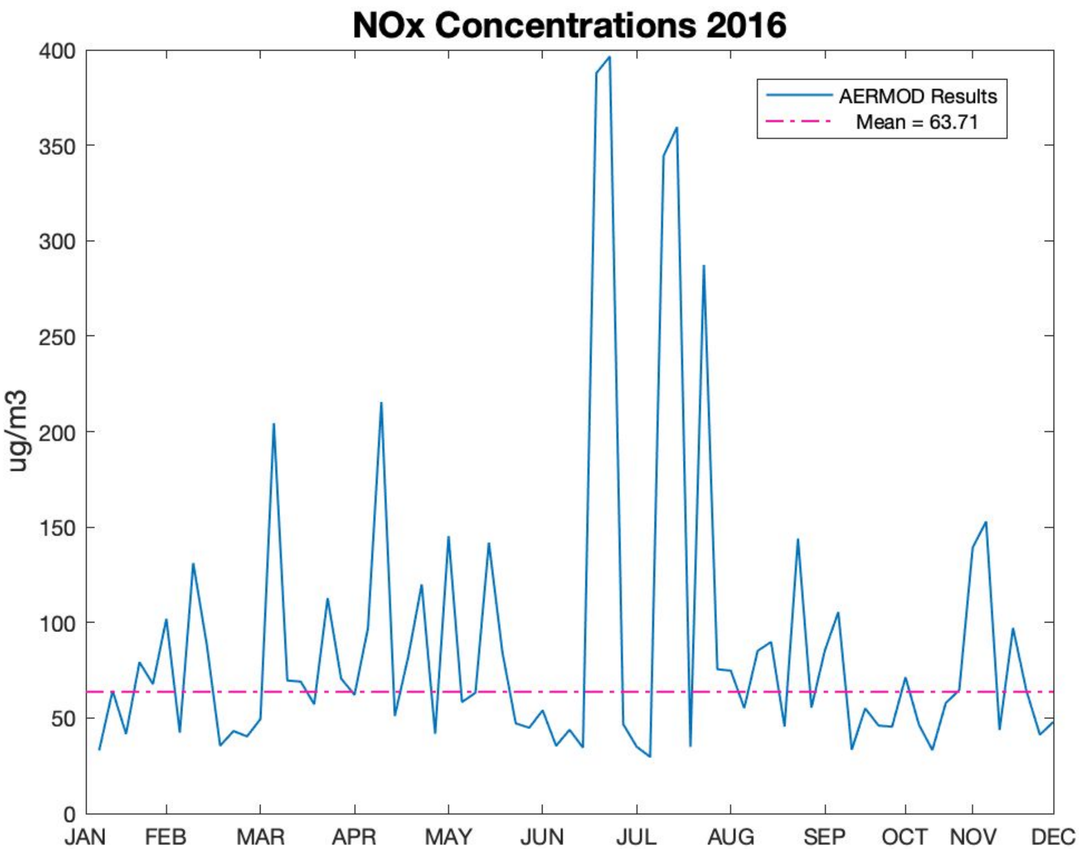

Figure 17. Daily NOx concentrations (ug/m^3) for the year 2016. Mean: 63.71 ug/m^3

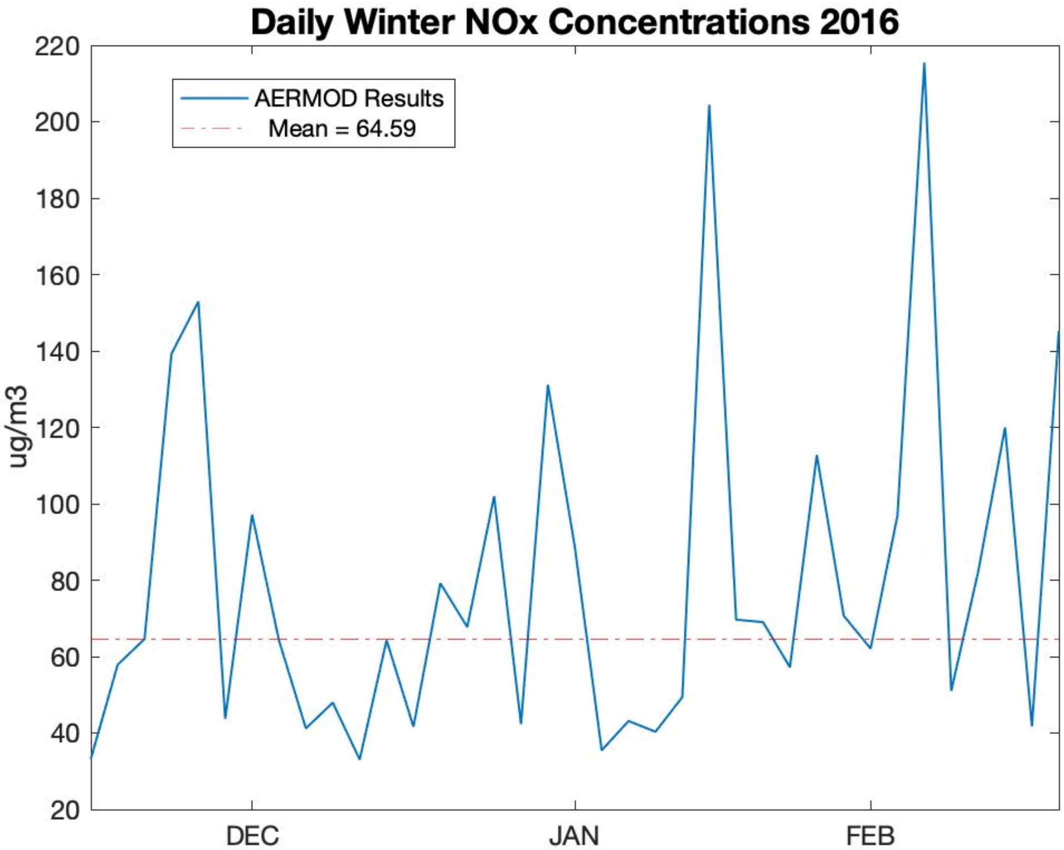

Figure 18. Seasonal daily NOx concentrations (ug/m^3) for Winter 2016. Mean: 64.59 ug/m^3

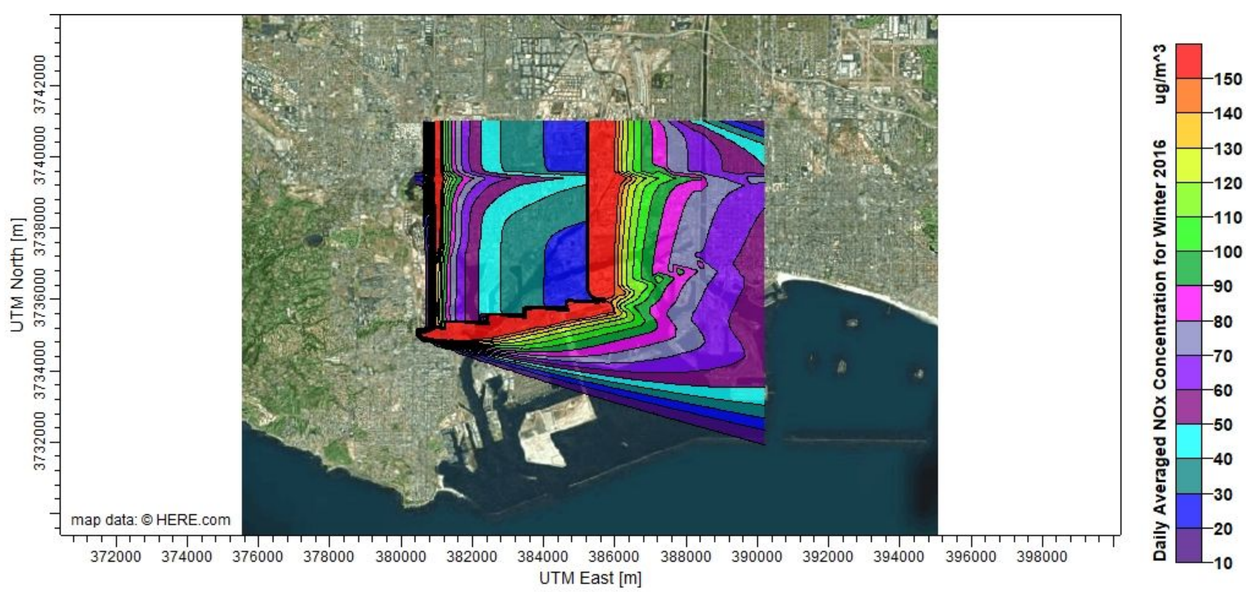

Figure 19. Spatial distribution of seasonal daily NOx concentrations (ug/m^3) for Winter 2016. Mean: 64.59 ug/m^3

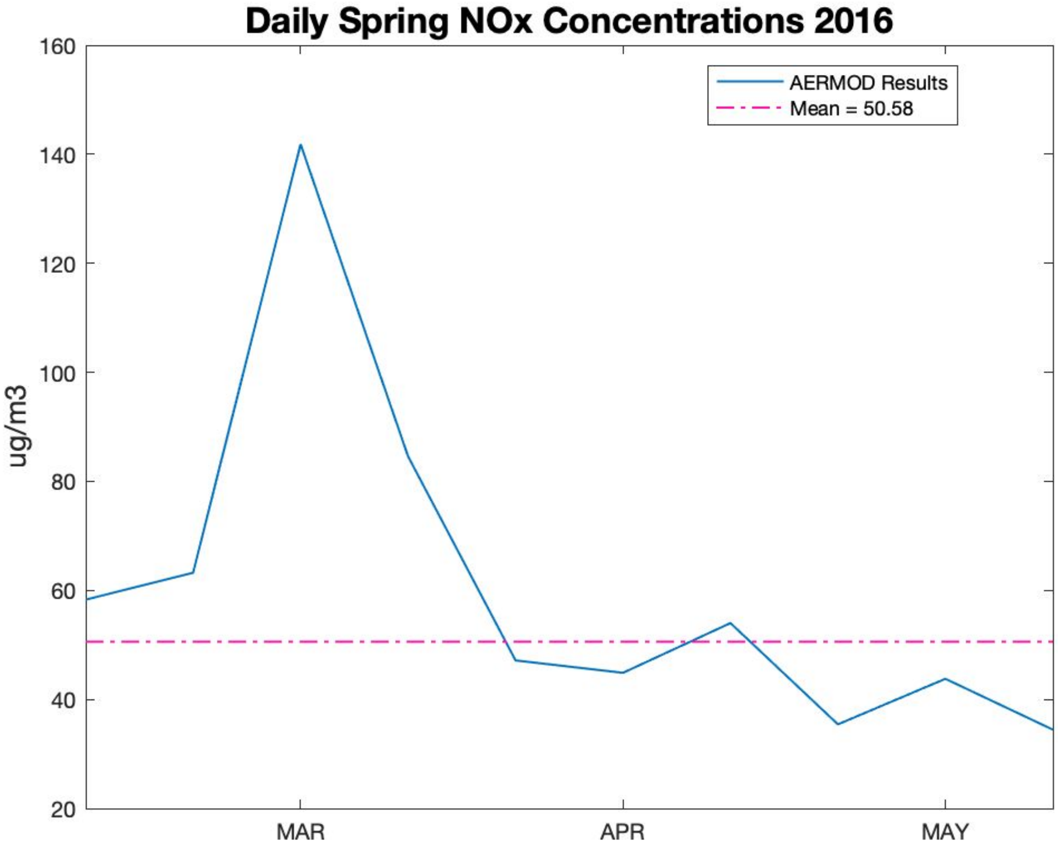

Figure 20. Seasonal daily NOx concentrations (ug/m^3) for Spring 2016. Mean: 50.58 ug/m^3

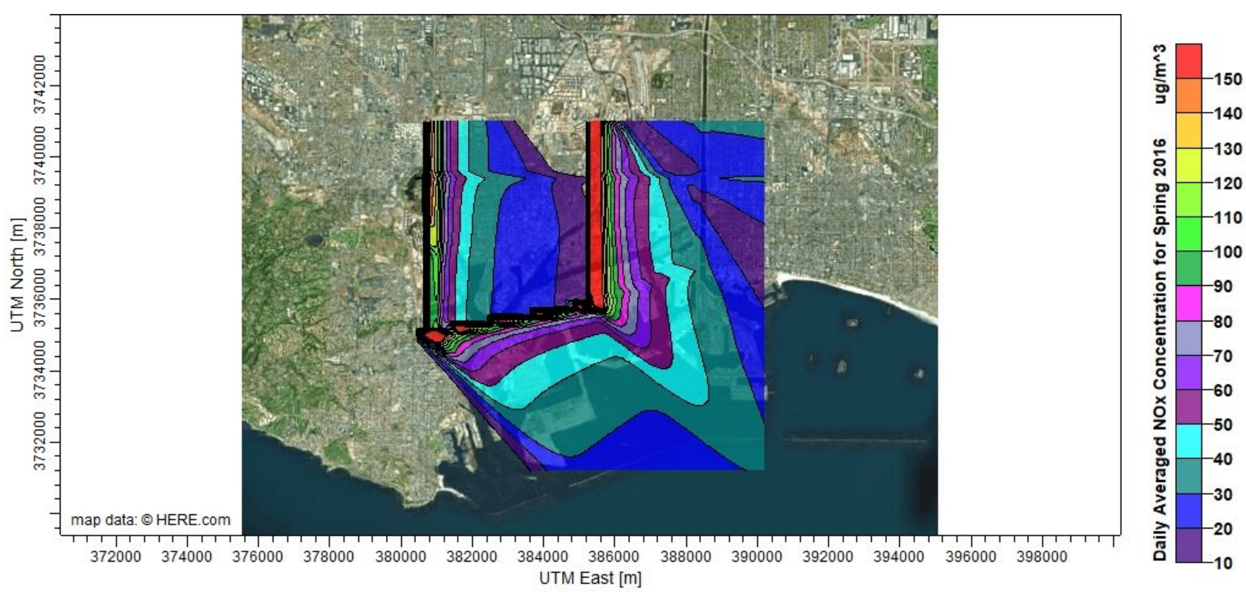

Figure 21. *Spatial distribution of* seasonal daily NOx concentrations (ug/m^3) for Spring 2016. Mean: 50.58 ug/m^3

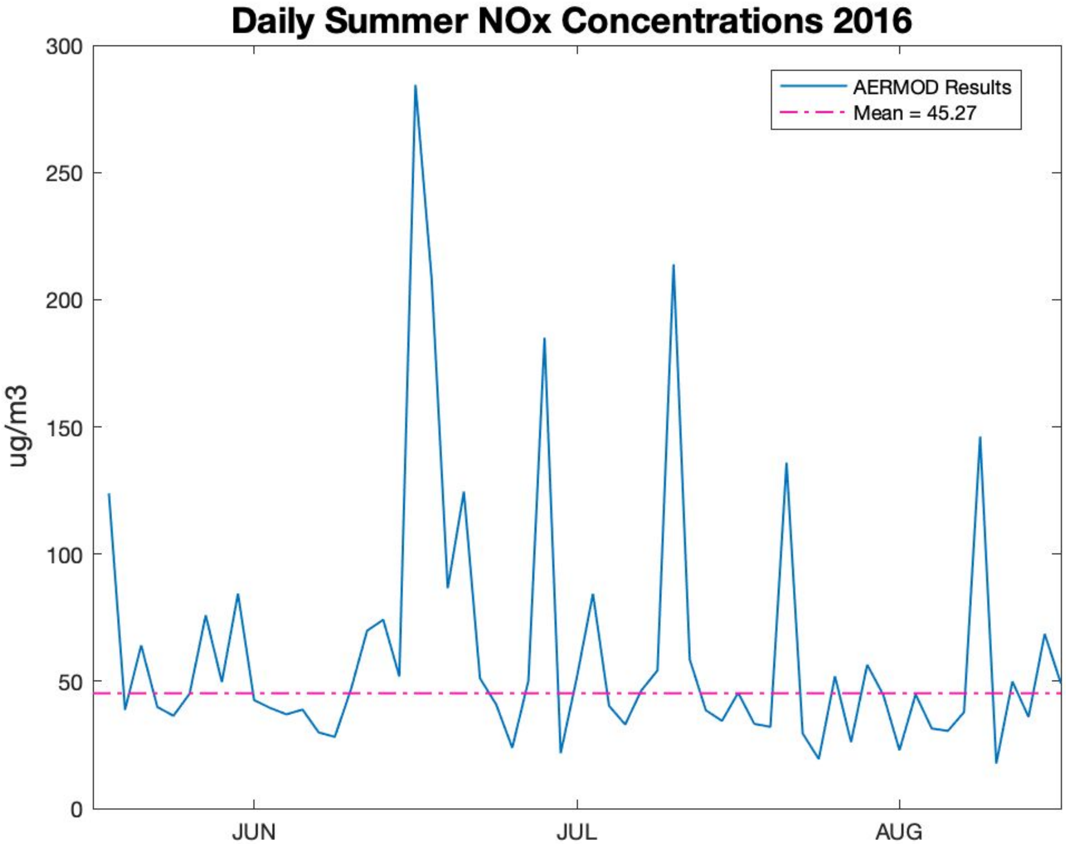

Figure 22. *S*easonal daily NOx concentrations (ug/m^3) for Summer 2016. Mean: 45.27 ug/m^3

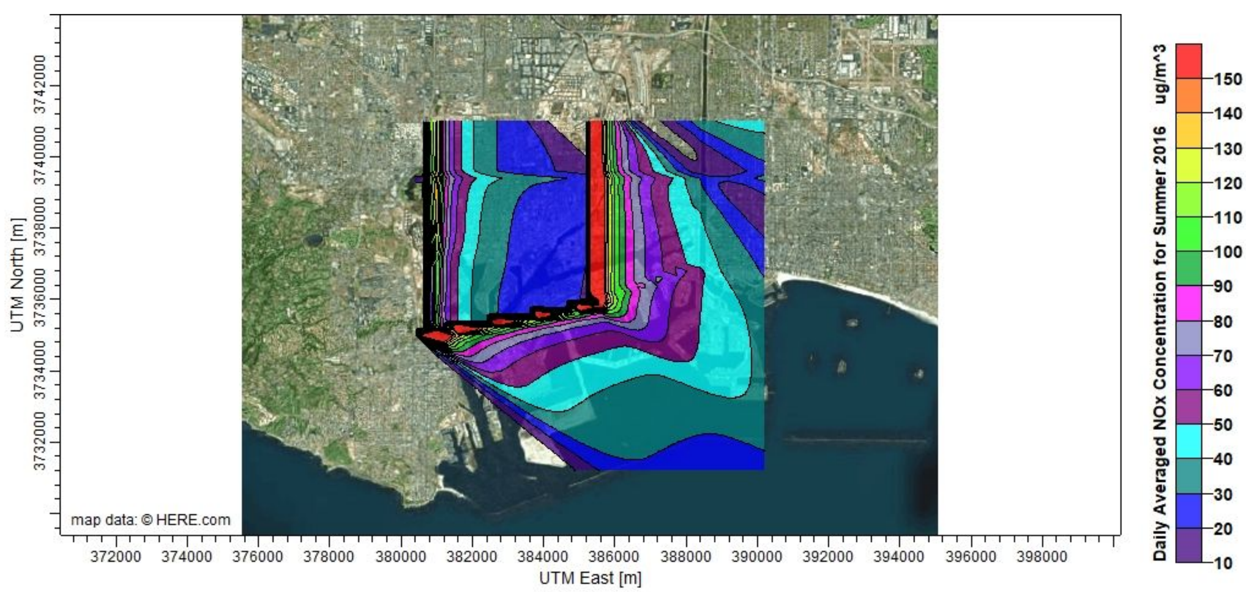

Figure 23. *Spatial distribution of s*easonal daily NOx concentrations (ug/m^3) for Summer 2016. Mean: 45.27 ug/m^3

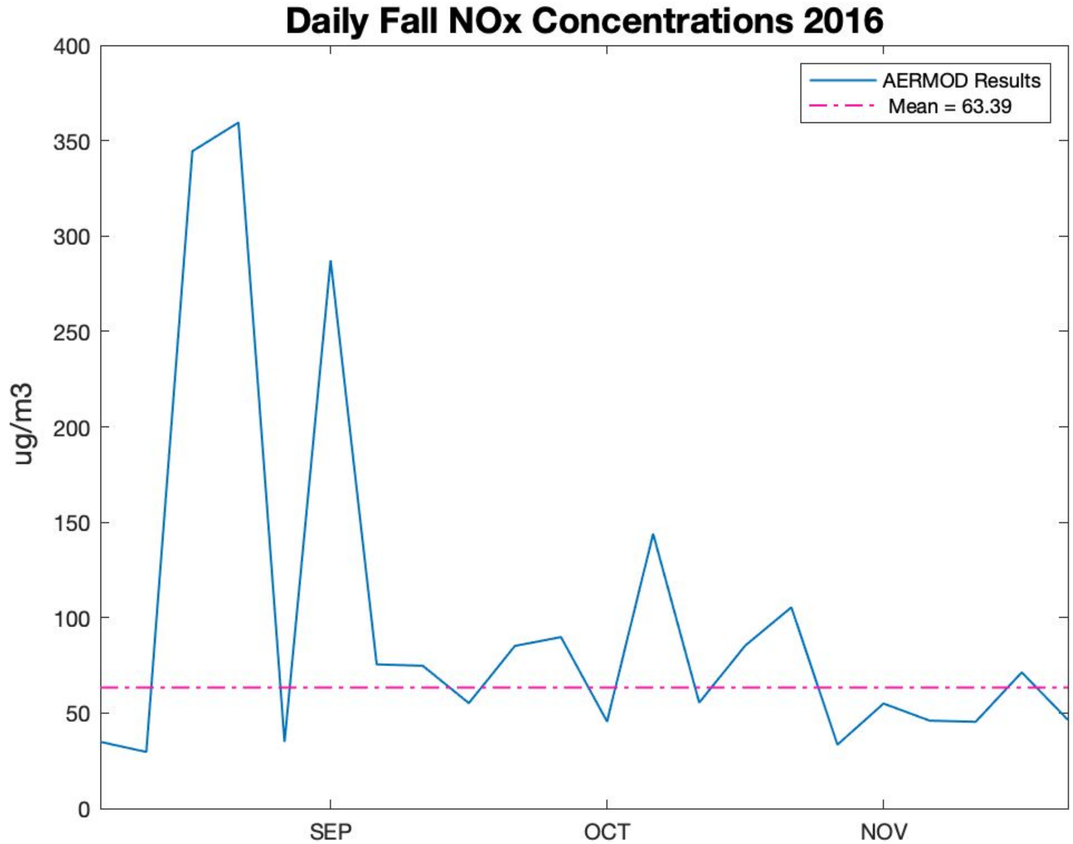

Figure 24. *S*easonal daily NOx concentrations (ug/m^3) for Fall 2016. Mean: 63.39 ug/m^3

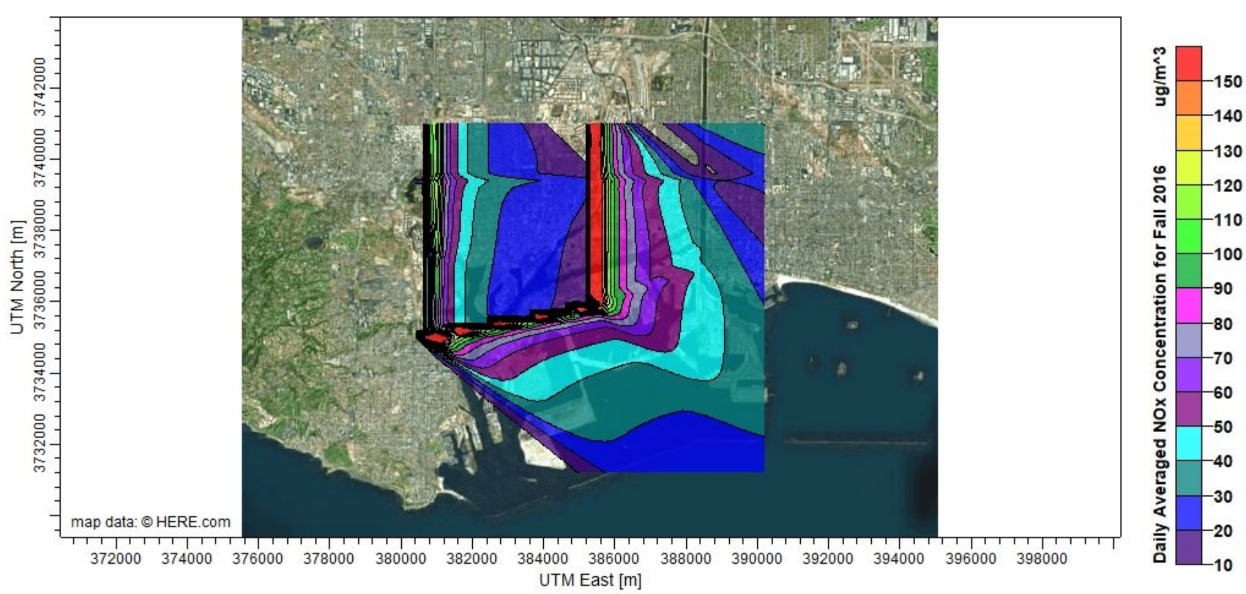

Figure 25 . *Spatial distribution of s*easonal daily NOx concentrations (ug/m^3) for Fall 2016. Mean: 63.39 ug/m^3

5. Discussion

5.1 IQAir

One of the limitations of using the IQAir Sensor in the field of interest was that when we initially chose our location at the intersection of Anaheim and Avalon St., we did not realize that we were standing directly in front of a bus stop. As a result, when a bus came by and stopped, our sensor picked up a much greater concentration of $PM_{2.5}$ than there would have been had the bus not stopped so close to the sensor. This may have led to the addition of an extra variable that we did not control for. However, on the other two site visits we moved to a different location at the same intersection that did not conflict with the bus stop. During the first visit there was ongoing construction, which closed down a portion of the road. Thus, the amount of trucks we observed while collecting data was minimal, and considering that Anaheim St. is a major truck route, this was unusual and unexpected. The decreased amount of trucks that traveled on the route during this time probably decreased due to the construction. Additionally, we only conducted the data collection in the morning because of limited availability to go out to the site multiple times in one day or even during the evening. This limited our potential to understand possible diurnal variations in $PM_{2.5}$ concentrations. It is very possible that the amount of diesel trucks on the streets, and the level of other industrial activities, varies throughout the day so this did not provide a holistic picture of the air quality that the residents of Wilmington face. Another limitation is that although we were trying to analyze diesel truck emissions, we were collecting data in an area which contains many variables that we could not control for. When deciding our place of interest, we tried our best to move away from areas in Wilmington that contain recycling facilities, oil refineries, and other heavy industrial processes that would greatly bias the data. However, even though we chose an intersection that was quite a distance away from these areas, there were still other factors that could contribute to higher $PM_{2.5}$ concentrations, such as emissions from personal vehicles and buses, and particulate matter from industries blown in by the wind. A final limitation is that we could not buy the highest quality sensor that we would have liked. As a student research group, we were limited within our budget and the IQAir was one of the better ones that fit within our price point. This unfortunately meant that we needed to sacrifice quality for price, which can have an impact on the reliability of data collected.

Despite these limitations, we were still able to gain valuable insight into the $PM_{2.5}$ concentration levels in the area. For example, the April 12 visit shows much higher concentrations than the other two visits. This can be attributed to changes in daily operations, such as the clearing up of roads which were closed for construction during previous visits. The removal of construction sites would lead to larger amounts of diesel trucks passing through our intersection of interest. As for the second visit, the data is more of an outlier due to how it depicts some drops in concentration levels where the other two days show peaks, as shown from 9:10 AM to 9:15 AM. Moreover, this day showed the greatest range in $PM_{2.5}$ concentration with a large spike shown at around 9:05 AM. Since we cannot attribute it directly to the bus stop because we moved locations, it might be due to the sensor or some other factor that could not have been controlled for. Given the data from Figure 1, we cannot reach a conclusion about the daily level of air quality that the residents of Wilmington face. The data varies every day, even in a considerable way in only a span of thirty minutes. The variation in meteorological factors, such as wind patterns, and traffic, including diesel trucks varies widely throughout that time.

5.2 Monitoring Station Data Evaluation

The six monitoring stations around the Long Beach and Los Angeles Ports record $PM_{2.5}$ and NO_x concentrations on an hourly basis. In order to compare AERMOD predictions to the real-time monitoring station data, we compiled it into hourly and monthly graphical representations and calculated the averages. As previously stated, in the hourly average results, there was a higher concentration level of $PM_{2.5}$ at 7:00 PM and a higher concentration of NO_x at 7:00 AM. This increase for both pollutants during that time is most likely due to higher vehicle activity, from both diesel trucks and automobiles. In general, mornings and evenings consist of heavy traffic because people are starting and ending their work-day, which explains why the hourly concentration levels are higher.

For the monthly average concentration results, the most notable trend is that $PM_{2.5}$ and NO_x are highest in the winter. This can be attributed to multiple reasons. First, fossil fuel demand is highest in the winter (Airlief, 2017). Heaters in Los Angeles homes generally require natural gas and become more utilized as temperatures decrease. So as heating increases, more fossil fuels are consumed and therefore more pollutants like $PM_{2.5}$ and NO_x are produced ("Energy Saver 101 Infographic,"). Secondly, and the most probable dominant factor, colder temperatures result in an inversion layer in the atmosphere. Warm air rises above cold air during the winter due to density differences, trapping cold air below. Because the cold air is trapped under the warm air layer, air pollution emitted by different sources circulate within the cold air and cannot escape. As a result, the concentration of each pollutant increases, which can be seen from December to January showing the highest average concentration and May through August showing the lowest average concentration.

5.3 AERMOD

According to the figures, the model represents a high level of pollutant concentration in the winter and a low level in the summer for both $PM_{2.5}$ and NO_x. This result is expected based on meteorological conditions varying in the winter versus the summer—in the winter, the colder weather creates a thinner atmospheric boundary layer closer to the surface which in turn results in a higher concentration due to the smaller volume available for the pollutants to disperse amongst. In the summer, a warmer temperature results in a thinner, larger boundary layer allowing the pollutants to inhabit a larger volume of air, and thus, a smaller concentration is present (Bonner et al., 2010).

When compared with observational station data, AERMOD results indicate a mean $PM_{2.5}$ value of 8.9 ug/m^3, whereas observations show an average of 14.1 ug/m^3. It makes sense that observations would show a higher mean value, since our model only takes into account $PM_{2.5}$ emitted from diesel trucks, and in fact there are various sources that contribute to ambient $PM_{2.5}$ levels. In contrast to $PM_{2.5}$, AERMOD results for NO_x showed a different relationship with observational data. While the mean NO_x concentration for AERMOD was 63.71 ug/m^3, observational results indicated an average of 33.4434 ug/m^3. A possible reason for this discrepancy could be that, since AERMOD is modeling only the source of NO_x, it does not take into account its reaction with VOC's to produce ozone. On the other hand, since the monitoring stations are measuring ambient NO_x levels, some of the NO_x produced by diesel emissions will have been converted to ozone in the ambient air. More research should be done regarding AERMOD's calculation of NO_x concentrations.

Due to limitations in the model and data availability, it is difficult to include each individual factor affecting emissions into the model; thus, assumptions must be made and some factors may be excluded from the modeling process. Truck count data provided by Caltrans has no diurnal variations meaning the average truck counts per hour is a constant amount. It is likely that there is not, for example, 13,000 trucks on the 405 Freeway every hour; if AADT is 13,000, it is unlikely that for every hour of each day, there are 541 trucks present. This poses a limitation to the plume model since hourly truck counts will always be the same in our model, when in reality there is a varying amount of trucks per hour. Also, the data for the year that truck counts are provided (2017) do not align with the year of meteorological data provided by SCAQMD (2016).

Building downwash, the existence and heights of buildings and other structures, is an important contribution in plume modeling that AERMOD allows the user to add to the model. However, creating building features for the study region was a task not feasible in the scope of the project. The building downwash effect reports that building structures play a role in the way wind patterns travel and disperse pollutants (Trinity Consultants, 2011). If given more time and the available data, the team would also have liked to incorporate diesel emissions from the port operations as well as factor in idling times into the model to further represent a more holistic picture of the amount of emissions in the neighboring community. By only taking into account diesel trucks from the freeway, we are only representing a portion of emissions and can expect real time averages to be higher relative to the model output.

An emissions model can only be as accurate as the data inputted, and even then, it is likely impossible to take into account every factor impacting emissions. For this reason, the AERMOD results in this project should be compared to similar studies, and independent analysis or replication of the study should be conducted in order to make informed decisions.

6. Conclusion

The San Pedro Bay Ports' operations emit a large amount of pollutants, particularly from diesel trucks impacting the surrounding area that consists mainly of low-income people of color. Thus, this population is disproportionately put at a higher risk of diseases associated with such emissions in addition to the greenhouse gas emissions released from diesel trucks that further exacerbate these health risks.

Based on our research question, our team conducted a series of data collection and analyses in order to understand how particulate matter and nitrogen oxide concentrations are dispersed over a hyperlocal area near the Port of LA.

Through field site visits, modelling with AERMOD, and evaluating CAAP data, we were able to gain a more holistic view of the ambient air quality surrounding the port. Field site data showed that daily variation showed no apparent pattern with $PM_{2.5}$ concentration levels since there were many confounding variables that could not be controlled for. Moreover, both the CAAP data and AERMOD model showed that concentrations are high in the winter and low in the summer. CAAP data from the six monitoring stations displayed high $PM_{2.5}$ concentrations in the evening and high NO_x concentrations in the morning. When we compared AERMOD to CAAP data, the observational measurements were much higher than the model for NO_x and lower than the model for $PM_{2.5}$.

There were various limitations that hindered our progress, such as field site visit times, reliability of field data, missing factors in AERMOD, making assumptions within the model, and more. Although the data we gathered is still valuable, unfortunately given the time and scope of the project there were many things that we could not do. Therefore, we recommend that future teams try to address the limitations we listed especially for AERMOD and the field site visits. Further research could also be focused on community work and collecting qualitative data by going to public hearings and listening to community concerns about ambient air quality.

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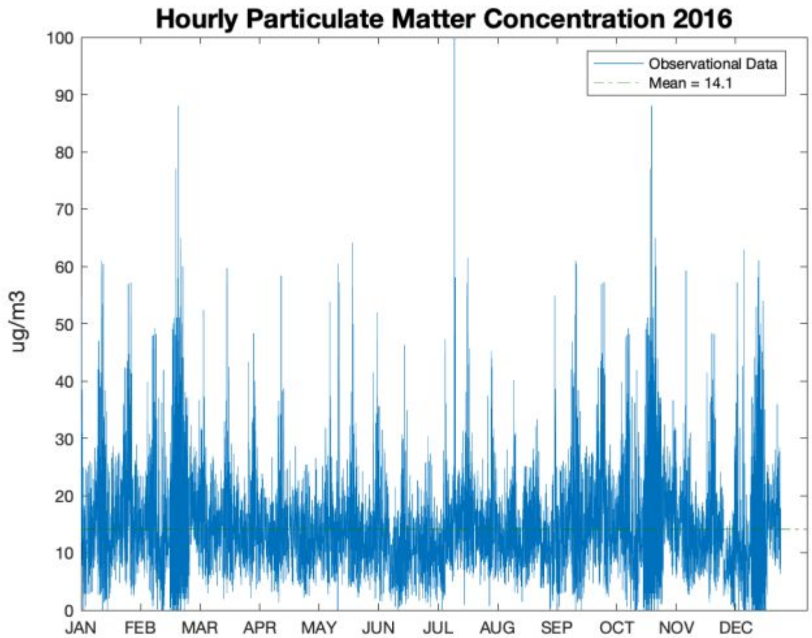
9. Appendix



Hourly Particulate Matter Concentration 2016
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Mean = 14.1
ug/m3
100
90
80
70
60
50
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10
0
JAN
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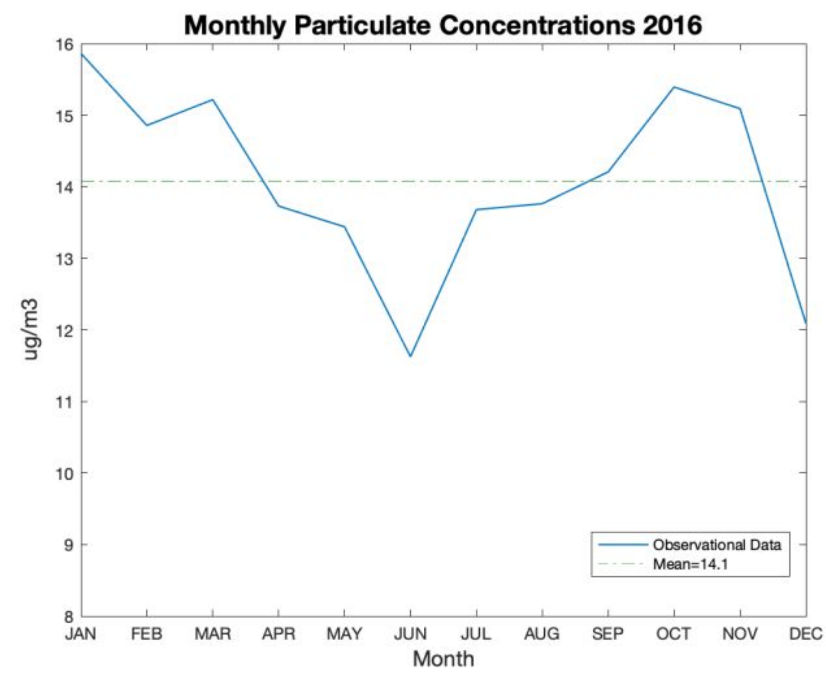
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC



Monthly Particulate Concentrations 2016
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ug/m3
16
15
14
13
12
11
10
9
8
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FEB
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MAY
JUN
JUL
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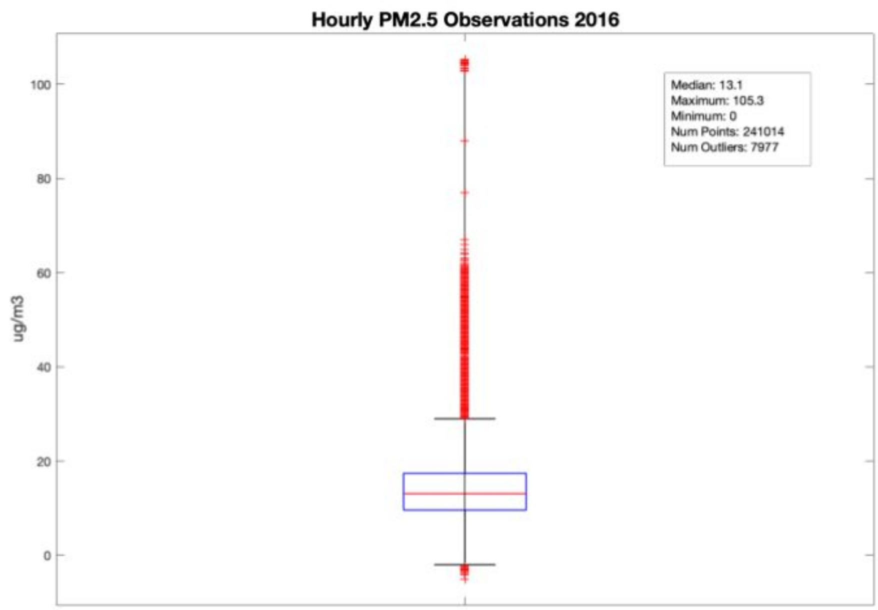
SEP
OCT
NOV
DEC
Month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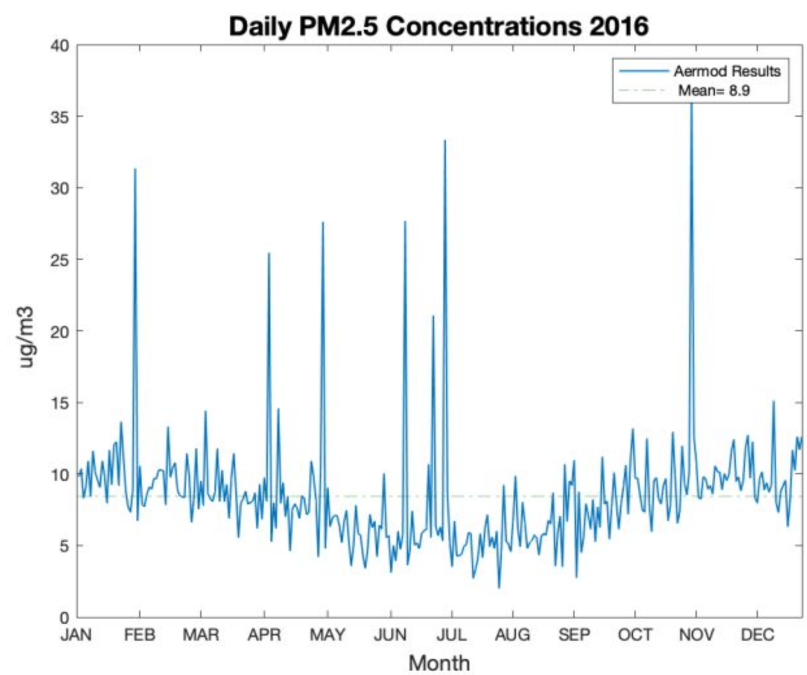
20
0


Daily PM2.5 Concentrations 2016
Aermod Results
Mean= 8.9
ug/m3
40
35
30
25
20
15
10
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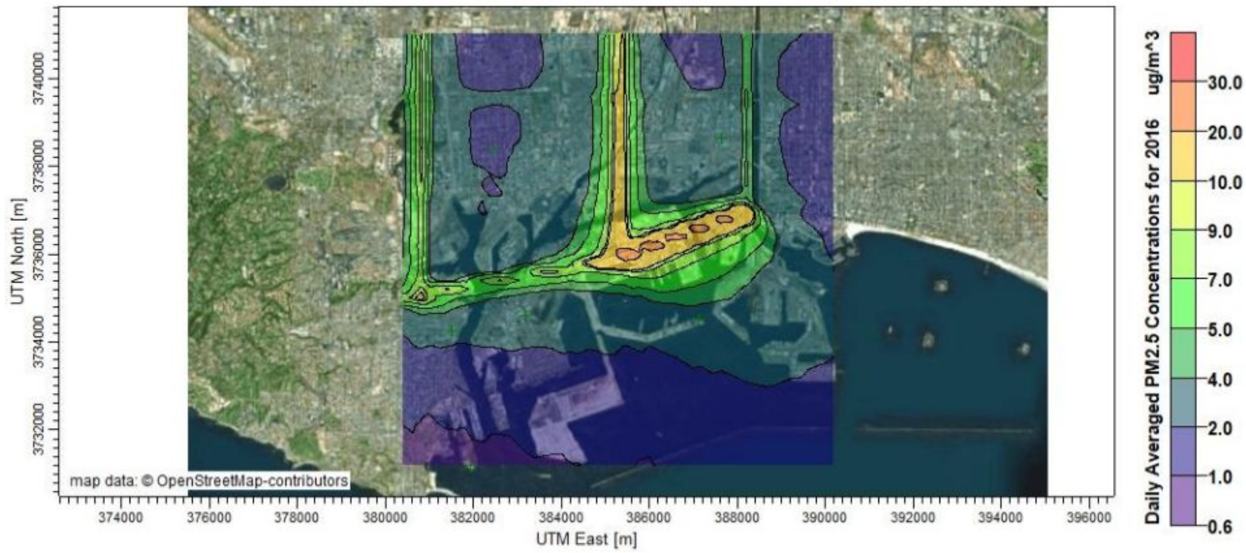
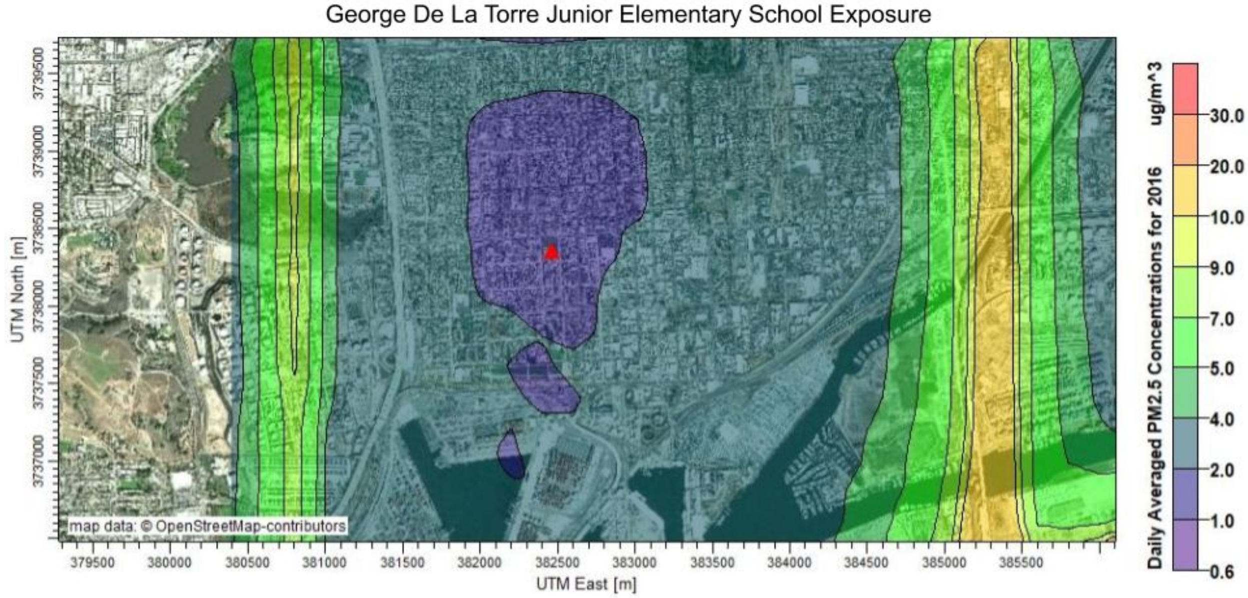
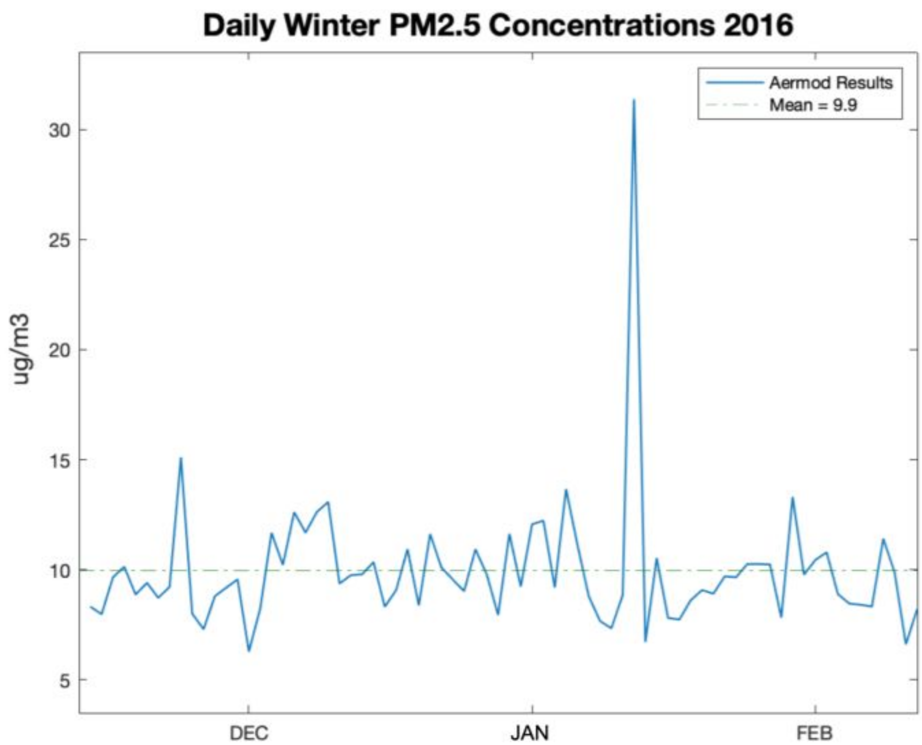
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
Month



George De La Torre Junior Elementary School Exposure

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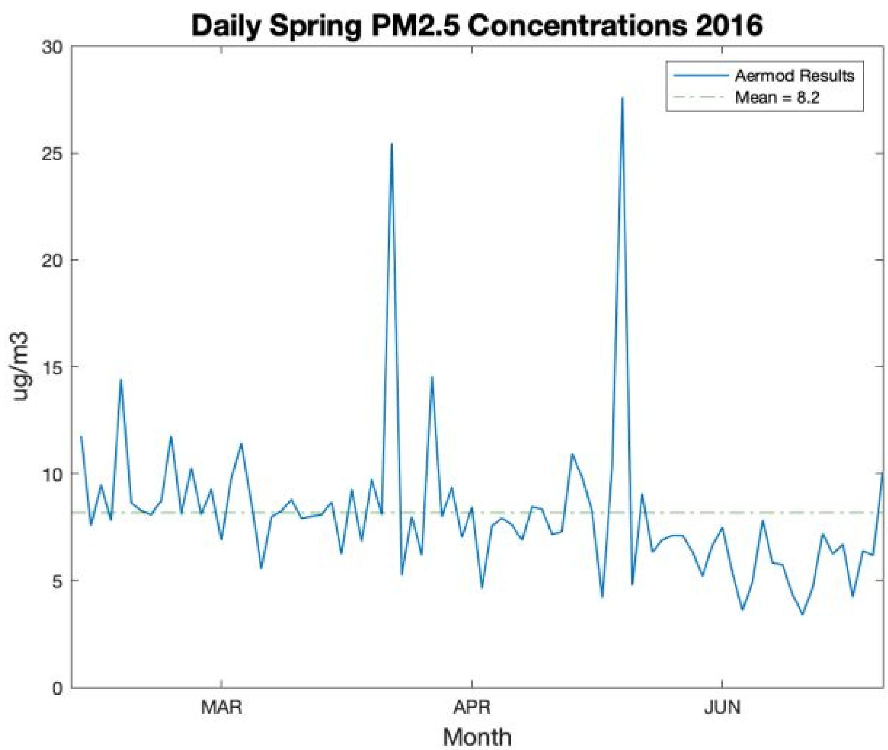
25
20
15
10
5
DEC
JAN
FEB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10
5
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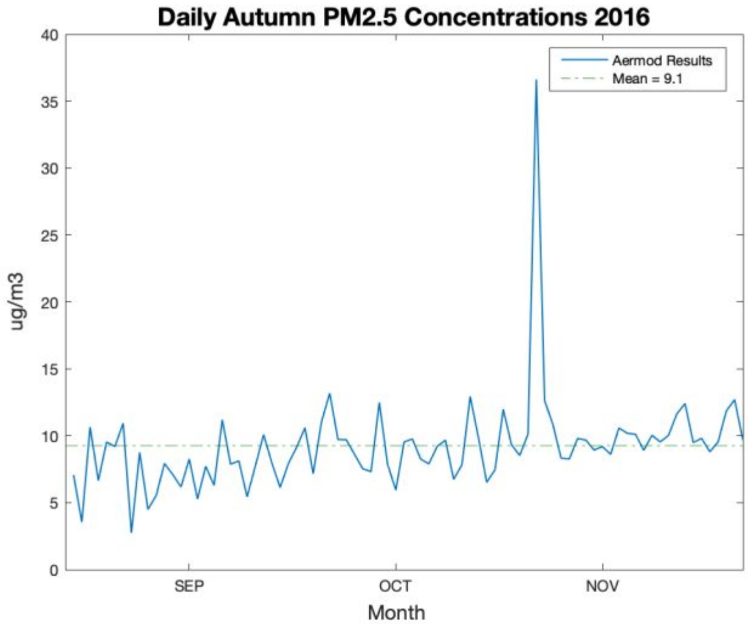
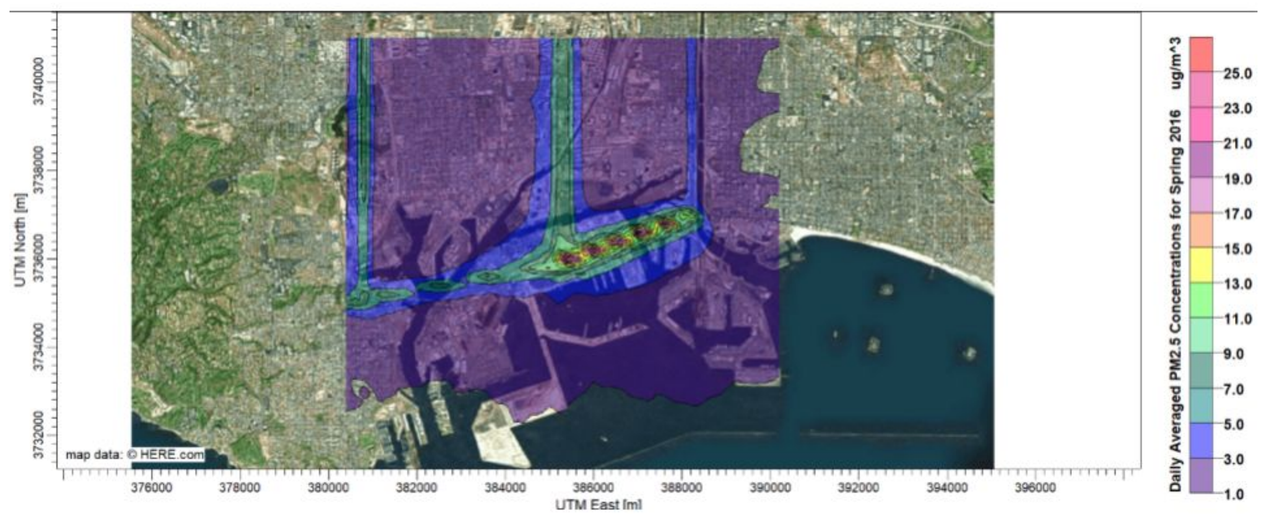
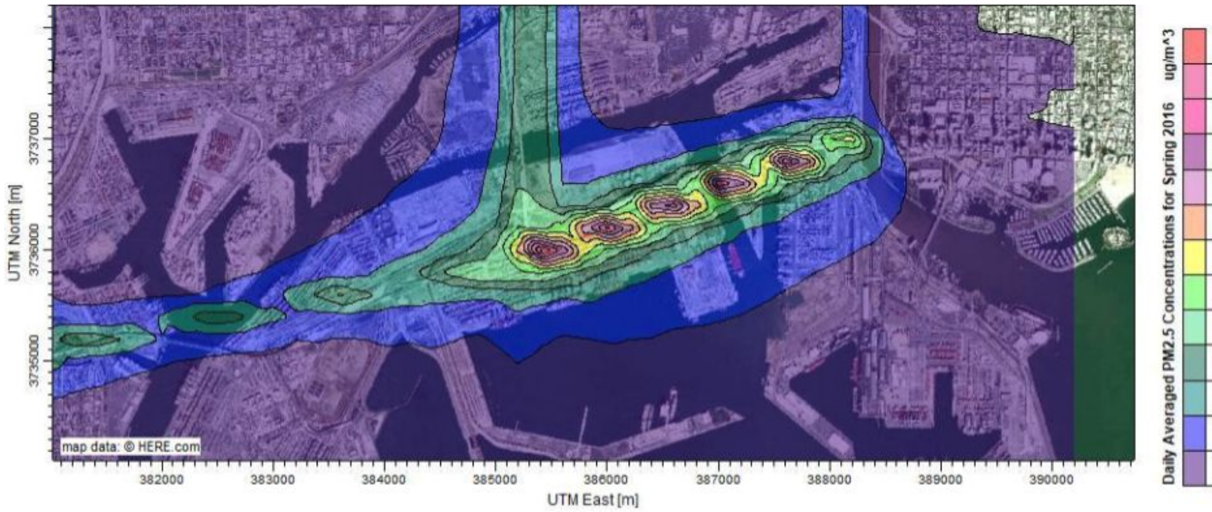
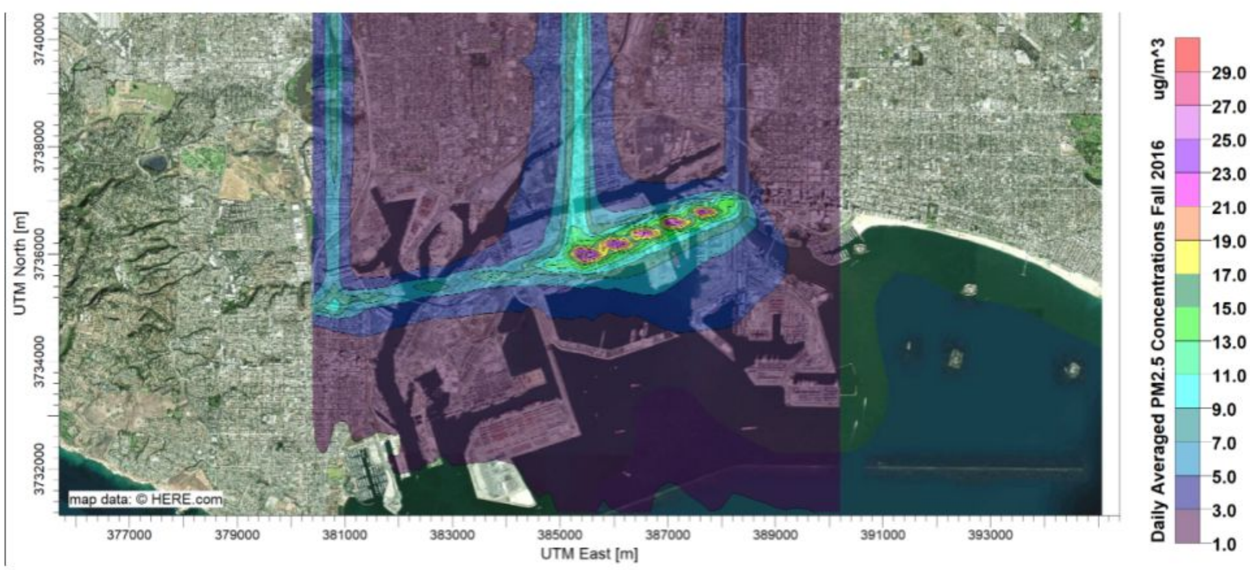
MAR
APR
JUN
Month

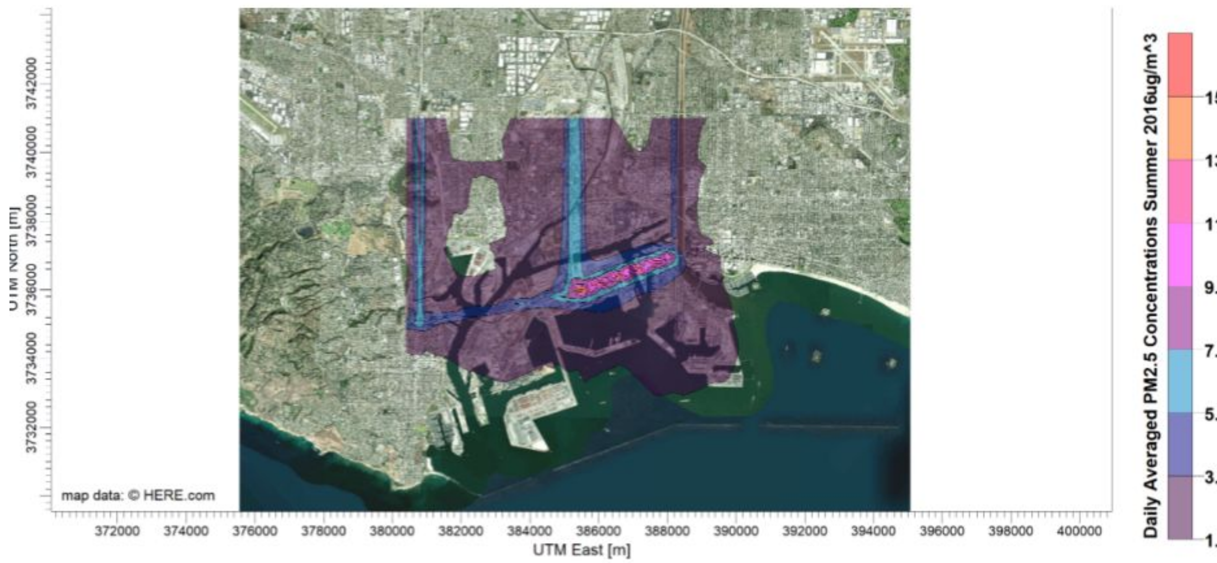

Daily Autumn PM2.5 Concentrations 2016
Aermod Results
Mean = 9.1
ug/m3
SEP
OCT
NOV
Month


map data: © HERE.com
UTM North [m]
UTM East [m]
Daily Averaged PM2.5 Concentrations for Spring 2016 ug/m^3

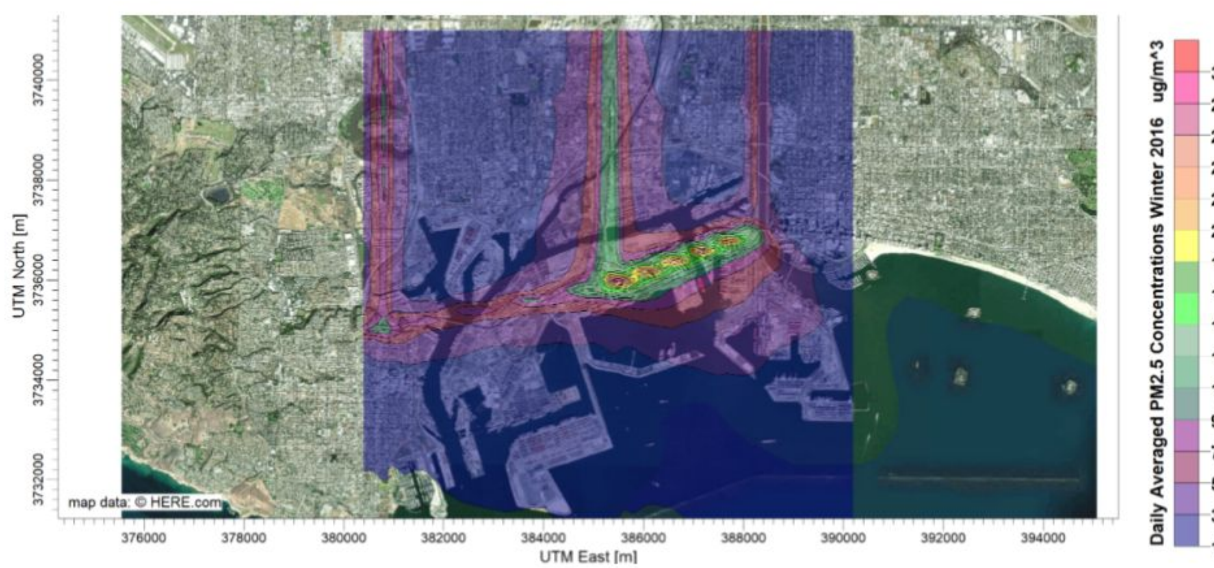
Zoomed in version for PM2.5 Spring 2016 (for better view of contours)



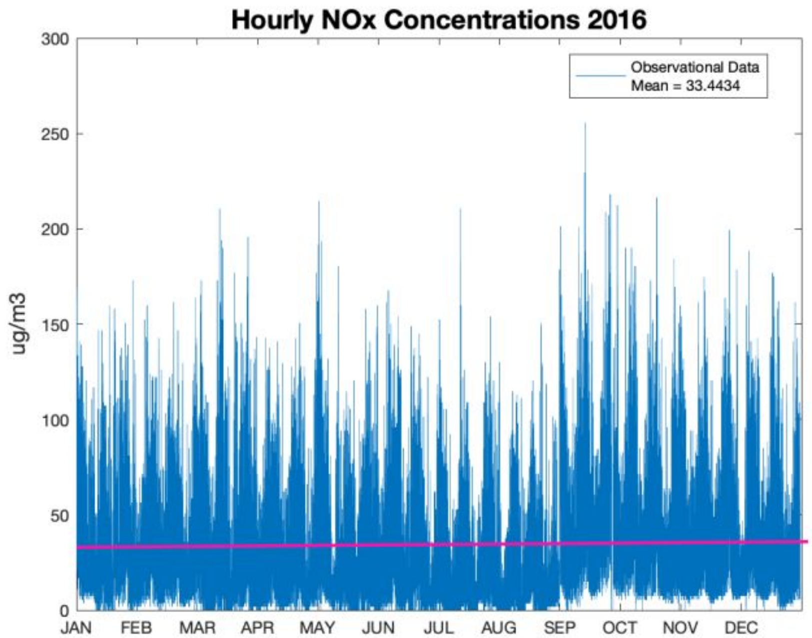




Daily Averaged PM2.5 Concentrations Summer 2016ug/m^3
15.0
13.0
11.0
9.0
7.0
5.0
3.0
1.0
UTM North [m]
UTM East [m]
map data: © HERE.com



Daily Averaged PM2.5 Concentrations Winter 2016 ug/m^3
31.0
29.0
27.0
25.0
23.0
21.0
19.0
17.0
15.0
13.0
11.0
9.0
7.0
5.0
3.0
1.0
UTM North [m]
UTM East [m]
map data: © HERE.com


Hourly NOx Concentrations 2016
Observational Data
Mean = 33.4434
ug/m3
300
250
200
150
100
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0
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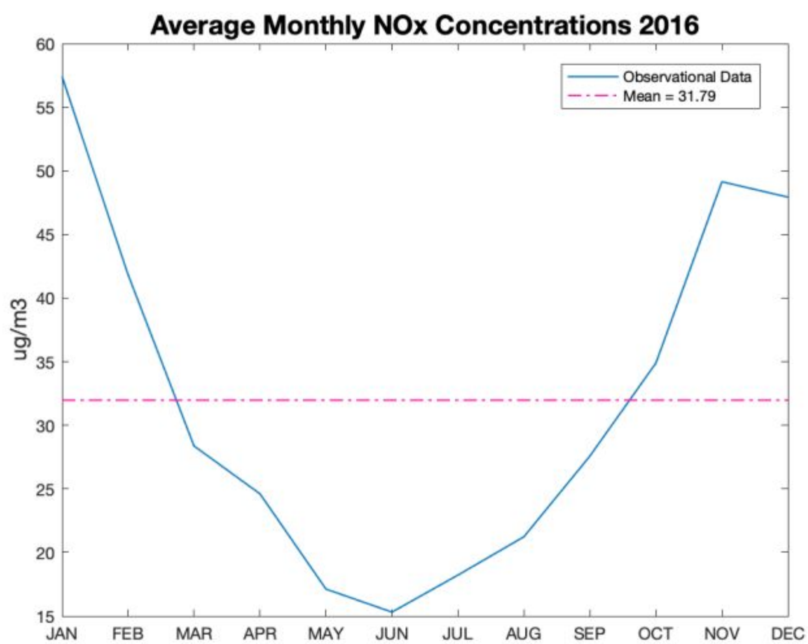
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC


Average Monthly NOx Concentrations 2016
Observational Data
Mean = 31.79
ug/m3
60
55
50
45
40
35
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25
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15
JAN
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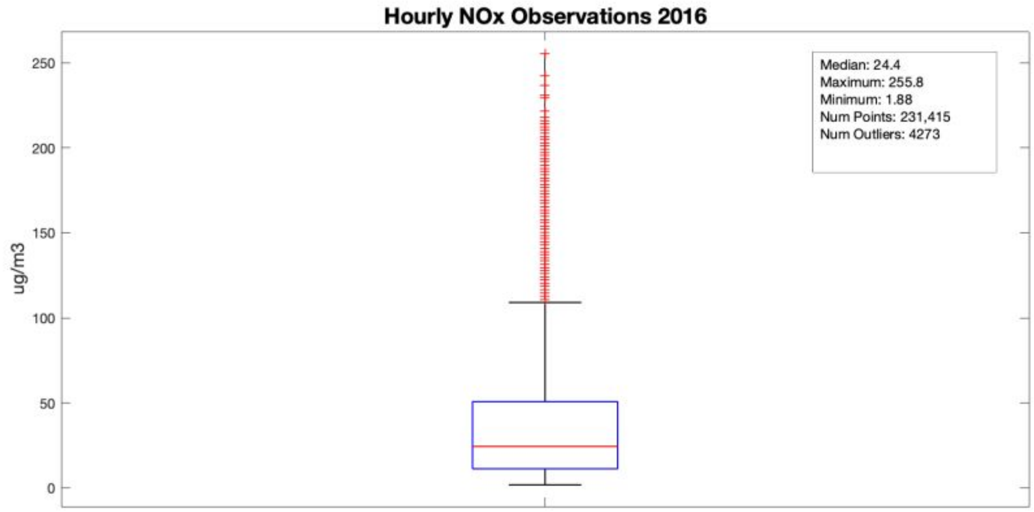
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC



Hourly NOx Observations 2016
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Maximum: 255.8
Minimum: 1.88
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Num Outliers: 4273
ug/m3
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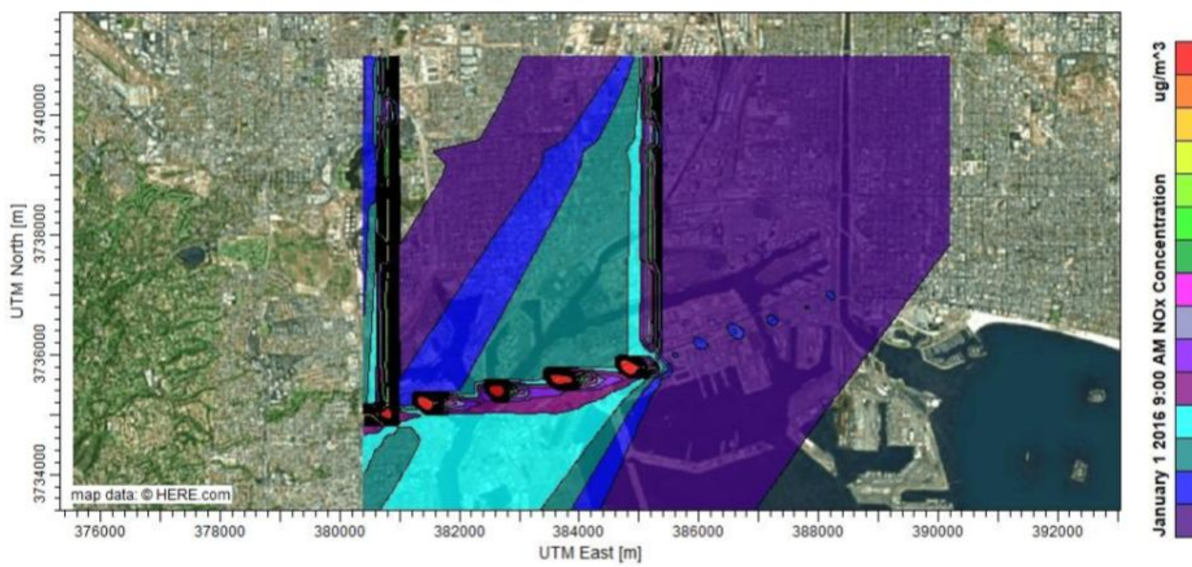
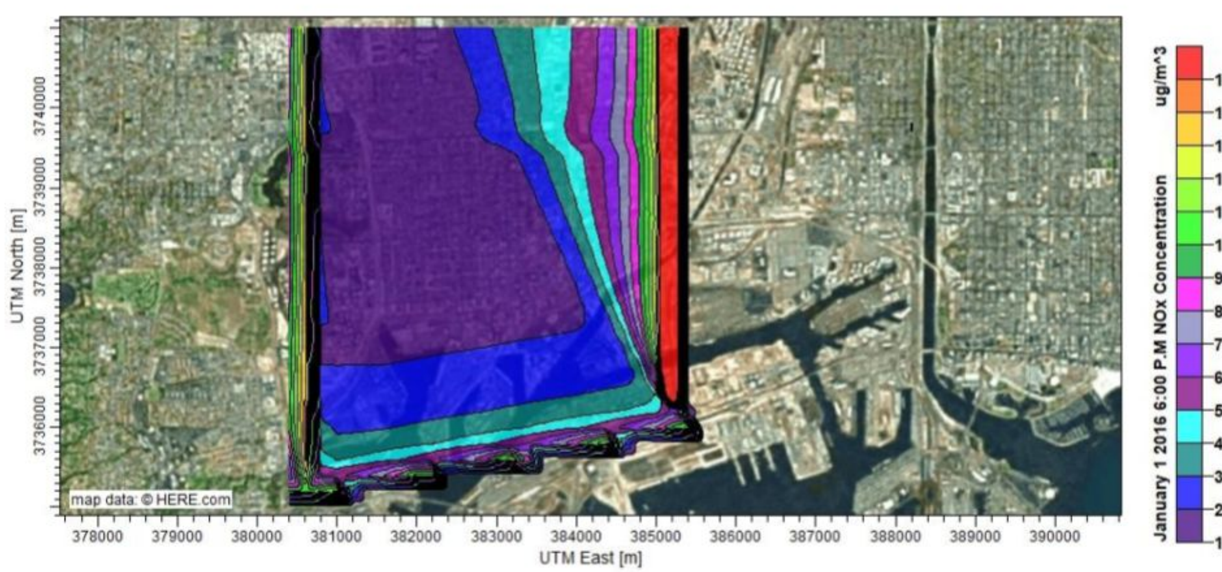
50
100
150
200
250

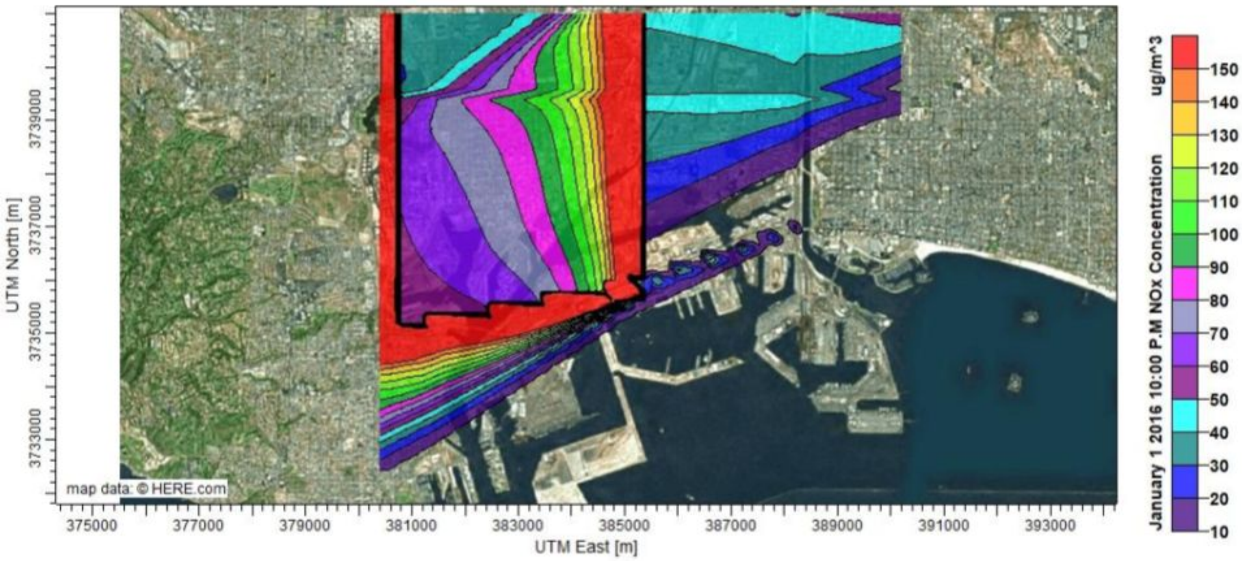


map data: © HERE.com
UTM North [m]
UTM East [m]
3734000
3736000
3738000
3740000
376000
378000
380000
382000
384000
386000
388000
390000
392000
January 1 2016 9:00 AM NOx Concentration
ug/m^3
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10

UTM North [m]
3736000
3737000
3738000
3739000
3740000
UTM East [m]
376000
377000
378000
379000
380000
381000
382000
383000
384000
385000
386000
387000
388000
map data: © HERE.com
January 1 2016 1:00 P.M NOx Concentration
ug/m^3
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150



UTM North [m]
3736000
3737000
3738000
3739000
3740000
UTM East [m]
378000
379000
380000
381000
382000
383000
384000
385000
386000
387000
388000
389000
390000
map data: © HERE.com
January 1 2016 6:00 P.M NOx Concentration
ug/m^3
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150



UTM North [m]
3739000
3737000
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3733000
map data: © HERE.com
375000
377000
379000
381000
383000
385000
387000
389000
391000
393000
UTM East [m]
January 1 2016 10:00 P.M NOx Concentration
ug/m^3
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130
120
110
100
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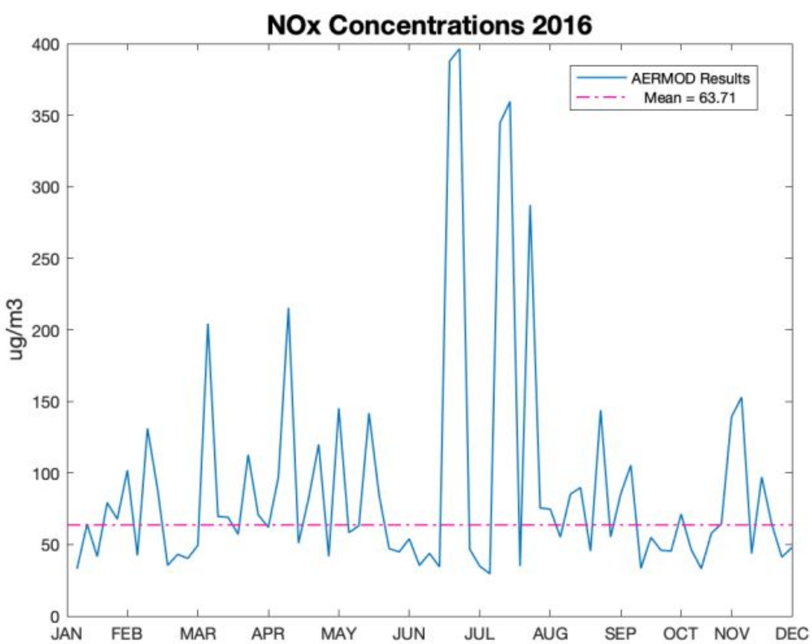
80
70
60
50
40
30
20
10



NOx Concentrations 2016
AERMOD Results
Mean = 63.71
ug/m3
400
350
300
250
200
150
100
50
0
JAN
FEB
MAR
APR
MAY
JUN
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AUG
SEP
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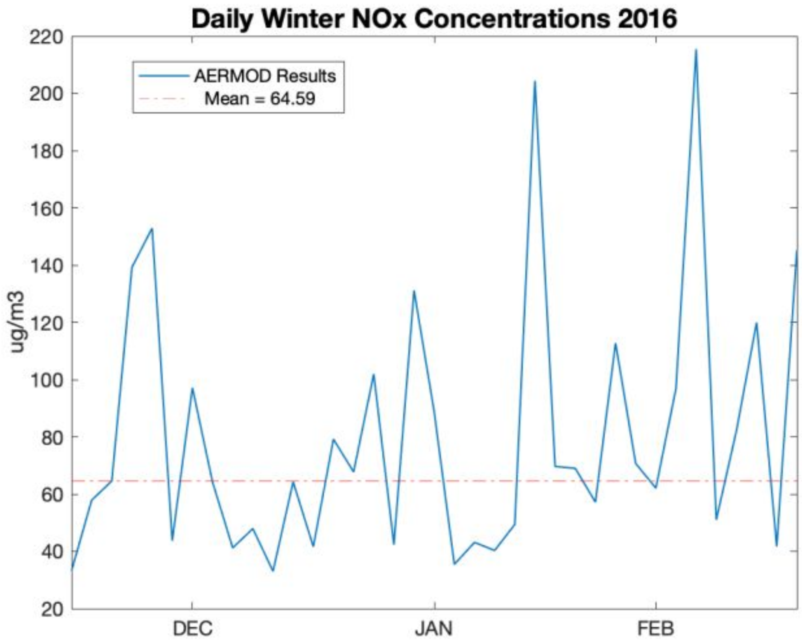
DEC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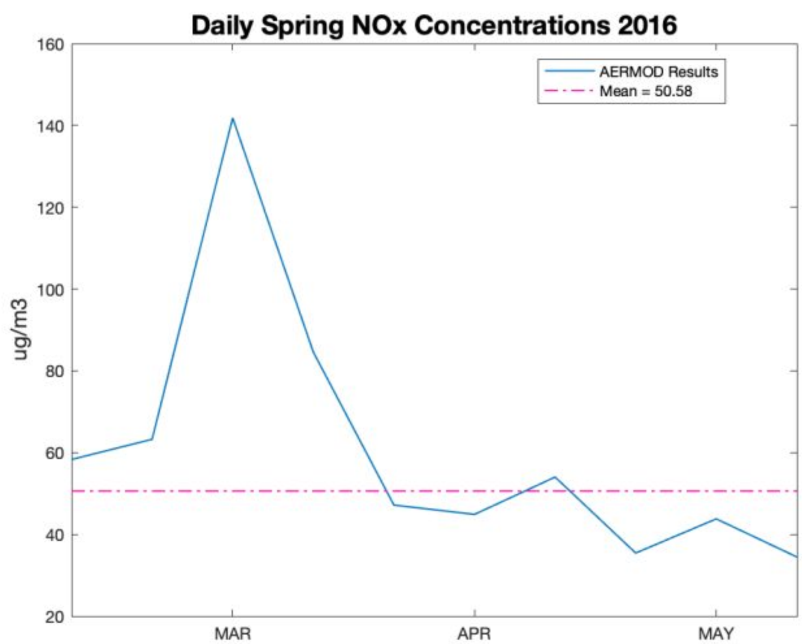
20
DEC
JAN
FEB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120
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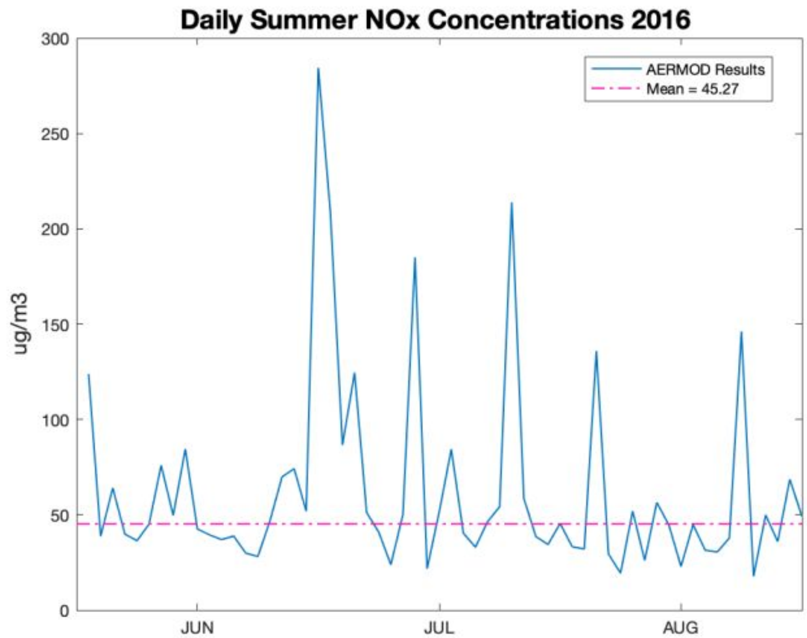
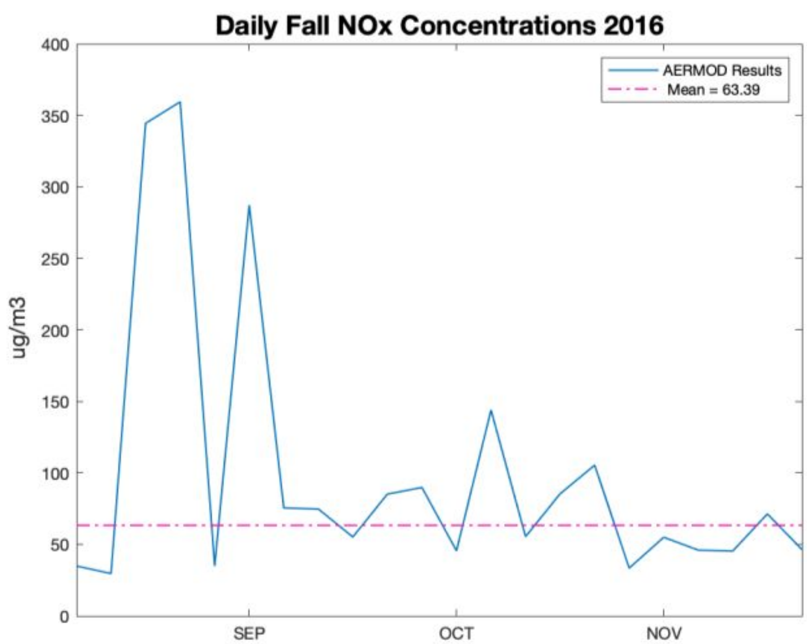
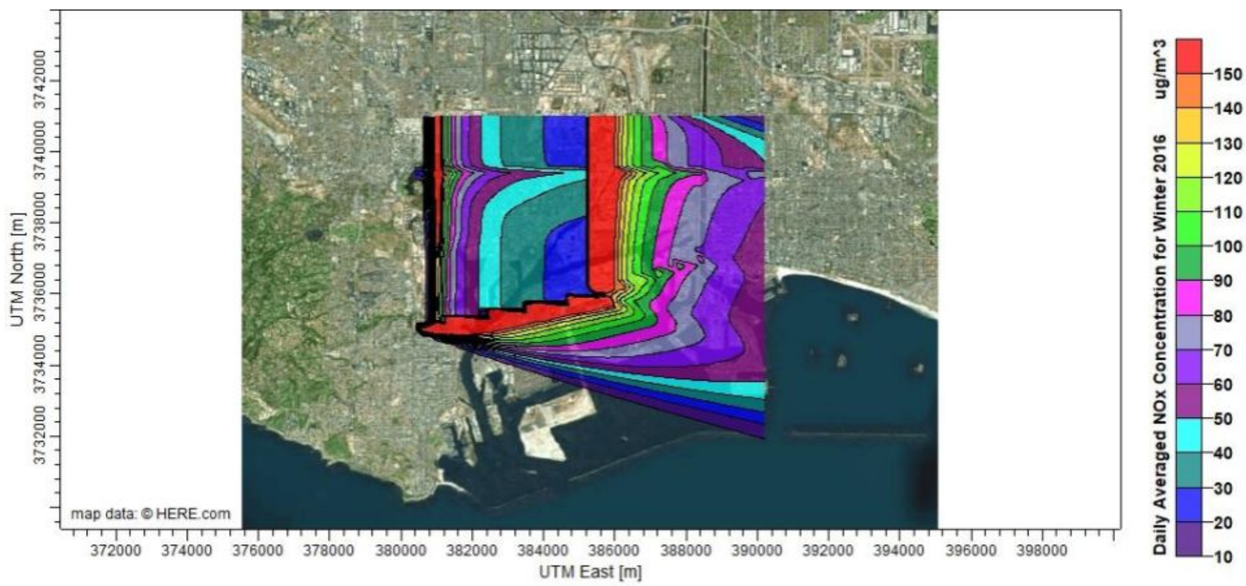
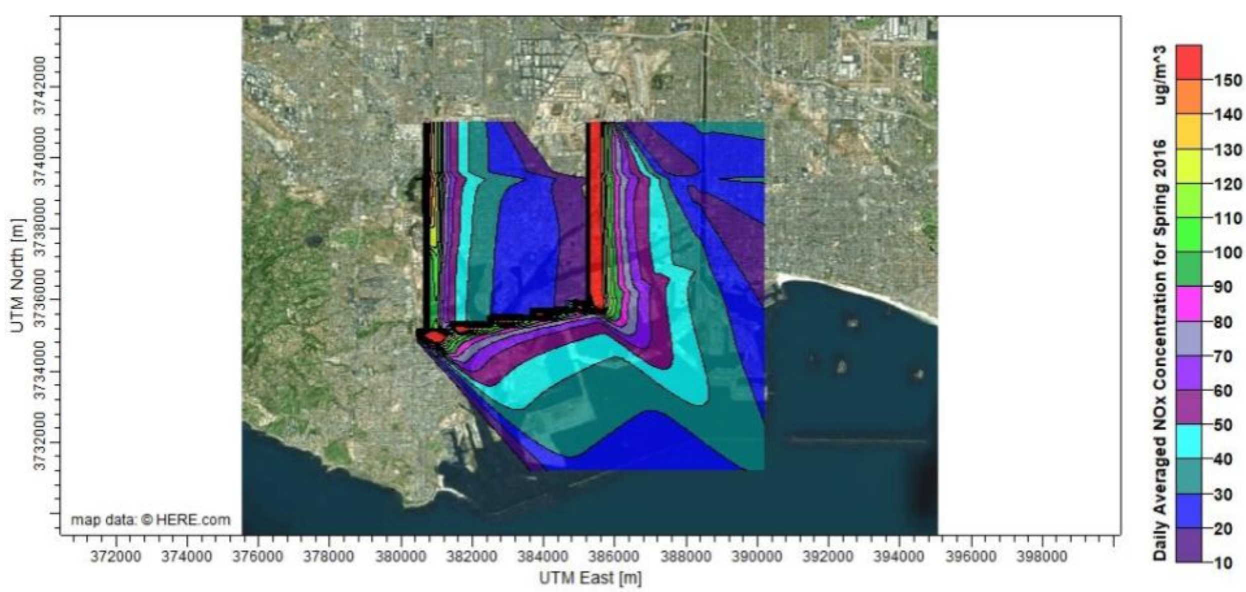
80
60
40
20
MAR
APR
MAY


Daily Summer NOx Concentrations 2016
AERMOD Results
Mean = 45.27
ug/m3
300
250
200
150
100
50
0
JUN
JUL
AUG

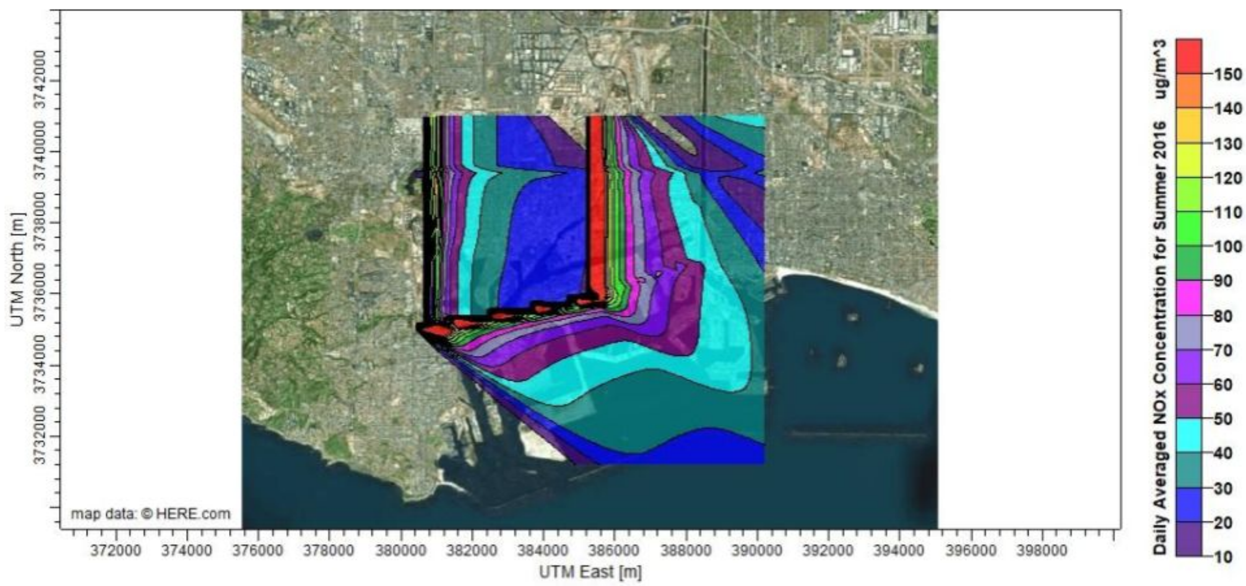

Daily Fall NOx Concentrations 2016
AERMOD Results
Mean = 63.39
ug/m3
400
350
300
250
200
150
100
50
0
SEP
OCT
NOV



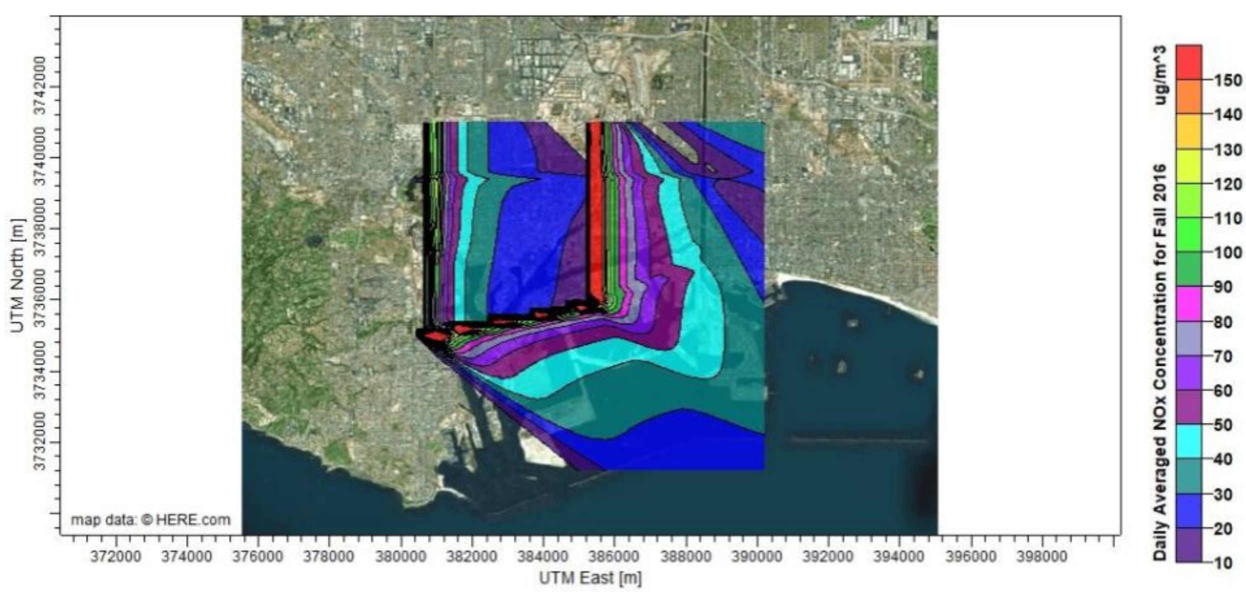
UTM North [m]
3732000
3734000
3736000
3738000
3740000
3742000
UTM East [m]
372000
374000
376000
378000
380000
382000
384000
386000
388000
390000
392000
394000
396000
398000
map data: © HERE.com
Daily Averaged NOx Concentration for Winter 2016
ug/m^3
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10



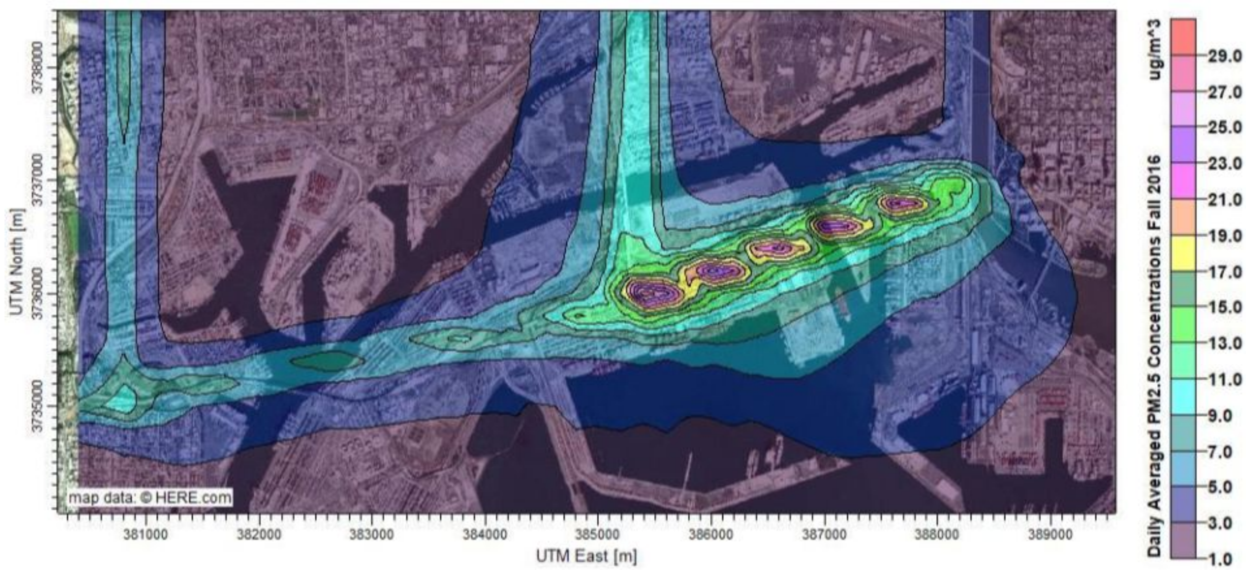
UTM North [m]
3732000
3734000
3736000
3738000
3740000
3742000
UTM East [m]
372000
374000
376000
378000
380000
382000
384000
386000
388000
390000
392000
394000
396000
398000
map data: © HERE.com
Daily Averaged NOx Concentration for Spring 2016
ug/m^3
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10



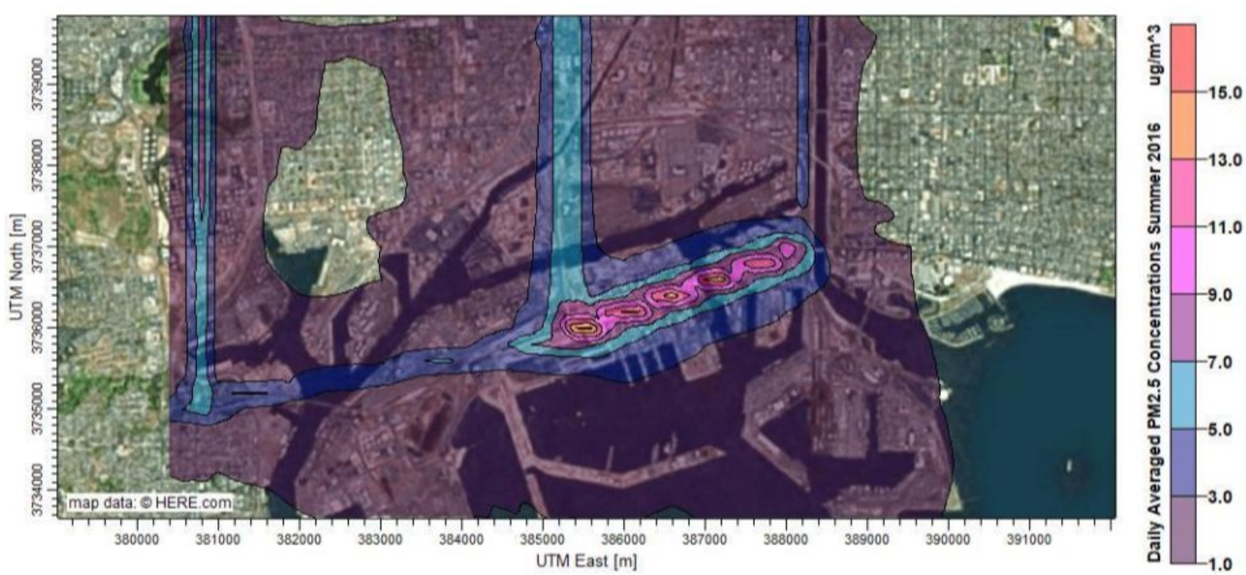
UTM North [m]
3742000
3740000
3738000
3736000
3734000
3732000
map data: © HERE.com
372000
374000
376000
378000
380000
382000
384000
386000
388000
390000
392000
394000
396000
398000
UTM East [m]
Daily Averaged NOx Concentration for Summer 2016 ug/m^3
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10



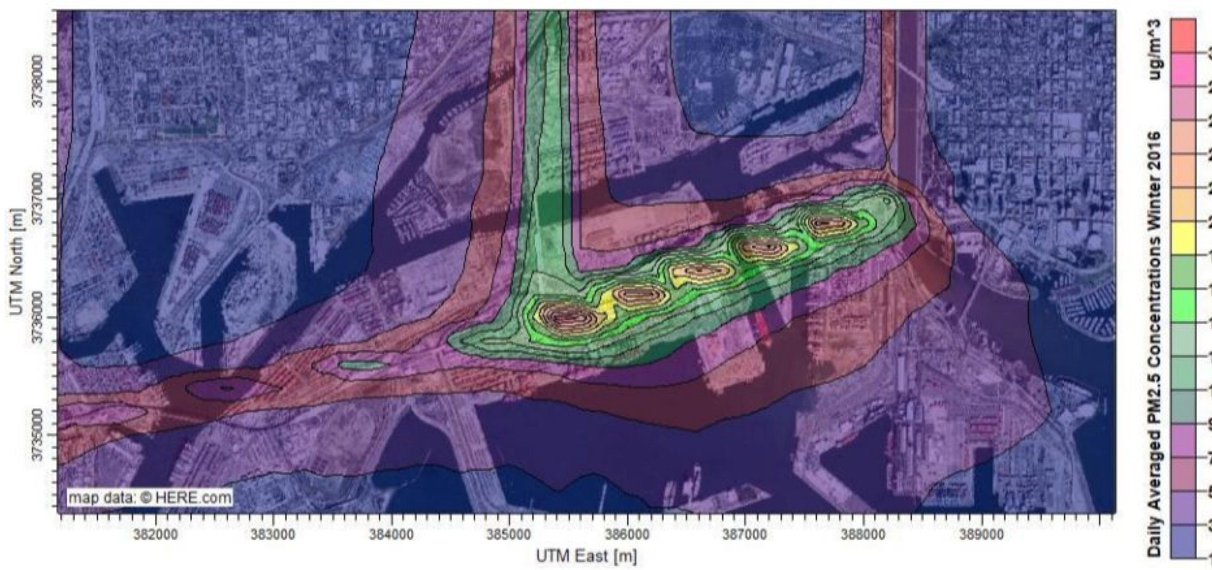
UTM North [m]
3742000
3740000
3738000
3736000
3734000
3732000
map data: © HERE.com
372000
374000
376000
378000
380000
382000
384000
386000
388000
390000
392000
394000
396000
398000
UTM East [m]
Daily Averaged NOx Concentration for Fall 2016 ug/m^3
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10

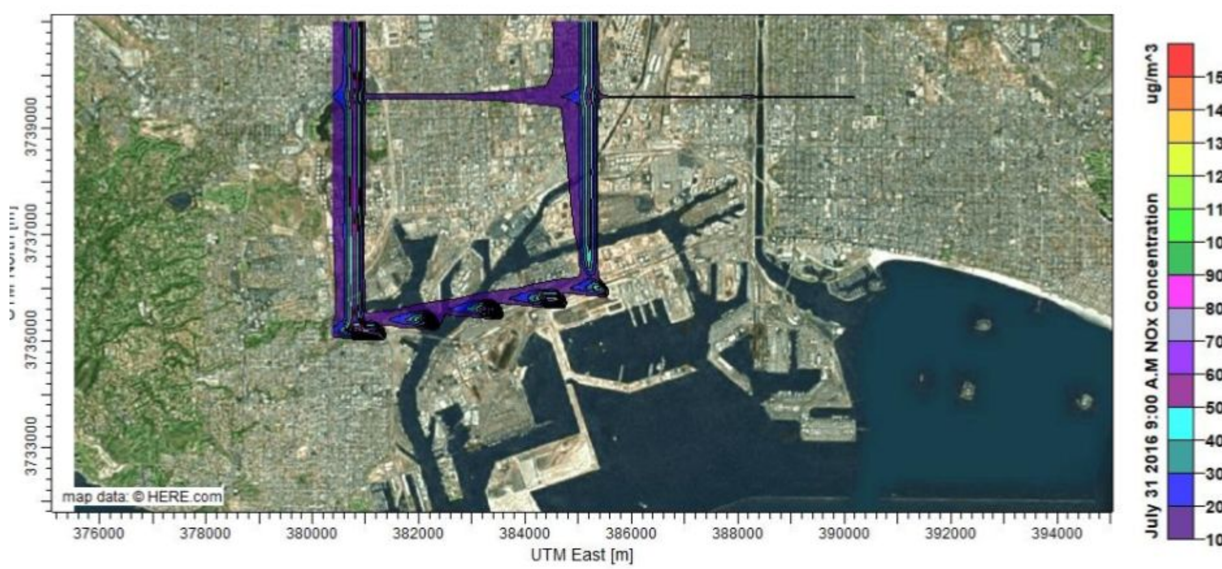


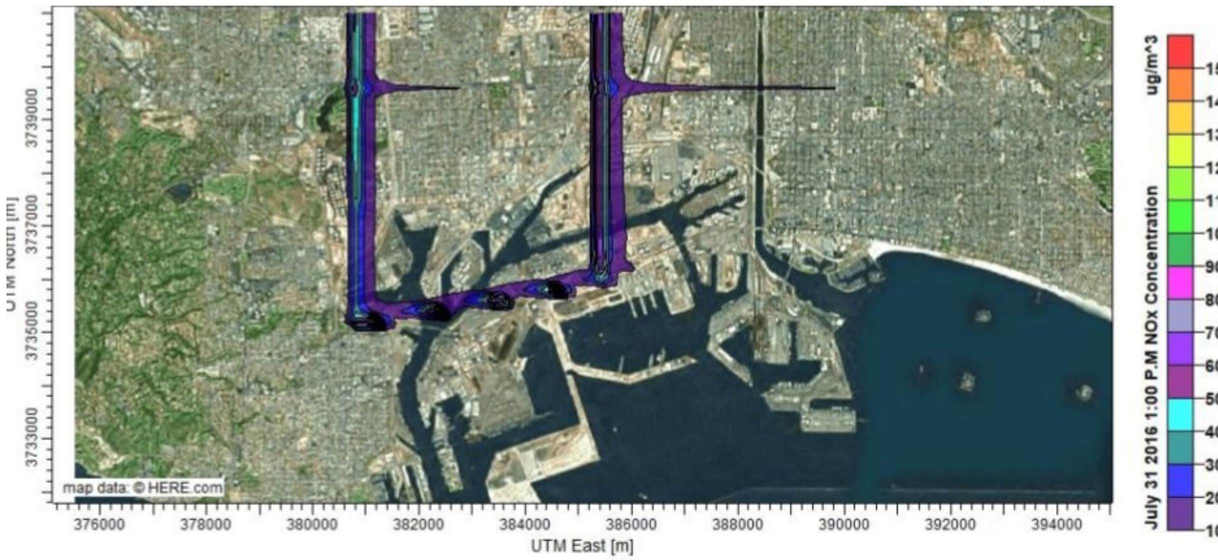
UTM North [m]
3738000
3737000
3736000
3735000
map data: © HERE.com
381000
382000
383000
384000
385000
386000
387000
388000
389000
UTM East [m]
Daily Averaged PM2.5 Concentrations Fall 2016
ug/m^3
29.0
27.0
25.0
23.0
21.0
19.0
17.0
15.0
13.0
11.0
9.0
7.0
5.0
3.0
1.0



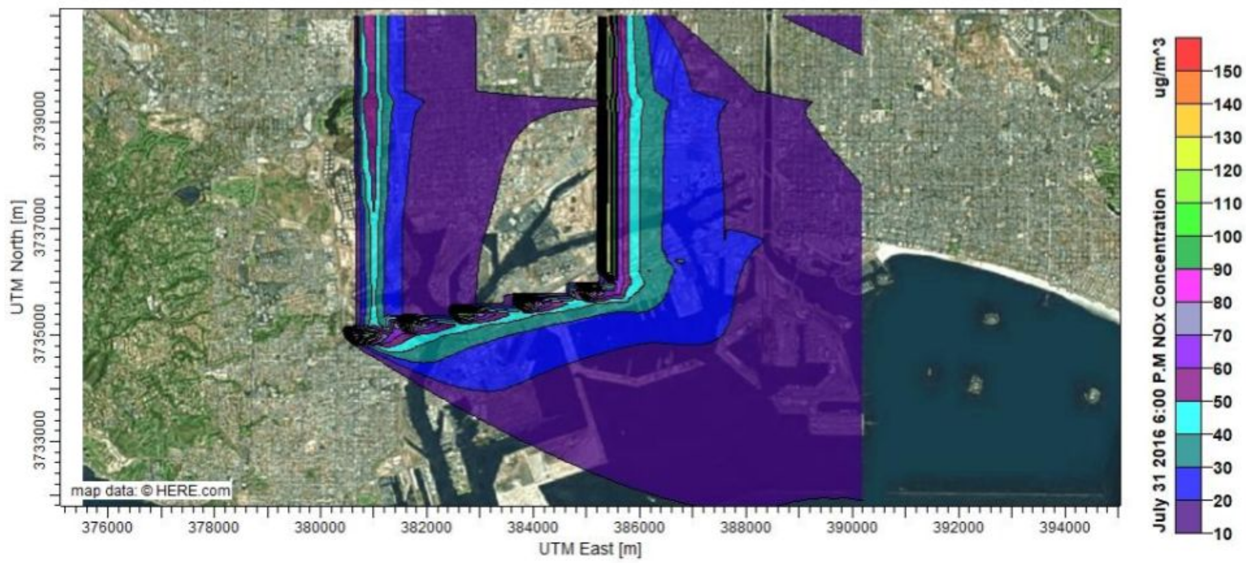
UTM North [m]
3739000
3738000
3737000
3736000
3735000
3734000
map data: © HERE.com
380000
381000
382000
383000
384000
385000
386000
387000
388000
389000
390000
391000
UTM East [m]
Daily Averaged PM2.5 Concentrations Summer 2016
ug/m^3
15.0
13.0
11.0
9.0
7.0
5.0
3.0
1.0


map data: © HERE.com
UTM North [m]
3738000
3737000
3736000
3735000
UTM East [m]
382000
383000
384000
385000
386000
387000
388000
389000
Daily Averaged PM2.5 Concentrations Winter 2016
ug/m^3
31.0
29.0
27.0
25.0
23.0
21.0
19.0
17.0
15.0
13.0
11.0
9.0
7.0
5.0
3.0
1.0

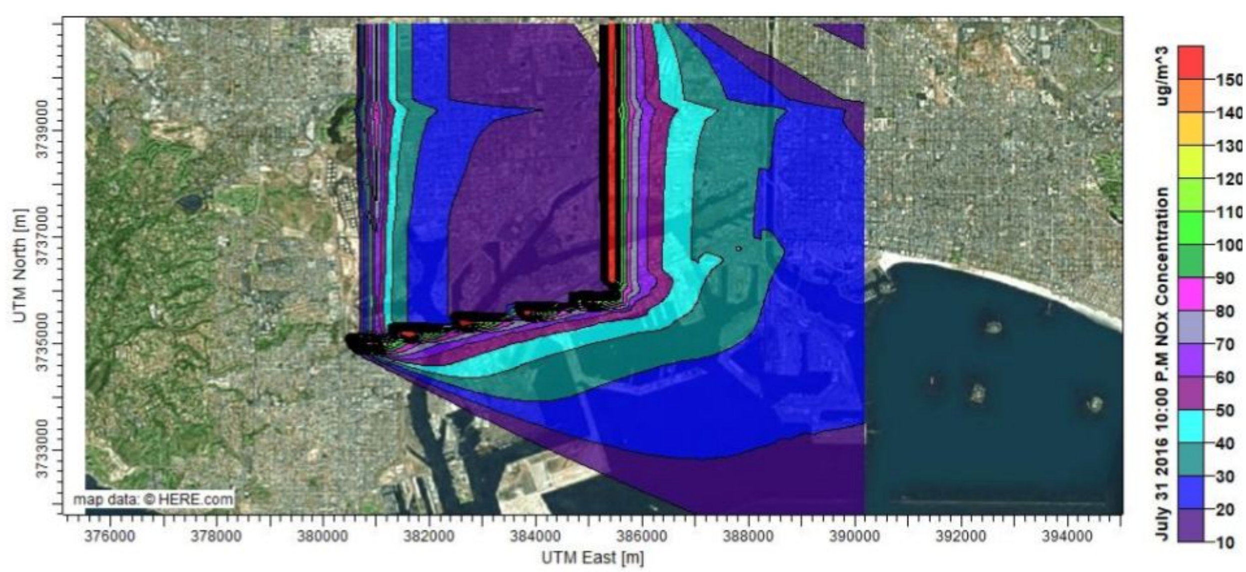

map data: © HERE.com
3739000
3737000
3735000
3733000
UTM East [m]
376000
378000
380000
382000
384000
386000
388000
390000
392000
394000
July 31 2016 9:00 A.M NOx Concentration
ug/m^3
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10



3739000
3737000
3735000
3733000
UTM North [m]
map data: © HERE.com
376000
378000
380000
382000
384000
386000
388000
390000
392000
394000
UTM East [m]
July 31 2016 1:00 P.M NOx Concentration
ug/m^3
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10



map data: © HERE.com
UTM North [m]
UTM East [m]
376000
378000
380000
382000
384000
386000
388000
390000
392000
394000
3733000
3735000
3737000
3739000
July 31 2016 6:00 P.M NOx Concentration
ug/m^3
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10



map data: © HERE.com
UTM North [m]
UTM East [m]
376000
378000
380000
382000
384000
386000
388000
390000
392000
394000
3733000
3735000
3737000
3739000
July 31 2016 10:00 P.M NOx Concentration
ug/m^3
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10