

Houston air quality assessment in response to Coronavirus social distancing measures

Gunnar W. Schade, Atmospheric Sciences Department, Texas A&M University, College Station, TX

10 April 2020

(peer review provided by Drs. Sarah Brooks, TAMU, and Don Collins, UC Riverside)

20 April 2020 UPDATE

Summary

A limited analysis of state air quality data in Houston was conducted with a focus on nitrogen oxides and fine particulate matter. Publically available data from three weeks before and up to four weeks after social distancing orders indicate that NO_x levels have dropped non-uniformly across Harris County. Highest reductions have occurred next to a major traffic axis, while lower reductions occurred at sites not directly next to such axes; for example, no significant reductions were observed in Deer Park. In turn, large fine particulate matter increases were observed at the Deer Park site, and smaller increases at two other sites, and neither can be explained by different weather conditions during the two periods investigated. A closer analysis of possible source changes suggests that long-range transport of smoke from Latin American fires may have caused uniform PM_{2.5} increases, which in combination with non-uniform decreases of the traffic source of PM_{2.5} might explain the ambient observations.

1. Introduction

Throughout the world, social distancing measures have been put in place to slow down the spread of SARS-CoV-2, also known as *coronavirus*. As a result of both voluntary and mandated measures of “shelter-in-place” or “stay-at-home” orders, or less drastic measures such as canceling large events and limiting gatherings to no more than 10 people, the sources of air pollutants attributable to car traffic and industrial processes have been reduced. Fewer people and goods travel long or short distances, reducing mobile source emissions, and lower amounts of production activities may also lead to lower stationary source pollutant emissions as the economy has slowed down. This has led to remarkable improvements of air quality in many cities and countries, and has been detectable from space using routine satellite data analysis ([NASA Earth Observatory](#), [NYTimes](#)). Interestingly, Texas cities have not yet featured in any associated analyses, despite the fact that there are three metropolitan areas in Texas, Houston, Dallas/Ft. Worth, and San Antonio, that deal with significant air quality issues. For historical reasons, Houston has among the densest air quality monitor networks in the nation, and is dealing with significant ozone and fine particulate matter levels.

In response to the growing spread of the coronavirus in Texas, on March 19 Governor Abbot announced the closing of bars, restaurants and schools ([Texas Tribune](#)) by end of Friday, 20 March, which was followed a few days later, 24 March, by a local stay-at-home order from Harris County Judge Hidalgo.

In this report, I have summarized the development of two common pollutants, nitrogen oxides (NO_x) and fine particulate matter (PM_{2.5}) since 1 March 2020 at selected Harris County air quality monitors, to evaluate whether these state and local orders caused a significant change in Houston air quality. NO₂,

typically the dominant component of NO_x , and $\text{PM}_{2.5}$ are known to cause significant health effects. NO_2 can aggravate respiratory diseases, particularly asthma, and causes respiratory symptoms such as coughing, wheezing or difficulty breathing. It may also contribute to the development of asthma at longer exposures to elevated concentrations. At-risk populations include people with asthma, children and the elderly ([EPA](#)). Exposure to $\text{PM}_{2.5}$ can affect both the respiratory and cardiovascular systems. High $\text{PM}_{2.5}$ concentrations can cause premature death in people with heart or lung disease, nonfatal heart attacks, irregular heartbeat, aggravated asthma, decreased lung function, increased respiratory symptoms, such as irritation of the airways, coughing or difficulty breathing. Similar to NO_2 , at-risk populations include people with pre-existing lung diseases, children, and older adults ([EPA](#)).

Sources of NO_x include internal combustion (major), industrial combustion processes and natural emissions from soils (minor). Diesel engines tend to contribute more NO_x than gasoline engines, often making big-rig trucks and other large diesel engine vehicle the major NO_x sources in urban areas.

Sources of fine particulate matter include both direct formation in combustion plumes/exhaust, and indirect formation from gas-phase pollutants, both man-made and natural, oxidized in the atmosphere. Previous, detailed studies in Houston by [Texas researchers](#) showed that $\text{PM}_{2.5}$ mass tends to be spatially and temporally near uniform, with only slight increases during rush-hour and during spring time. Sources include both local and regional primary emissions, and secondary production. A large fraction of $\text{PM}_{2.5}$ is organic carbon (OC), and the associated ratio between organic and elemental carbon (soot, EC) shows that OC consist dominantly of secondary organic aerosol (SOA). Recent [NSF funded work](#) including Rice University scientists showed that most of the OC in $\text{PM}_{2.5}$ in east Houston stems from both primary and secondary fossil fuel emissions, including industrial emissions.

The traffic contribution to $\text{PM}_{2.5}$ is comparatively small. [UT and TCEQ scientists](#) estimated the traffic source to be around 20% ten years ago, and more recent work by [scientists at Texas A&M](#) showed a similar contribution around 23%.

2. Methodology

I used public access to State of Texas air quality monitoring data through TCEQ's website at https://www.tceq.texas.gov/cgi-bin/compliance/monops/select_year.pl

Air quality and precipitation data was downloaded from monitors circled in Figure 1 for all of 2020 so far, up to and including 8 April 2020. The data was reordered into a continuous timeline for analysis purposes. No other sub-selection was performed, no detailed analysis was carried out to determine individual pollutant sources, or the detailed influences of local weather on the data. The focus was on determining whether there are detectable and significant differences in ambient pollutant levels of nitrogen oxides (NO_x) and fine particulate matter ($\text{PM}_{2.5}$) during the three weeks prior to, compared to the three weeks after, the state and local social distancing orders. Data selection was limited to three to four weeks each to minimize possible biases in the comparison resulting from different period lengths and the effect of seasonal changes during spring time. Additional comparisons are of course possible, but were deferred to a later point in time.

3. Results

3.1 Nitrogen Oxides

Nitrogen oxides at most AQ monitors dropped after social distancing began, likely due to reduced traffic on Houston's roads, because car traffic is a known, dominant contributor to nitrogen oxide emissions in urban areas. Figure 2 shows an example timeline through March into April from the monitor at Bayland Park in Houston's western region. In this case, a drop in NO_x is obvious only for high hourly values during the morning and evening rush hours. Thus, average NO_x, driven by these values, was 22% lower after the social distancing order, but midpoint (median) NO_x levels were slightly higher post-order.

This analysis shows that any effects of reduced traffic should not be expected to be necessarily uniform. In the case of Bayland Park, a largely residential area, rush hour NO_x levels were significantly reduced, but median NO_x levels were not.

To have a closer look at traffic NO_x emissions, data from the Houston North Loop monitor are useful since the monitor is located close to a busy, major traffic axis, Interstate 610. Figure 3 shows the diurnal medians and pre-order variability of NO_x at CAMS 1052. At this site, significantly higher NO_x levels are recorded due to its nearness to I-610, and all post-order hourly medians are below the pre-order hourly medians, demonstrating a strong effect from NO_x emission reductions due to lower traffic densities. In this case median reductions were of order 50% between the periods.

At two other urban monitoring sites, CAMS 8 in Aldine, and CAMS 403 at Clinton Dr., reductions were similar to the North Loop site but with average levels 46% lower in Aldine, and 35% lower at Clinton Dr., as compared to the three weeks prior to the Governor's social distancing order.

The picture is different at the Deer Park site, where nearby industrial sources other than traffic may contribute to local NO_x abundances, and there are no major traffic axes close-by. Figure 4 shows diurnal nitrogen oxides levels at the Deer Park monitor. In this case, pre- and post-order levels were not significantly different. While NO_x averages were slightly larger pre-order, medians were slightly larger post-order. This suggests that outside of small reductions during rush-hour, no drop in NO_x levels occurred in an area where traffic emissions are not the dominant contributor to ambient NO_x pollution.

3.2 Fine particulate matter, PM_{2.5}

Not all the sites analyzed for NO_x also maintain PM_{2.5} measurements. Measurements at the Aldine, Clinton Dr., and Deer Park sites show that concentrations of PM_{2.5} did not drop after the social distancing order. At the Aldine site, PM_{2.5} levels slightly increased after 20 March, by a statistically significant amount of 14%. The respective increases at the industrial emissions impacted Clinton Dr. and Deer Park sites were 12% and 52%, both statistically significant. Figure 5 shows the pre- and post-order diurnal cycle of PM_{2.5} at Deer Park, showing that fine particulate matter levels increased at all hours.

4. Discussion

Despite widespread social distancing in the US, the effects of this on air quality are apparently not uniform. In Houston, maybe contrary to expectations, NO_x air quality has seen limited improvement, and fine particulate matter pollution arguably worsened. In places where car traffic emissions are the

dominant contributor to ambient nitrogen oxide concentrations, NO_x levels have declined significantly more since the governor’s social distancing order as compared to sites with less direct traffic impacts, exemplified by the CAMS 1052 next to Interstate 610 north of downtown. However, reductions have been somewhat smaller than expected considering the usually dominant NO_x source from traffic, suggesting that traffic may have been reduced less than in other urban areas such as Los Angeles or New York. Traffic counts in different parts of Houston should be compared between pre- and post-order periods, especially with respect to heavy duty vehicles which tend to contribute the bulk of NO_x emissions from their diesel engines. Meaning, while NO_x reductions may have come dominantly from reduced commuter traffic, this part of the traffic source does not dominate NO_x emissions, wherefore NO_x reductions are not expected to scale 1:1 with traffic reductions. In addition, the effects of weather conditions would need to be studied in more detail to evaluate possible effects on ambient NO_x levels from changing boundary layer depths and dispersion characteristics.

Somewhat surprisingly, fine particulate matter levels have increased, not decreased, since the social distancing measures were put in place. This cannot be straightforwardly explained by conditions of increased precipitation removing more PM prior to the social distancing orders, as both periods contained a similar amount of rainy days. Instead, this suggests that the sources of PM_{2.5} in Houston may be more active since the social distancing orders were enacted. The most likely candidates are long-range transport, local primary emissions, and local secondary production. Long-range transport at this time of year is typically related to biomass burning in Latin America, bringing smoke to the central US Gulf Coast, which contributes to local PM_{2.5}. This was recently evaluated by scientists at the [University of Houston](#), showing that during at least 10% of all days during April and May, smoke affects PM_{2.5} levels along the Texas Gulf Coast by 3-5 μg m⁻³. Since spring 2020 arrived early, this source was active early, demonstrably visible on [satellite atmospheric aerosol measurements](#). Impacts on the Gulf Coast were [forecasted](#) to be fluctuating, and of order 10 μg m⁻³.

PM_{2.5} level increases were higher at the Deer Park monitor than either at the Clinton Dr. or Aldine monitors. The non-uniform increase at first appears incompatible with contributions to PM_{2.5} from long-range smoke transport from Central American sources. However, this could be related to a combination of effects. If we assume, based on the lack of NO_x changes, that PM_{2.5} contributions from traffic to PM_{2.5} at the Deer Park site are negligible, then the observed median changes at that site may be assigned 100% to smoke from long-range transport. If, at the same time, we assume traffic reductions to have reduced PM_{2.5} levels at the other sites by 20-25%, based on the established traffic contributions to PM_{2.5} mass, this might explain lower net increases at those sites. These assumptions and associated calculations are summarized in Table 1.

Table 1: Rough PM_{2.5} mass balance assuming only two effects, a reduction from less car traffic (assumed to be 100%) plus an addition from long-range transport of smoke. Other effects were presumed to be negligible. All values in μg m⁻³. CAMS 35 used as baseline *.

Site CAMS#	Median pre-order PM2.5	Presumed traffic impact	Presumed smoke impact	Net post-order median PM2.5	Observed post-order median PM2.5
35	6.0	-0	+3.2	9.2*	9.2
8	8.3	-1.7 (-20%)	+3.2	9.8	9.7
403	8.7	-2.2 (-25%)	+3.2	9.7	9.2

This rough estimation shows that the forwarded explanation is reasonable, though would have to be investigated in more detail. Especially the assumptions of a 100% reduction of PM_{2.5} impacts from traffic at the Aldine and Clinton Drive sites, as well as the assumption of negligible other impacts, are somewhat questionable in this respect.

Some more insight into this will be gained via watching the smoke impact forecasts. While impacts were present over nearly the entire post-order period, they may be dropping from 20 April forward, which should then materialize in lower PM_{2.5} values at all monitors if the hypothesis of long-range transport smoke impacts is correct.

Insights into the assumption of negligible other impacts may be gained by looking at other pollutant change that may have occurred. For instance, slightly higher SO₂ values were measured at the Clinton Drive site (data not shown), which, however, also require careful data quality assurance.

Additional, pending analyses will look into isoprene as a marker of biogenic emissions that contribute to local SOA formation, and other hydrocarbons as marker for industrial emissions that may have contributed primary or secondary pollutants to PM_{2.5} formation.

5. Conclusions

A brief analysis of Houston NO_x and PM_{2.5} air quality across different monitors in Houston's west, north, east, and southeast, representing residential, traffic dominated, and mixed use areas, reveals that air quality may not have improved overall as much as preliminary analyses of recent satellite data depictions for urban areas such as Seattle, Los Angeles and New York indicated (the satellite NO₂ measurements over Texas occur in the early afternoon). While the published satellite data focused on NO₂ abundances, which are typically driven by car traffic emissions in urban areas, this analysis includes fine particulate matter data. It shows that PM_{2.5} levels have not improved similar to NO_x. On the contrary, the observed PM_{2.5} level increases since social distancing measures were enacted may point to changes in non-traffic sources counteracting traffic related reductions. Long-range transport of smoke from Central America may be a significant source present in much of April 2020, as indicated by satellite data and smoke transport analyses. This does not exclude other possible changes to industrial emissions or atmospheric chemistry as contributors to observed PM_{2.5} increases, but they might currently be less relevant. Data analyses thus continues.

Figures

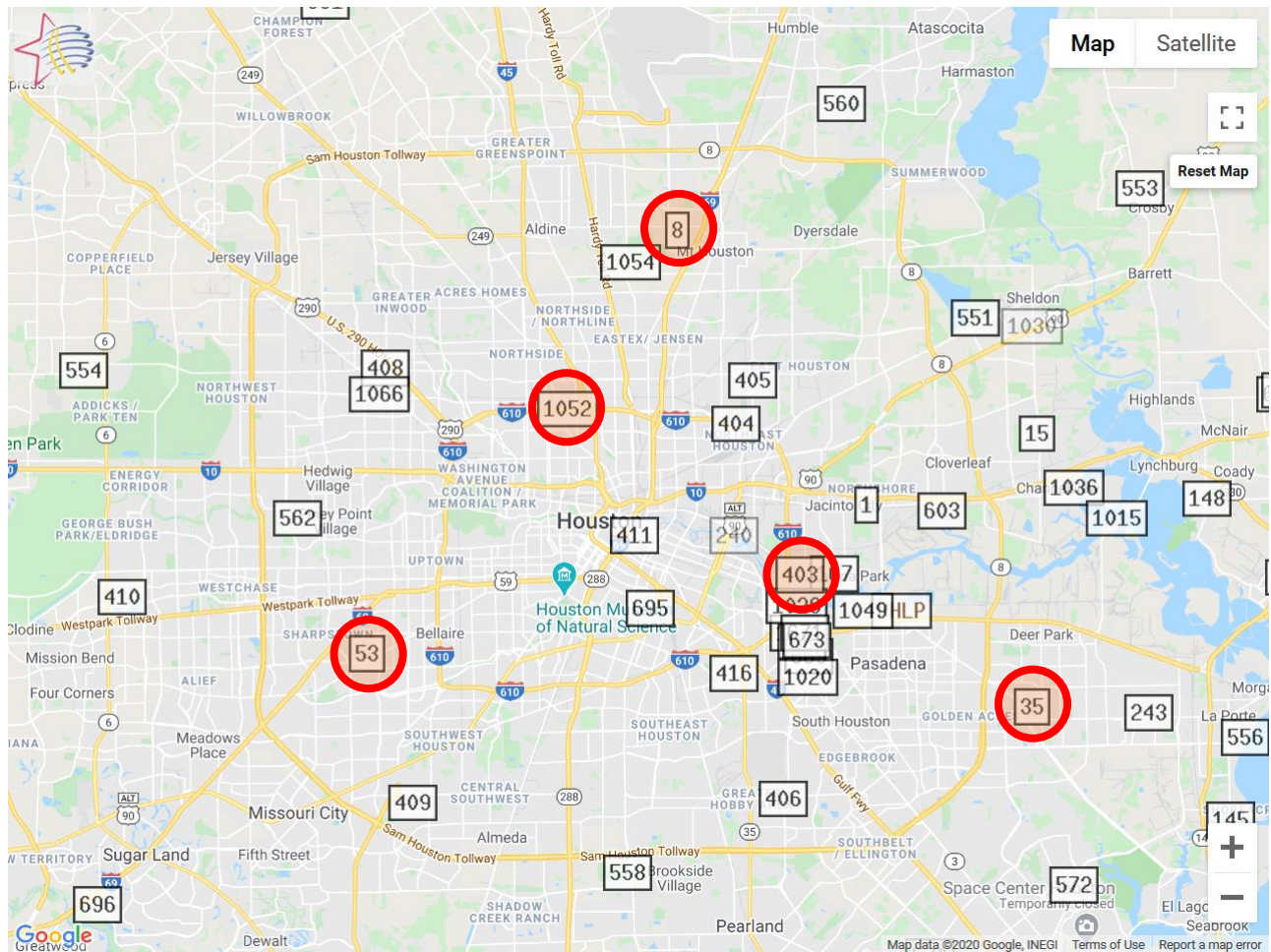


Figure 1: Houston air quality Continuous Air Monitoring Station (CAMS) map. The circled numbers identify the currently analyzed locations: CAMS 8 – Aldine, CAMS 1052 – Houston North Loop, CAMS 53 – Bayland Park, CAMS 403 –Clinton Dr., and CAMS 35 – Deer Park.

Bayland Park

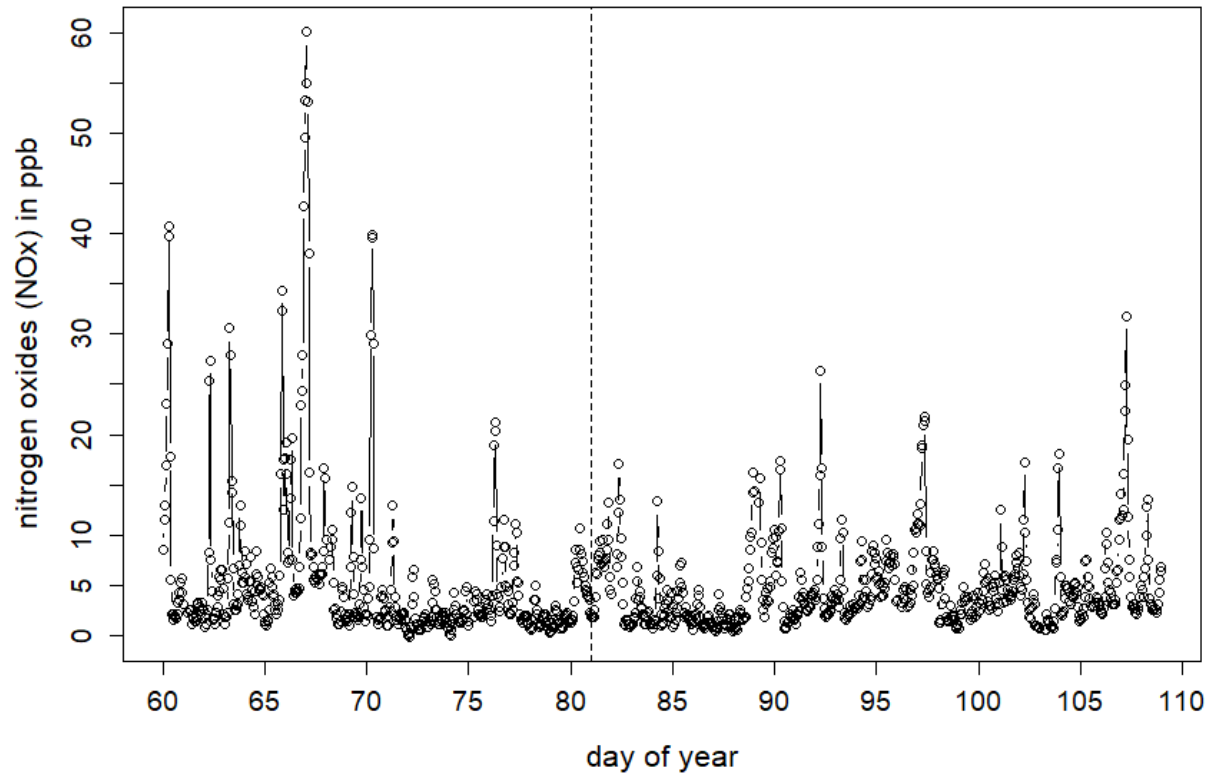


Figure 2: Hourly NO_x abundance at CAMS 53, a residential area, in March/April 2020. The vertical dashed line demarcates the state social distancing order in effect after Friday, March 20 (the last day in this data set is Friday, April 18, 2020).

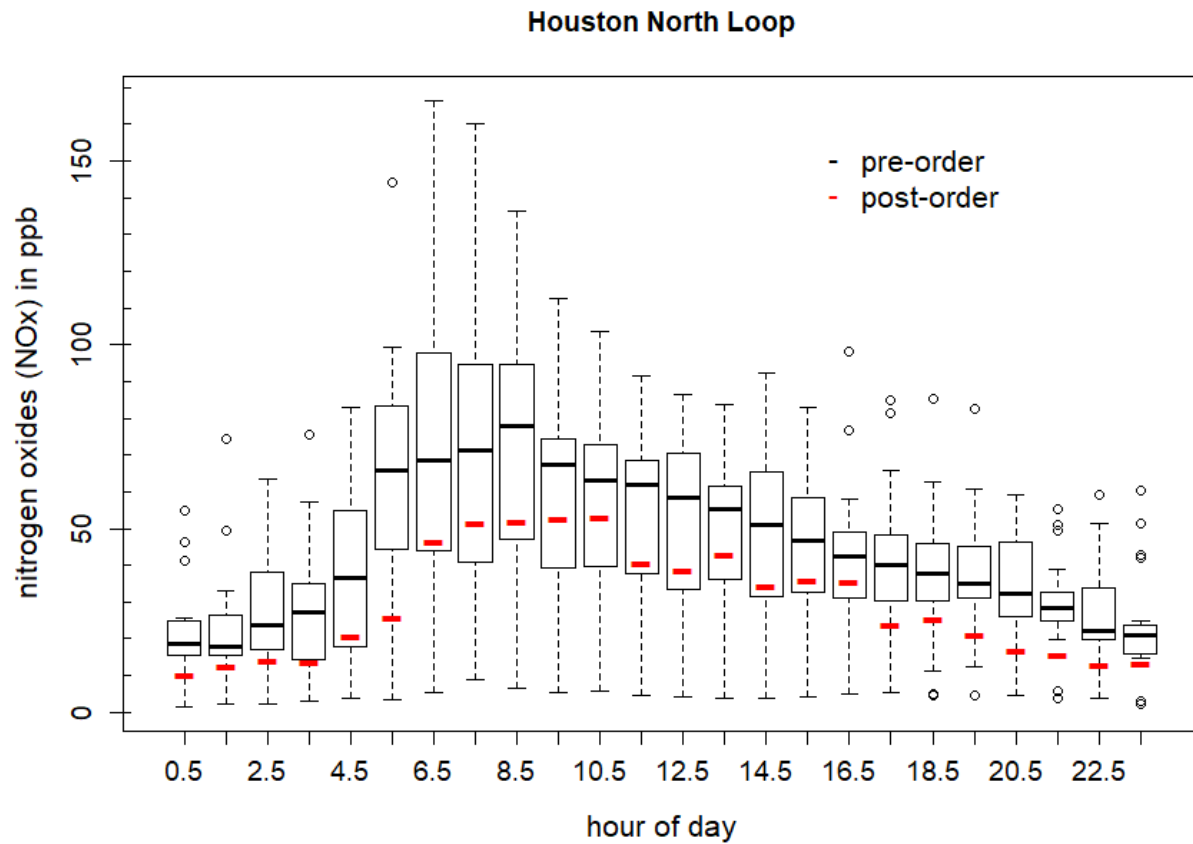


Figure 3: Boxplot of CAMS 1052, next to I-610, diurnal NO_x data prior to the 20 March cutoff compared to median (midpoint values) NO_x levels after the social distancing order (red bars). Horizontal bars are medians, boxes are interquartile ranges (the center 50% of the data), whiskers represent 95% confidence levels, and individual data points show extreme hourly values outside the central 90% of the data.

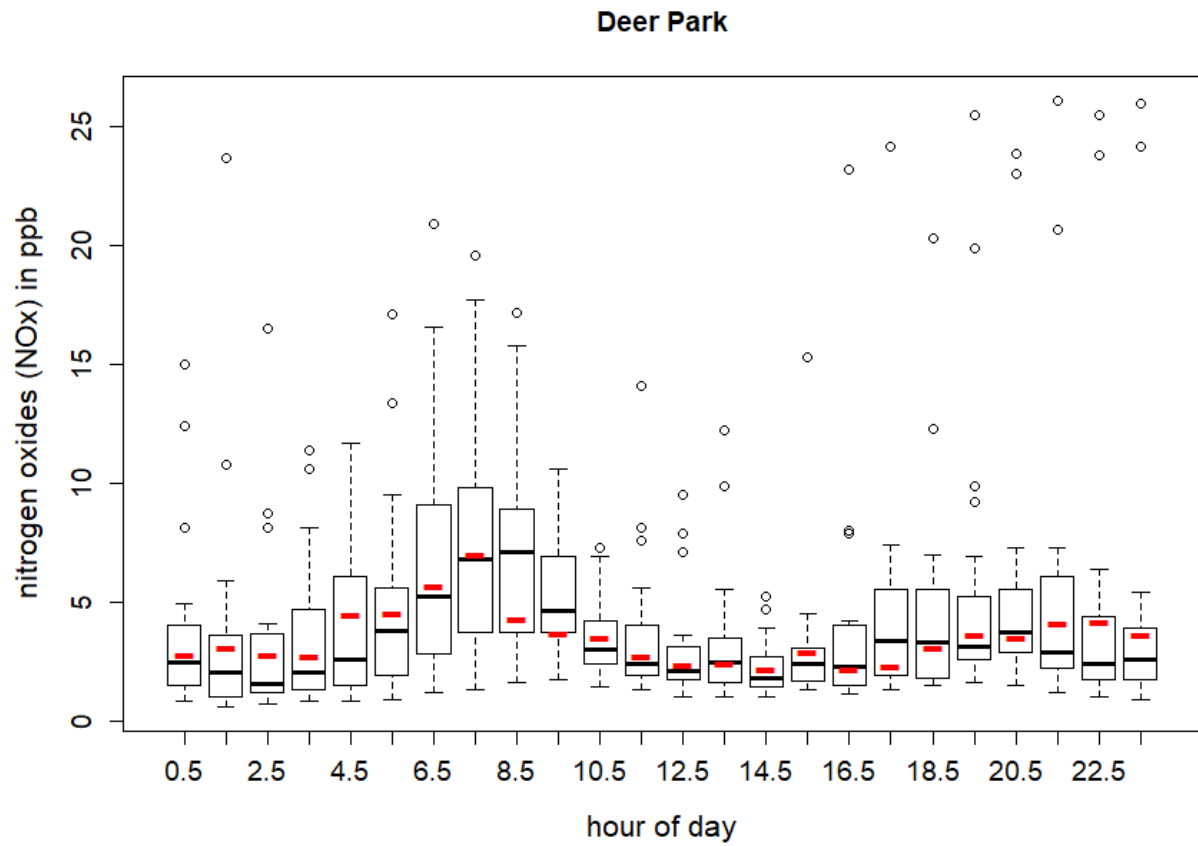


Figure 4: Same as Figure 3 but for the Deer Park site, CAMS 35, in southeast Harris County. Note low overall NOx levels at this site, which is located further away from major traffic axes.

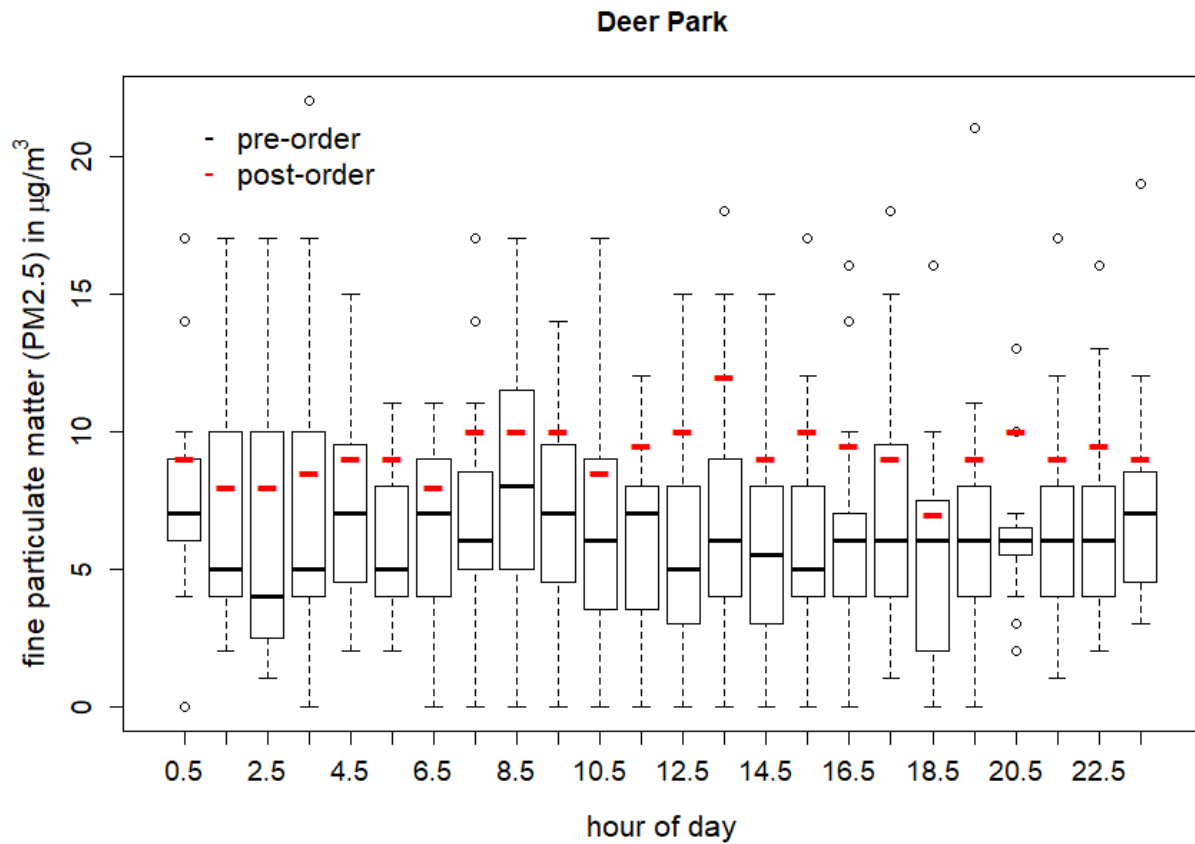


Figure 5: Deer Park PM_{2.5} diurnal changes pre- and post-social distancing orders effective 21 March 2020. Horizontal bars are medians (midpoint values), boxes are interquartile ranges (the center 50% of the data), whiskers represent 95% confidence levels, and individual data points show extreme hourly values outside the central 90% of the data. Red bars indicate hourly medians from 21 March to 18 April.