Analysis of First Quarter 2019 and 2020 Ambient Air Quality in Southeast Michigan

Stuart Batterman, University of Michigan, Ann Arbor, MI

April 22, 2020

Contents

1 Summary

A review of air quality monitoring data collected in Detroit and SE Michigan shows that levels of some pollutants have decreased in the last month: nitrogen oxides has shown moderate decreases (about 10 – 31% reduction depending on location) due to greatly reduced traffic from the corona virus pandemic and shutdown; other pollutants show marginal or modest decreases, e.g., particulate matter has shown smaller decreases (about 7 to 17% reduction). Both indoor and outdoor pollution is important, and steps to reduce indoor exposure can reduce exposure and are now especially important as we shelter in our homes.

2 Introduction

There has been considerable interest regarding recent changes in pollutant levels in SE Michigan that may have resulted from the quarantine and state-wide shut-down. The following analysis focuses on ambient (outdoor) air pollutants at the State of Michigan Department of Environment, Great Lakes and Energy (EGLE) monitoring sites in SE Michigan. EGLE has made the data available from these sites. The analysis uses hourly EGLE monitoring data at 8 sites plus hourly data from local airport weather stations, which was obtained from the National Climatic Data Center (part of NOAA).

The analysis focuses on four pollutants:

- Particulate matter under 2.5 microns in size or PM2.5. These are very small particles that are responsibility for a wide range of morbidity and mortality outcomes. PM2.5 is emitted by many sources, including combustion sources and industrial sources.
- Sulfur dioxide, or SO2, is a toxic gas released primarily by burning coal (especially without scrubbers), by flaring sulfur-containing gases at refineries and other sources, coke oven emissions, and some other industrial sources. Portions of SW Detroit do not meet the SO2 ambient standards. Individuals with asthma are especially sensitive to SO2.
- Nitrogen oxides, or NOx, is a toxic gas, comprised mostly of NO and NO2. It results from combustion, and most emissions occur from vehicles (cars, trucks, etc.) and industrial sources. Exposure to high concentrations of NOx is harmful, and this pollutant also forms ozone, another hazardous pollutant.
- Black carbon or BC is a portion of PM2.5. It mostly results from diesel exhaust, though some BC is emitted by wood fires and other sources. Diesel exhaust is a hazardous pollutant associated with cancers and other adverse health outcomes.

PM2.5, SO2 and NOx are described in the CAPHE fact sheets http://caphedetroit.sph.umich.edu/air-quality-health/pollutant-fact-sheets/. There are state-enforced national ambient standards for PM2.5, SO2 and NO2.

This analysis does not include ozone, or O3, which is an important pollutant for SE Michigan since the area does not meet the national ozone standard. However, O3 levels are very low until the temperature warms up (hopefully soon!). I will provide an update on O3 when we get into the O3 season (May – Sept).

2.1 How to show trends?

Air pollution levels vary considerably from place-to-place, hour-to-hour, day-to-day, month-to-month, and year-to-year. The major reasons for this variation are (1) changes in local meteorological conditions (such as wind speed, direction, rain/snow, sunlight intensity, inversions); (2) changes in local emissions (such as the reduction in vehicle traffic we have seen in the shut-down, but also changes in industrial emissions and heating-related emissions); and (3) changes in the levels of pollutants from distant sources or from atmospheric reactions that are transported by winds into the region (most significantly PM2.5 and ozone). For these reasons, we need to examine several weeks, months or seasons of data to obtain statistically meaningful results, and to consider multiple monitoring locations.

This analysis includes several aspects:

- Pollutant trends over the first quarter of 2020 - looking for changes starting about the time of Michigan's shut down orders (mid-March). Both daily data and weekly data are examined.
- Comparison of the March 15, 2020 to April 16, 2020 period with the same dates a year earlier.
- Comparison of peak and average levels. For PM2.5 and BC, the analysis focuses on the daily 24-hour average. For SO2 and NOx, the analysis focuses on the daily 1-hour maximum concentration, that is, the highest 1-hr measurement over the day at each monitoring site. The choice of peak or average follows the form of the US National Ambient Air Quality Standards.

Some caveats: The pollution data appear good, but EGLE and US EPA have not completed their final quality assurance checks, so the data is preliminary. The analysis does not include SO2 data from four monitoring sites operated by Marathon around the refinery – this data will be available later in the year from EPA. Different sites monitor different pollutants. The analysis is descriptive in nature and preliminary for these reasons. More data will help confirm conclusions.

2.2 What are the results?

A fairly complex pattern of changes is summarized in the plots below, which contrast levels in March/April of 2019 (blue diamond) with levels in Feb/March of 2020 (green diamond) and March/April 2020 (red diamond).

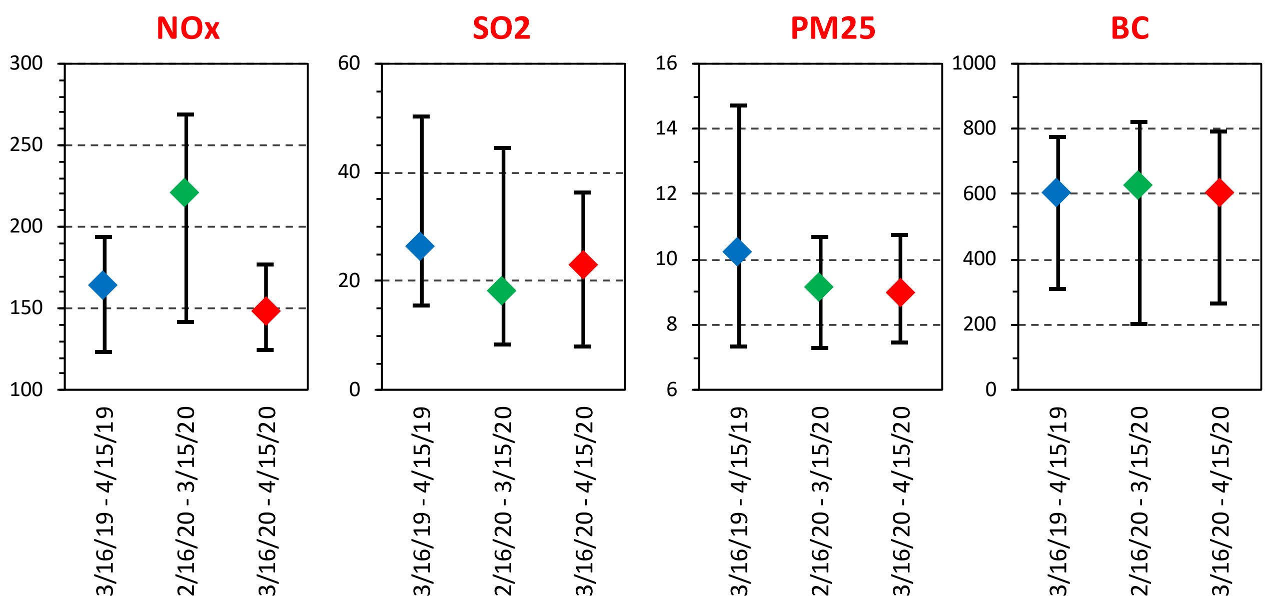


Figure 1. Pollutant concentrations of NOx (ppb) and SO2 (ppb) as daily 1-hr maximum, and PM2.5 (µg/m3) and BC (ng/m3) for three time periods. Diamond is average across monitoring sites; error bars are minimum and maximum across sites.

In brief, we see;

- PM2.5 shows an average reduction of 7-11% from last year and a negligible change (2% lower) from last month. Some sites show greater reductions. High PM2.5 levels or "peaks" occurred less frequently in the past month. Some of the high levels in SW Detroit have been associated with construction and industrial activities; this work has slowed or stopped which probably explains the changes. A large portion of PM2.5 arises from regional sources, particularly coal-fired power plants in Michigan and neighboring states that are baseload facilities that essentially run full time. The lack of change in PM2.5 levels suggests only small changes in emissions from these other facilities.

Southeast Michigan meets the ambient PM2.5 standard, but exposures below the standard remain of concern. We estimated (see CAPHE materials) that significant health effects are associated with PM2.5 exposure at current levels.

- NOx shows significant reductions, averaging about 10% down from last year and 39% down from last month. Some sites show greater reductions. This is likely due to the large reduction of car traffic. In Feb/March 2020 (e.g., 2/24/20 and 3/3/20) NOx levels were unusually high due to a cold snap, low winds, and inversion conditions.

  SE Michigan meets the ambient NO2 standard. However, NO2 and NOx are important as they form ozone, which is a problem in the area.

- SO2 shows a small reduction (11%) from last year, but a slight increase (up 25%) from last month. However, monitoring data from the last month is well below the standard. Generally, peak levels have decreased only slightly, but the frequency of peaks appears to have decreased.

  Portions of SE Michigan exceed the SO2 standard (which is based on 3 years of data). The most recent data do not show levels above the standard, but exposure below the standard remains of concern, particularly to individuals with asthma.

- BC shows only small decrease (3 to 4%) from levels last year or last month. This suggests a modest change in diesel exhaust emissions.

  There is no enforceable standard for BC.

Overall, depending on the pollutant and monitoring site, concentrations in Detroit and SE Michigan have shown small (PM2.5) to moderate (NOx) decreases since the shut-down. The pages following provide a lot more detail including spatial and temporal trends.

2.3 Concerns for Detroit and indoor pollution

Despite lower levels of some pollutants, many Detroit residences remain susceptible to air pollutants. This occurs for many reasons: the location of their homes near freeways, industry or other emission sources; preexisting health conditions like obesity, diabetes, asthma, etc.; and other personal, economic, social and health service factors, like a good diet and access to medical care. A recent analysis has linked air pollution levels to higher risks of corona virus infections: https://www.hsph.harvard.edu/news/hsph-in-the-news/air-pollution-linked-with-higher-covid-19-death-rates/. This analysis does not demonstrate a cause-effect relationship. In any event, minimizing air pollution exposure has definite health benefits.

As people shelter in home, it is important to recognize that air pollutant exposures occur both indoors and outdoors, and these days, indoor exposure is particularly important now as we remain inside. Often, pollutant levels are higher indoors than outdoors. This is due to emission sources such as cigarette smoking, gas stoves and cooking (particularly frying foods), use of deodorizers and scents, use of pesticides and cleaners (including bleach, ammonia and other chemicals to disinfect surfaces), home renovation activities (including painting, use of solvents and caulks, lead and asbestos), and many other sources. There has been an increase in emergency calls from inappropriate cleaning and disinfection practices (like mixing different cleaning products together).

You can do many things to lower indoor pollutant levels. For example:

- Use appropriate ventilation when cooking and cleaning (with exhaust fans); and keep people and children out of rooms when cleaning
- Do not use deodorizers and fragrances (especially plug in “air fresheners”, mothballs).
- Do not smoke indoors or where smoke might enter your house.
- Do not burn candles or wood (most stoves and all fireplaces still produce indoor pollution and contaminate outdoor air)
- Control any activity that might generate dust or fumes, including home renovations and hobbies
- Use a high quality furnace filter or stand-alone air filter; see http://caphedetroit.sph.umich.edu/project/indoor-air-filters/
- Repair water leaks and waste damage promptly to avoid mold issues
- Do not mix cleaning or disinfectants chemicals together, and ventilate areas being cleaned.

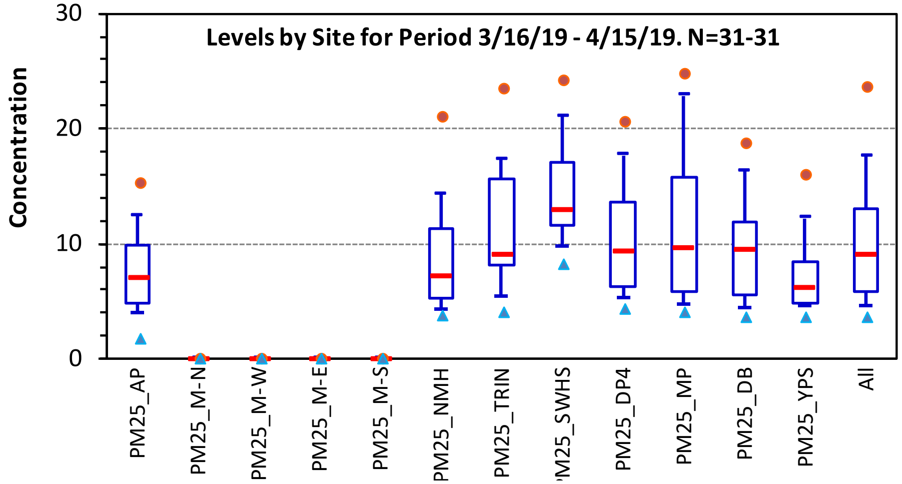
The remainder of this report goes through the four pollutants in detail.

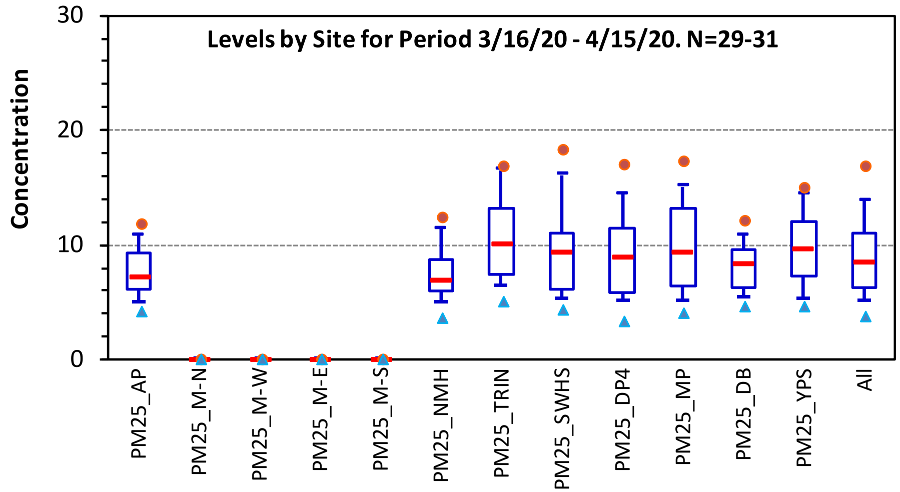
3 PM2.5

The following table and plots show daily $PM_{2.5}$ levels from mid-March to mid-April in 2019 and 2020. The largest change was at the SH High School monitor, which reflected a decrease in nearby site activities likely associated with the Gordie Howe International Bridge (GHIB) construction. Excluding this site, overall, PM2.5 levels decreased by 6.5%; excluding Ypsilanti as well as the Southeast High School (SWHS) sites, gives a 11.5% decrease.

Figure 2. Left: Table showing statistics of daily data showing concentrations (µg/m^3) including mean and standard deviation, as well as number of observations (NOBs) and percentage change. Right: Figures showing levels at each site, including 2nd, 10th, 25th, median, 75th, 90th, and 98th percentile concentrations.

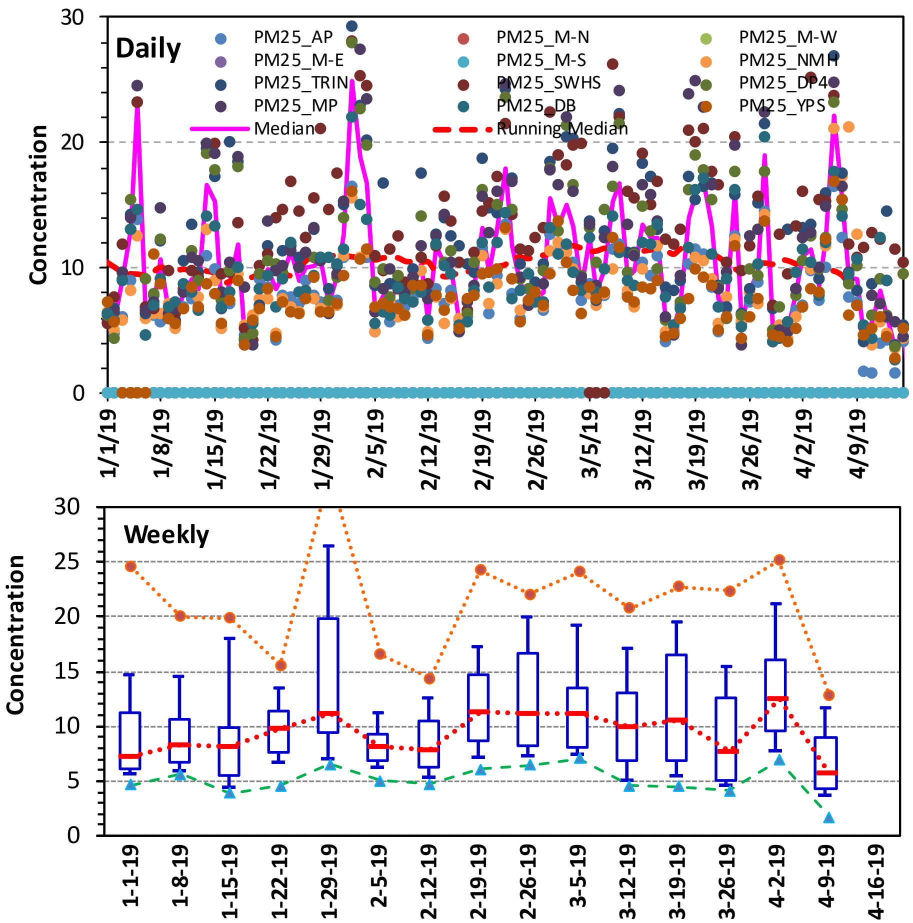
	3/16/19 - 4/15/19			3/16/20 - 4/15/20			Change
	Mean	SD	NOBs	Mean	SD	NOBs	(%)
PM25_AP	7.4	3.7	31	7.7	2.2	31	3.6
PM25_M-N			0			0	
PM25_M-W			0			0	
PM25_M-E			0			0	
PM25_M-S			0			0	
PM25_NMH	8.7	4.8	31	7.5	2.5	31	-15.8
PM25_TRIN	11.5	5.5	31	10.8	3.8	31	-6.9
PM25_SWHS	14.7	4.7	31	9.5	4.0	31	-42.8
PM25_DP4	10.4	5.0	31	9.0	3.9	31	-14.6
PM25_MP	11.6	6.8	31	9.8	4.1	31	-17.1
PM25_DB	9.7	4.5	31	8.1	2.2	31	-18.3
PM25_YPS	7.4	3.5	31	9.7	3.3	29	27.4
All	10.2	4.8	21	9.0	3.3	21	-10.6
All but SWHS	9.6	4.8	20	8.9	3.2	20	-6.5





As shown in the trend plots below, both 2019 and 2020 data show considerable fluctuation and little indication of trends at most sites except for the highest concentrations; no $PM_{2.5}$ levels over 20 µg/m^3 were observed in the last month of 2020.

Figure 3. Left: $PM_{2.5}$ trend plots for first quarter of 2019 levels showing levels at each site as well as median (purple line) and 2-week running median (dashed red line); Bottom shows weekly summary showing 2nd, 10th, 25th, median, 75th, 90th, and 98th percentile concentrations of the daily data over the week (starting with the date indicated. Right: Trend plots for first quarter of 2020.



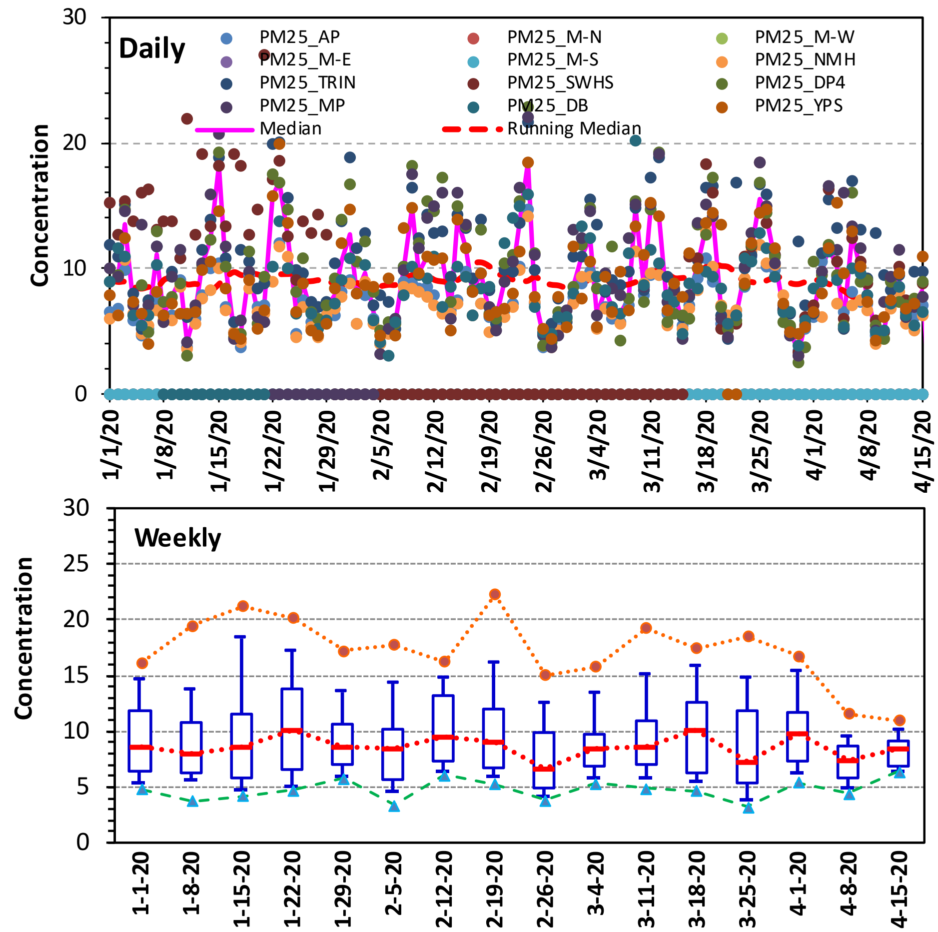
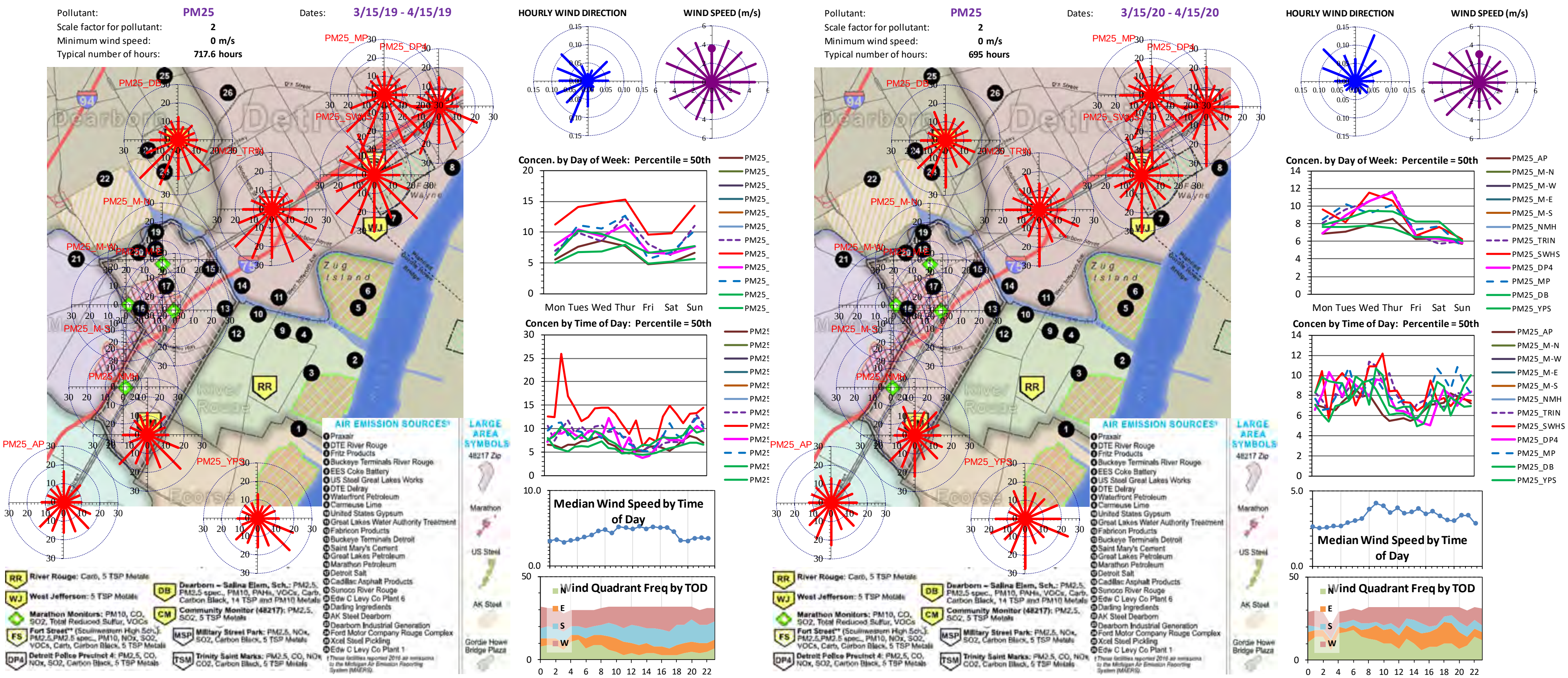


Figure 4. Pollution roses, time of day, and day of week plots. The most noticeable change is the decrease in weekend levels of $PM_{2.5}$ in 2020, and the lower $PM_{2.5}$ levels at SWHS noted above. During the March 15 – April 15 period, winds were slightly stronger in 2019, averaging 4.2 ± 2.1 m/s, as compared to 3.7 ± 2.2 m/s in 2020; there was also a cold spell at the beginning of April 2020 for about 5 days which resulted in nocturnal inversions that affect NOx levels, shown later..



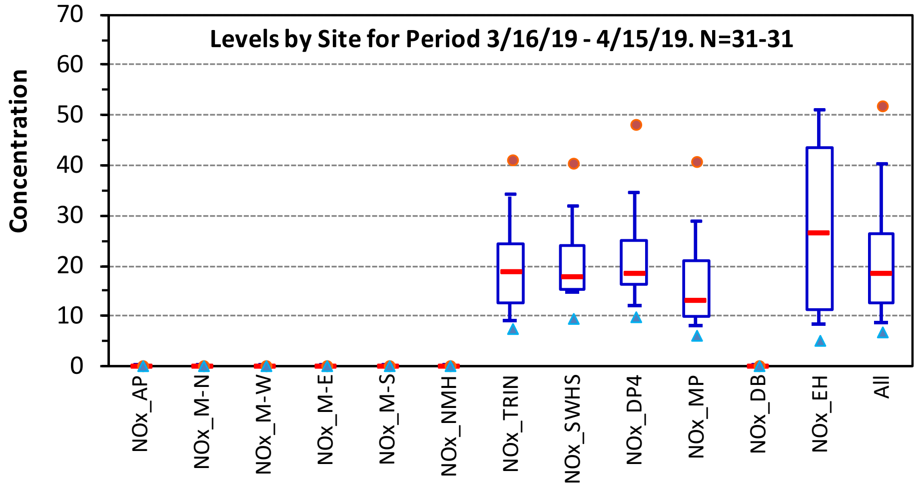
4 NOx – 24-hour averages

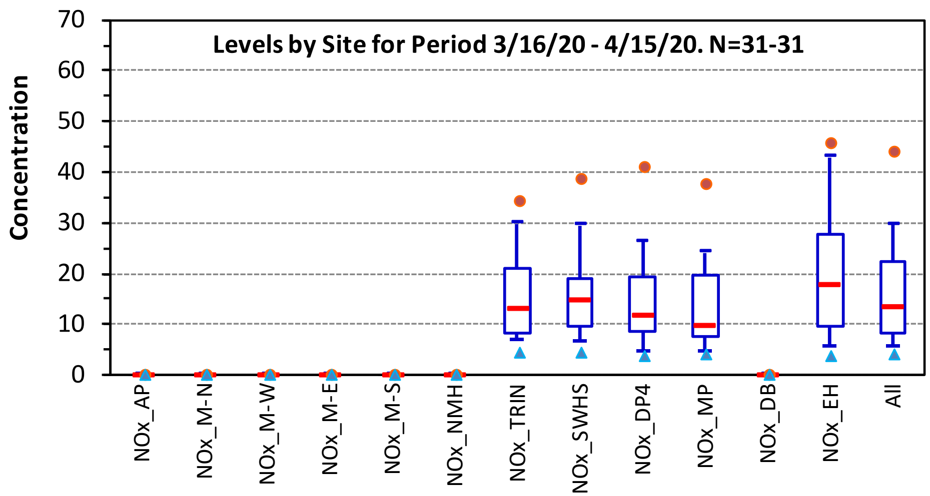
This section provides an analysis of 24-hr averages for NOx, which is primarily relevant for NOx's role in ozone formation. The following section provides an analysis using daily 1-hr maximum of NOx, which is most relevant to direct health impacts from this pollutant.

The following table and plots show daily 24-hr NO_x levels from mid-March to mid-April in 2019 and 2020. Decreases in the daily mean ranged from 21 to 39%; the largest decrease occurred at the Eliza Howell (EH) monitor, a near-road site.

Figure 5. Left: Table showing statistics of daily data showing concentrations (ppb) including mean and standard deviation, as well as number of observations (NOBs) and percentage change. EH 98th percentile = 74 ppb. Right: Figures showing levels at each site, including 2nd, 10th, 25th, median, 75th, 90th, and 98th percentile concentrations.

	3/16/19 - 4/15/19			3/16/20 - 4/15/20			Change
	Mean	SD	NOBs	Mean	SD	NOBs	(%)
NOx_AP			0			0	
NOx_M-N			0			0	
NOx_M-W			0			0	
NOx_M-E			0			0	
NOx_M-S			0			0	
NOx_NMH			0			0	
NOx_TRIN	19.7	9.9	31	15.5	9.2	31	-23.7
NOx_SWHS	20.7	8.2	31	16.1	9.5	31	-24.9
NOx_DP4	21.6	9.9	31	15.2	10.1	31	-35.0
NOx_MP	16.8	9.7	31	13.6	9.4	31	-21.3
NOx_DB			0			0	
NOx_EH	30.0	20.2	31	20.2	13.2	31	-39.0
All	21.8	11.6	13	16.1	10.3	13	-28.8
All but SWHS	22.0	12.2	11	16.1	10.4	11	-29.6





As shown in the trend plots below, both 2019 and 2020 data show considerable fluctuation, but the last month shows a downward trend with the exception of the week of April 2, 2020, which was due to several factors, primarily high morning levels of NO_x due to nocturnal inversions, low wind speeds, and temperatures that fell to freezing.

Figure 6. Left: NO_X trend plots for first quarter of 2019 levels showing levels at each site as well as median (purple line) and 2-week running median (dashed red line); Bottom shows weekly summary showing 2nd, 10th, 25th, median, 75th, 90th, and 98th percentile concentrations of the daily data over the week (starting with the date indicated. Right: Trend plots for first quarter of 2020.

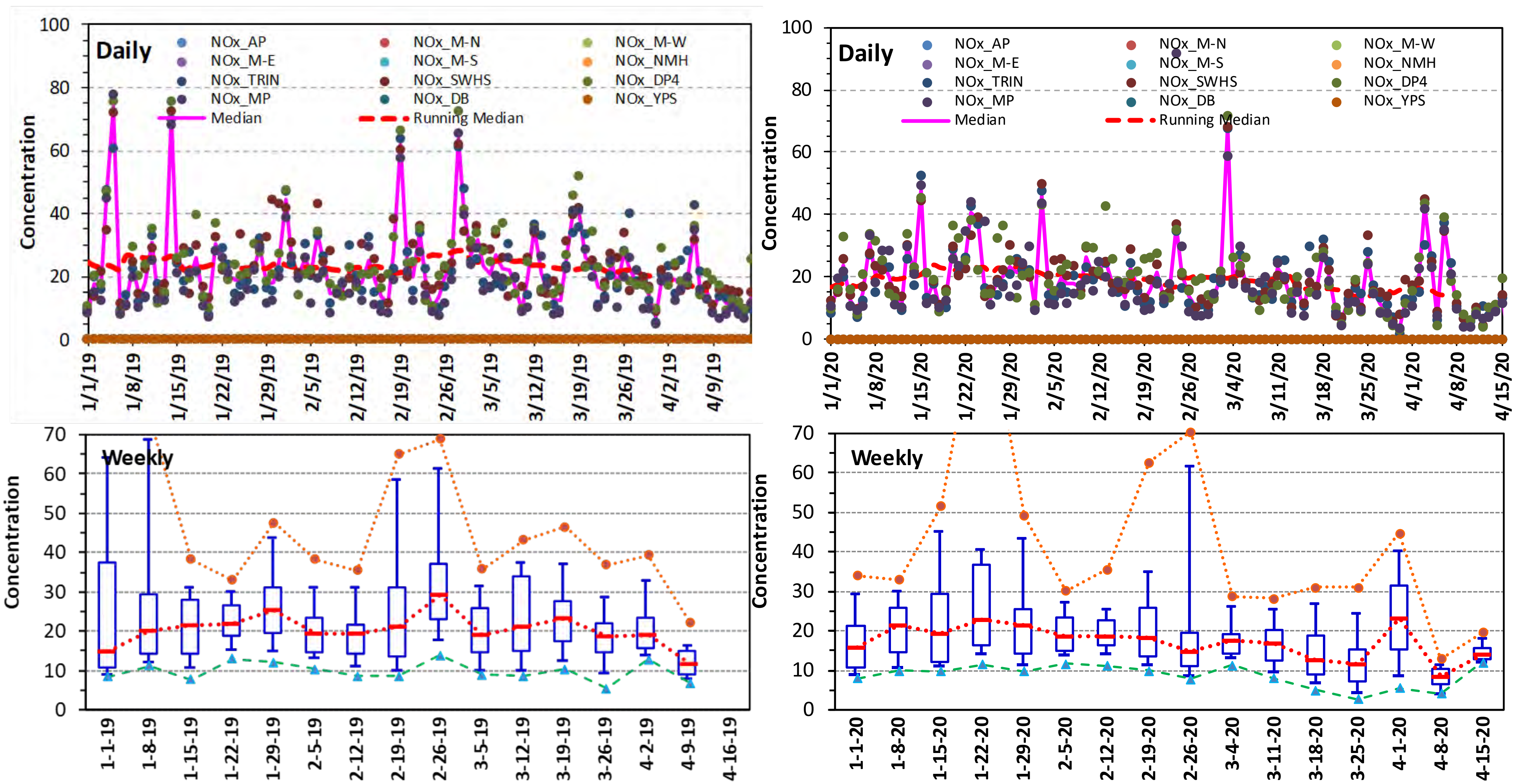
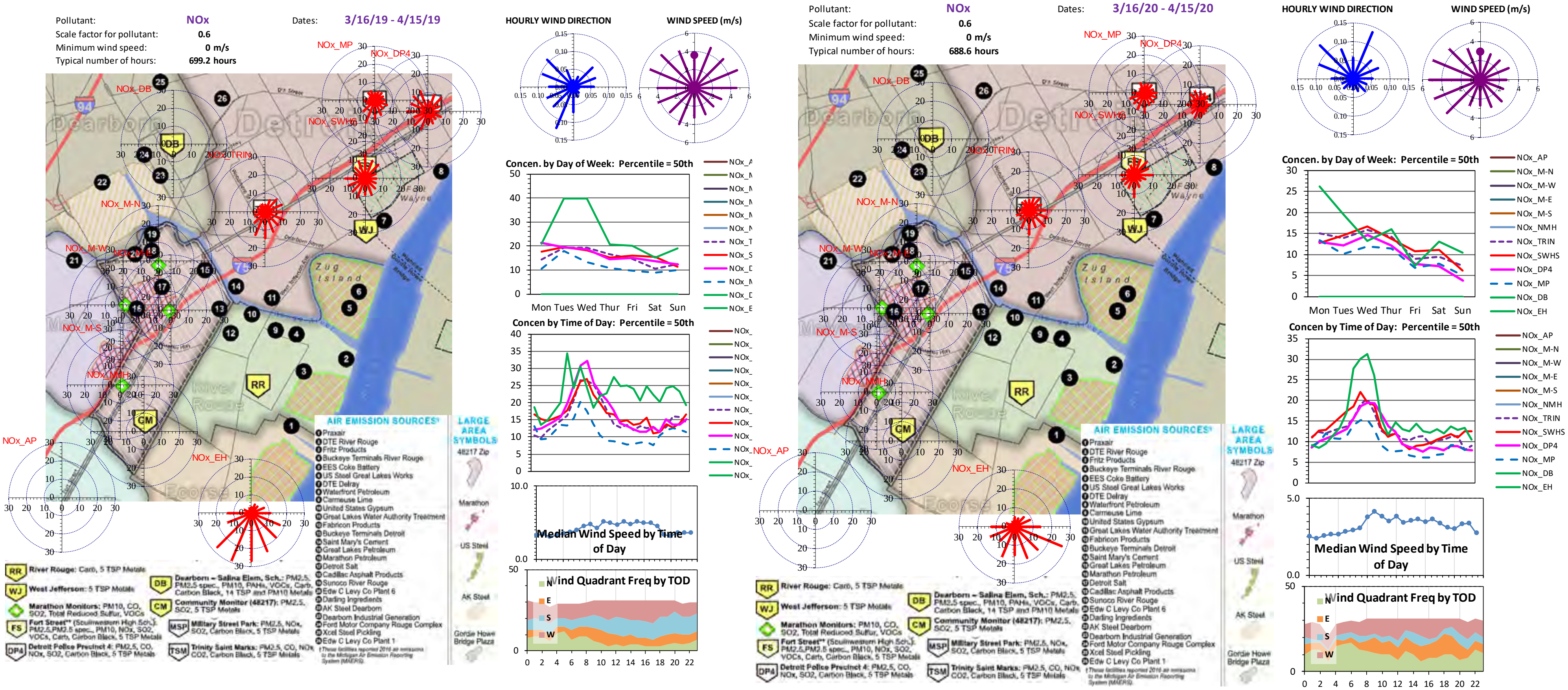


Figure 7. Pollution roses, time of day, and day of week plots. The most noticeable change is the decrease in weekend levels of NO_X at the end of the first quarter in 2020, with the exception of one week due to nocturnal inversion noted earlier.



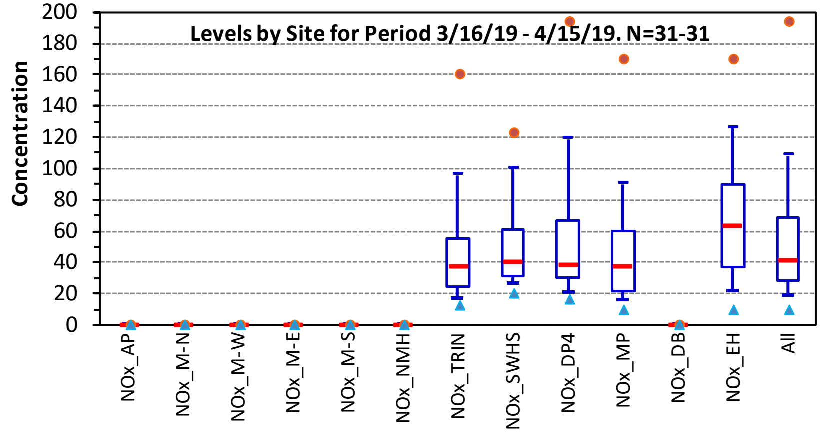
5 NOx – daily 1-hour maximum

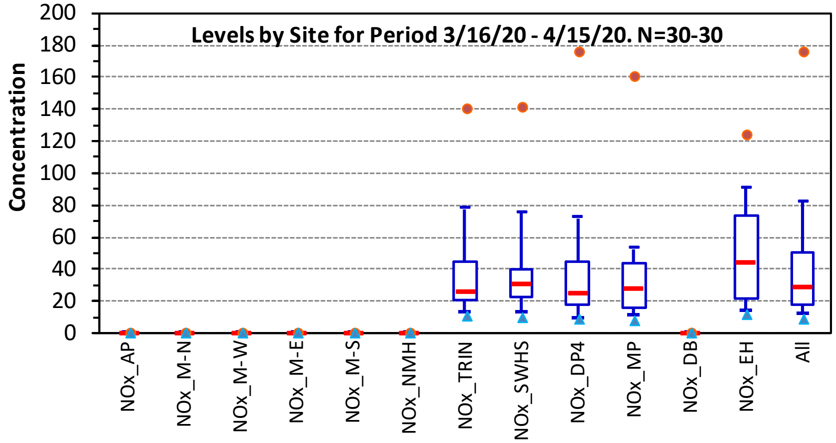
The following table and plots show daily 1-hr maximum NO_x levels from mid-March to mid-April in 2019 and 2020. The 1-hr maximum concentration relates to the form of the NAAQS, which is 100 ppb. Decreases in the maximum 1-hr maximum averaged 11% across the sites; the average 1-hr maximum decreased by 30%; the largest decrease occurred at the Eliza Howell (EH) monitor, a near-road site.

Figure 8. Left top: Table showing mean and standard deviation of daily 1-hr maximum by site, number of observations (NOBs) and percentage change. Left bottom: Table showing daily 1-hr maximum and 90th percentile 1-hr maximum at each site, number of observations (NOBs) and percentage change. Right: Daily 1-hr maximum levels at each site, including 2nd, 10th, 25th, median, 75th and 90th percentiles and maximum concentrations.

	3/16/19 - 4/15/19			3/16/20 - 4/15/20			Change
	Mean	SD	NOBs	Mean	SD	NOBs	(%)
NOx_AP			0			0	
NOx_M-N			0			0	
NOx_M-W			0			0	
NOx_M-E			0			0	
NOx_M-S			0			0	
NOx_NMH			0			0	
NOx_TRIN	50	38	31	38	31	30	-27
NOx_SWHS	50	28	31	40	32	30	-23
NOx_DP4	55	42	31	40	42	30	-32
NOx_MP	47	37	31	35	33	30	-29
NOx_DB			0			0	
NOx_EH	70	45	31	50	31	30	-35
All	55	38	13	41	34	13	-29
All but SWHS	55	40	11	41	34	11	-30

	3/16/19 - 4/15/19			3/16/20 - 4/15/20			Change (%)	
	Max	90th	NOBs	Max	90th	NOBs	Max	90th
NOx_AP			0			0		
NOx_M-N			0			0		
NOx_M-W			0			0		
NOx_M-E			0			0		
NOx_M-S			0			0		
NOx_NMH			0			0		
NOx_TRIN	161	96	31	141	77	30	-13	-21
NOx_SWHS	123	100	31	141	75	30	14	-28
NOx_DP4	194	119	31	177	72	30	-10	-49
NOx_MP	171	90	31	161	53	30	-6	-52
NOx_DB			0			0		
NOx_EH	170	126	31	124	91	30	-31	-32
All	164	106	13	149	74	13	-10	-36
All but SWHS	172	107	11	150	73	11	-14	-38





As shown in the trend plots below, both 2019 and 2020 data show considerable fluctuation, but the last month shows a downward trend with the exception of the week of April 2, 2020, which was due to several factors, primarily high morning levels of NO_x due to nocturnal inversions, low wind speeds, and temperatures that fell to freezing.

Figure 9. Left: NO_X trend plots for first quarter of 2019 levels showing levels at each site as well as median (purple line) and 2-week running median (dashed red line); Bottom shows weekly summary showing 2nd, 10th, 25th, median, 75th, 90th, and 98th percentile concentrations of the daily data over the week (starting with the date indicated. Right: Trend plots for first quarter of 2020.

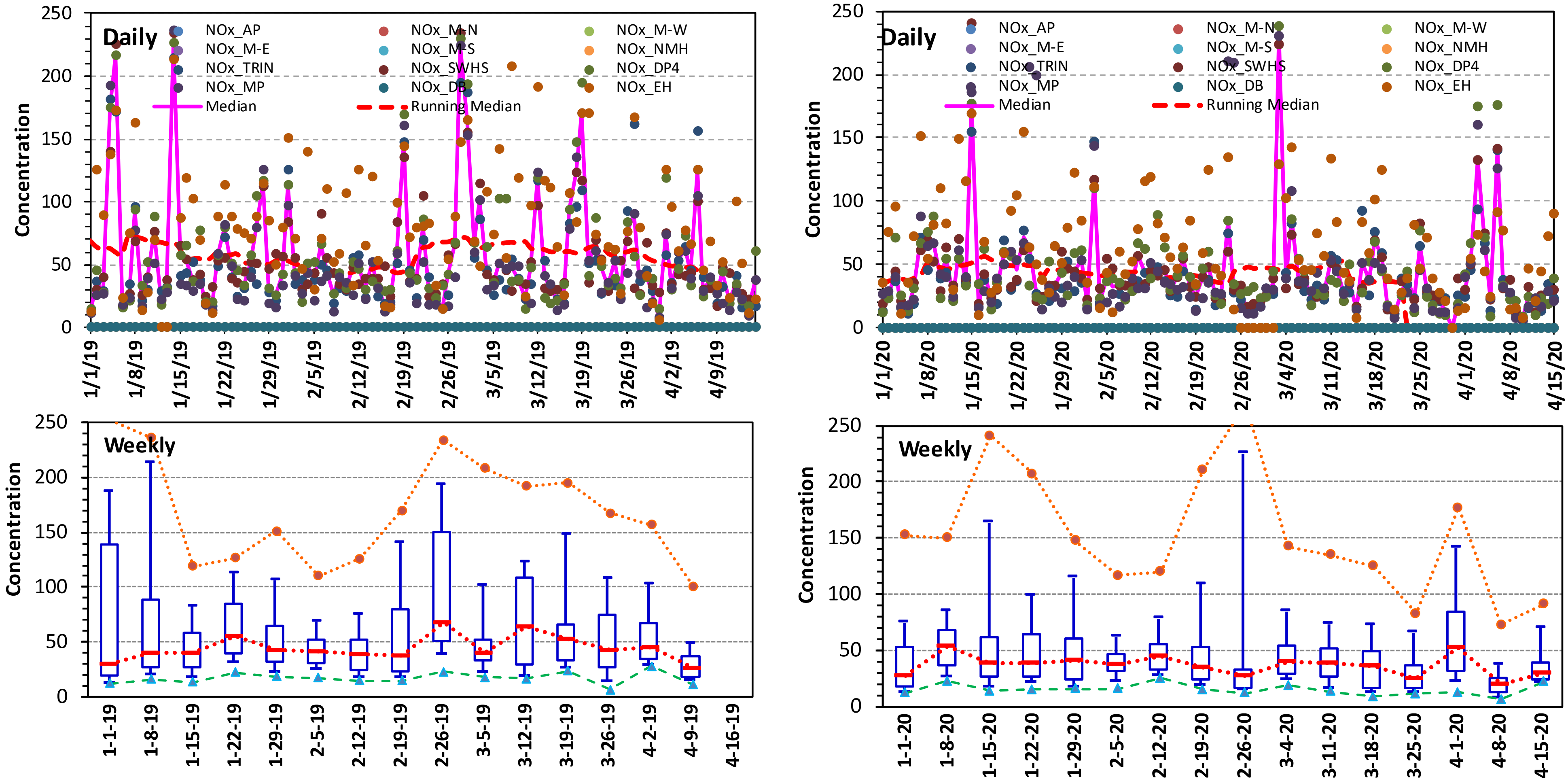
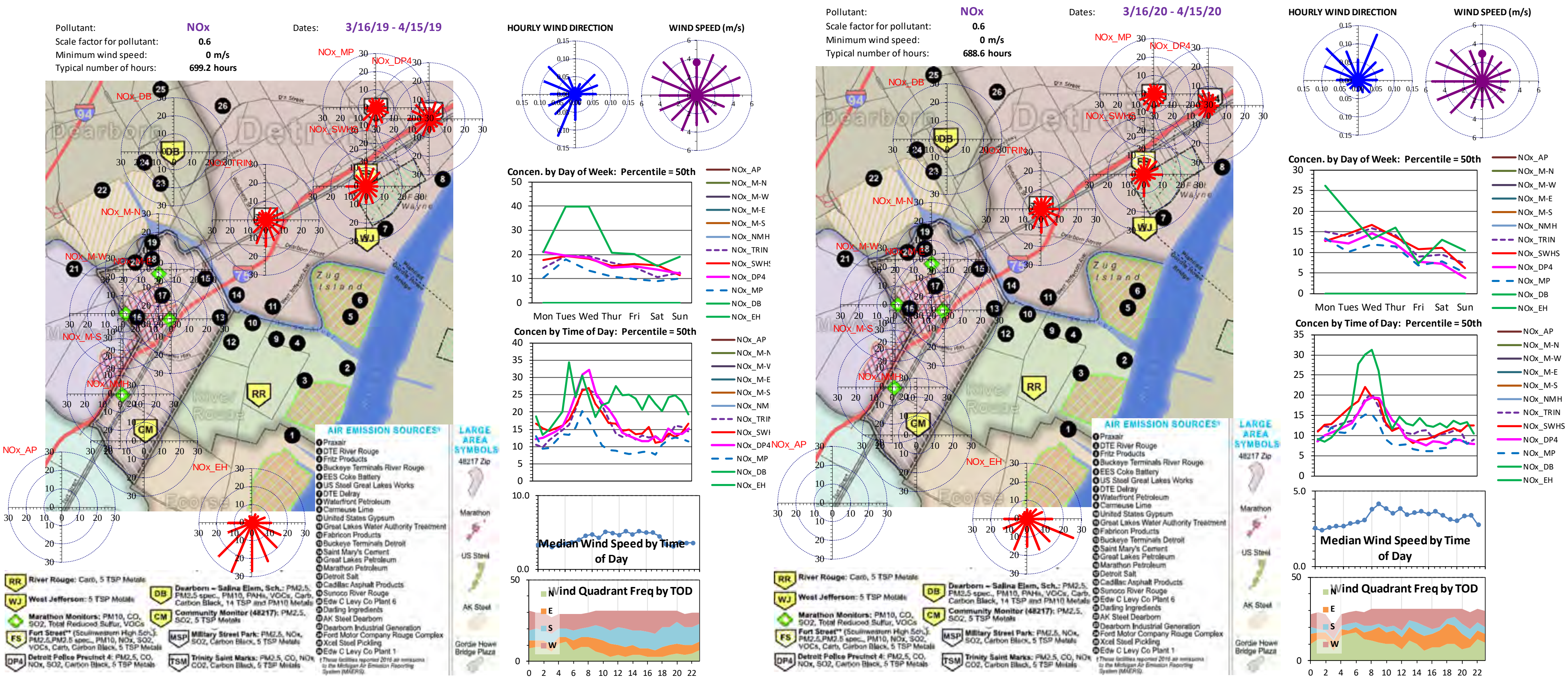


Figure 10. Pollution roses, time of day, and day of week plots. The most noticeable change is the decrease in weekend levels of NO_X at the end of the first quarter in 2020, with the exception of one week due to nocturnal inversion noted earlier.



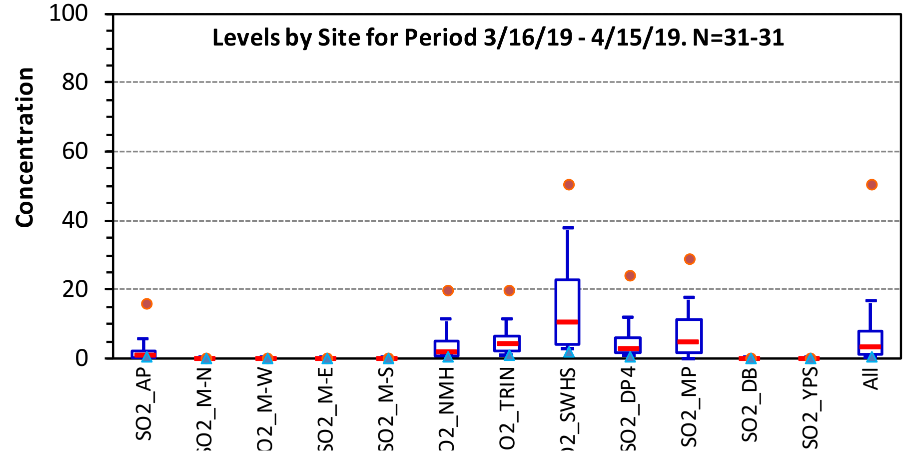
6 SO2

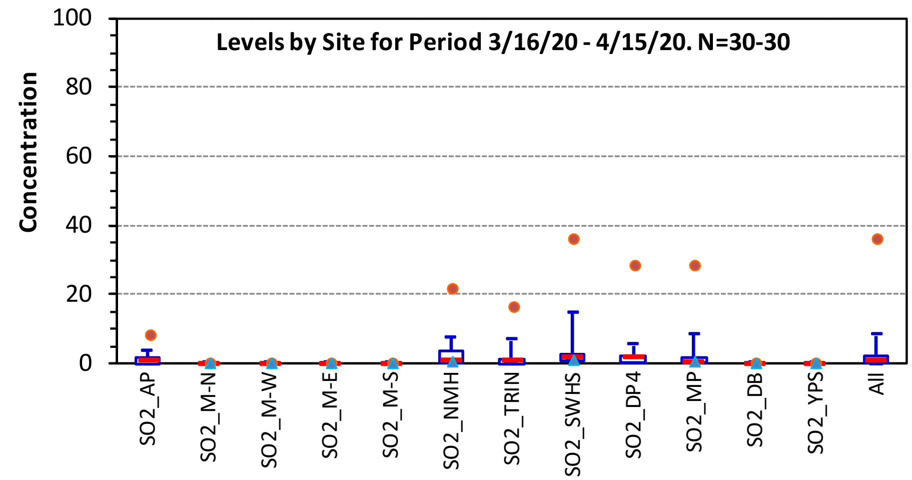
The following table and plots show daily 1-hr maximum SO_2 levels from mid-March to mid-April in 2019 and 2020. The 1-hr maximum is the most relevant level for health effects; this decreased by an average of 13% across all sites and by 32% at the most impacted site, SW High School. Decreases for other statistics were much larger, e.g., averages decreased by 67%. The 1-hr data is highly variable, but statistics and trends (below) show substantial decreases.

Figure 11. Left top: Table showing mean and standard deviation of daily 1-hr maximum by site, number of observations (NOBs) and percentage change. Left bottom: Table showing daily 1-hr maximum and 90th percentile 1-hr maximum at each site, number of observations (NOBs) and percentage change. Right: Daily 1-hr maximum levels at each site, including 2nd, 10th, 25th, median, 75th and 90th percentiles and maximum concentrations.

	3/16/19 - 4/15/19			3/16/20 - 4/15/20			Change (%)
	Mean	SD	NOBs	Mean	SD	NOBs	Mean
SO2_AP	2.5	3.7	31	1.4	2.1	30	-61.0
SO2_M-N			0			0	
SO2_M-W			0			0	
SO2_M-E			0			0	
SO2_M-S			0			0	
SO2_NMH	4.0	4.9	31	2.9	4.7	30	-32.3
SO2_TRIN	5.2	4.4	31	2.2	4.2	30	-82.2
SO2_SWHS	15.2	14.4	31	5.5	8.9	30	-93.9
SO2_DP4	5.1	5.5	31	2.9	5.7	30	-54.7
SO2_MP	7.4	8.0	31	3.2	6.5	30	-79.2
SO2_DB			0			0	
SO2_YPS			0			0	
All	6.6	6.8	16	3.0	5.4	15	-67.2
All but SWHS	5.1	5.6	14	2.6	4.8	14	-62.7

	3/16/19 - 4/15/19			3/16/20 - 4/15/20			Change (%)	
	Max	90th	NOBs	Max	90th	NOBs	Max	90th
SO2_AP	15.5	5.4	31	8.0	3.6	30	-64.3	-41.7
SO2_M-N			0			0		
SO2_M-W			0			0		
SO2_M-E			0			0		
SO2_M-S			0			0		
SO2_NMH	19.8	11.1	31	21.8	7.4	30	9.3	-39.9
SO2_TRIN	19.7	11.2	31	16.4	6.7	30	-18.1	-50.1
SO2_SWHS	50.3	37.3	31	36.2	14.7	30	-32.4	-87.0
SO2_DP4	24.0	11.8	31	28.4	5.3	30	16.7	-76.3
SO2_MP	28.8	17.1	31	28.1	8.4	30	-2.3	-68.3
SO2_DB			0			0		
SO2_YPS			0			0		
All	26.3	15.6	16	23.1	7.7	15	-12.9	-68.4
All but SWHS	22.3	12.0	14	21.0	6.5	14	-11.9	-57.4





As shown in the trend plots below, both 2019 and 2020 data show considerable fluctuation, but the last month shows a downward trend.   These plots use a logarithmic scale.

Figure 12. Left: SO2 trend plots for first quarter of 2019 levels showing levels at each site as well as median (purple line) and 2-week running median (dashed red line); Bottom shows weekly summary showing 2nd, 10th, 25th, median, 75th, 90th, and 98th percentile concentrations of the daily data over the week (starting with the date indicated. Right: Trend plots for first quarter of 2020.

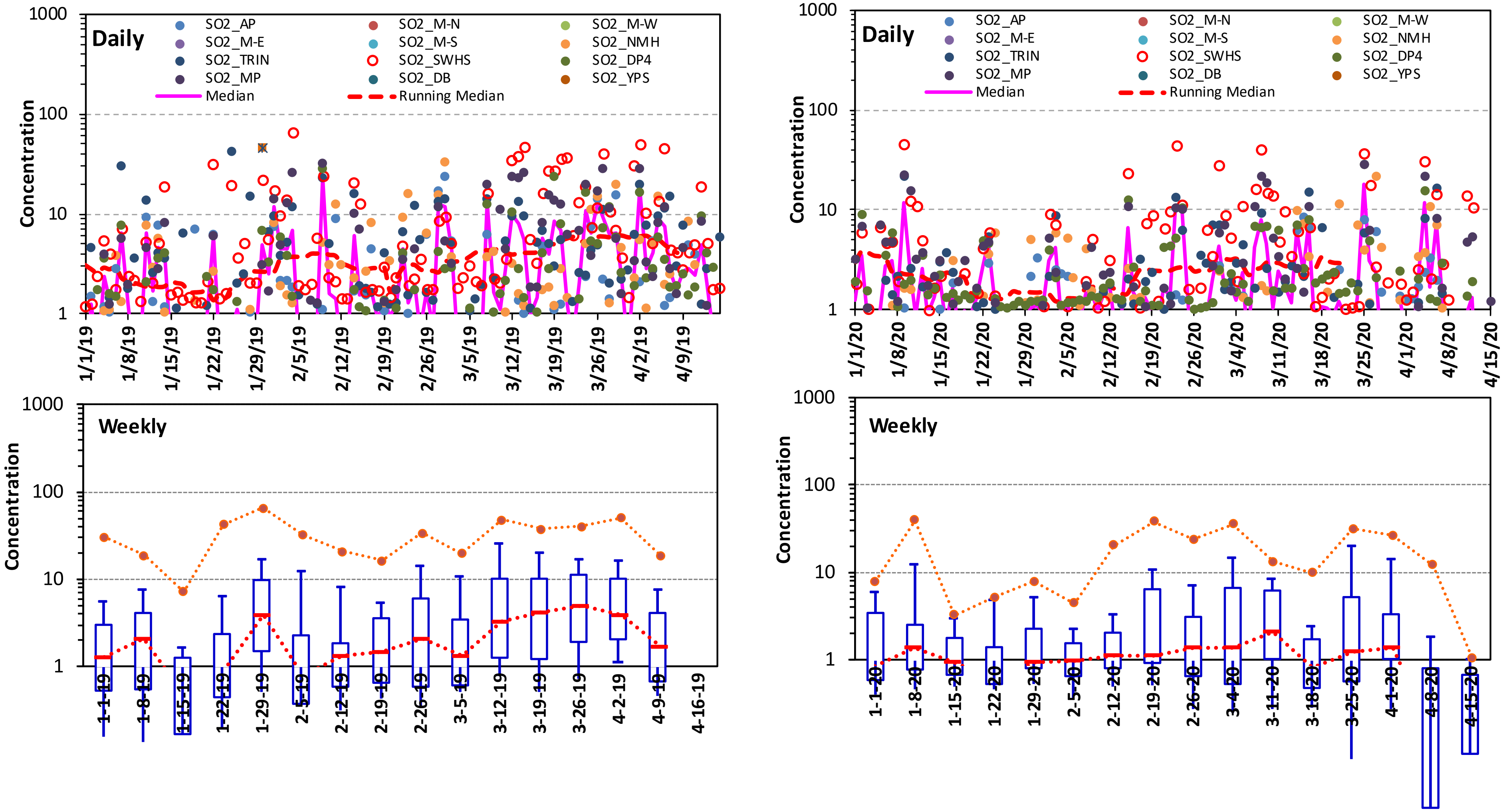
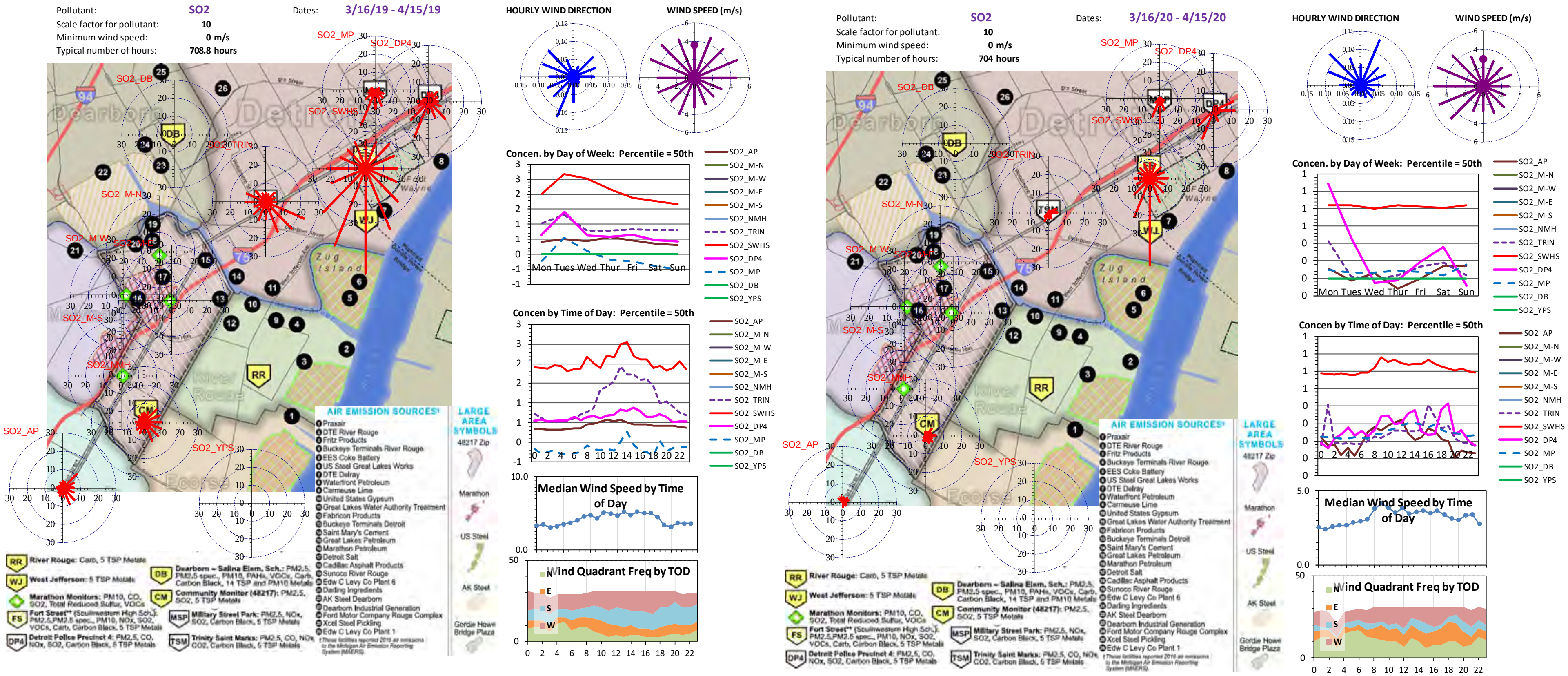


Figure 13. Pollution roses, time of day, and day of week plots. SO_2 retain their sharp directional dependence, showing strong sources on Zug Island and vicinity; levels in 2020 noticeably declined at most sites; the SWHS site continues to show the highest levels.

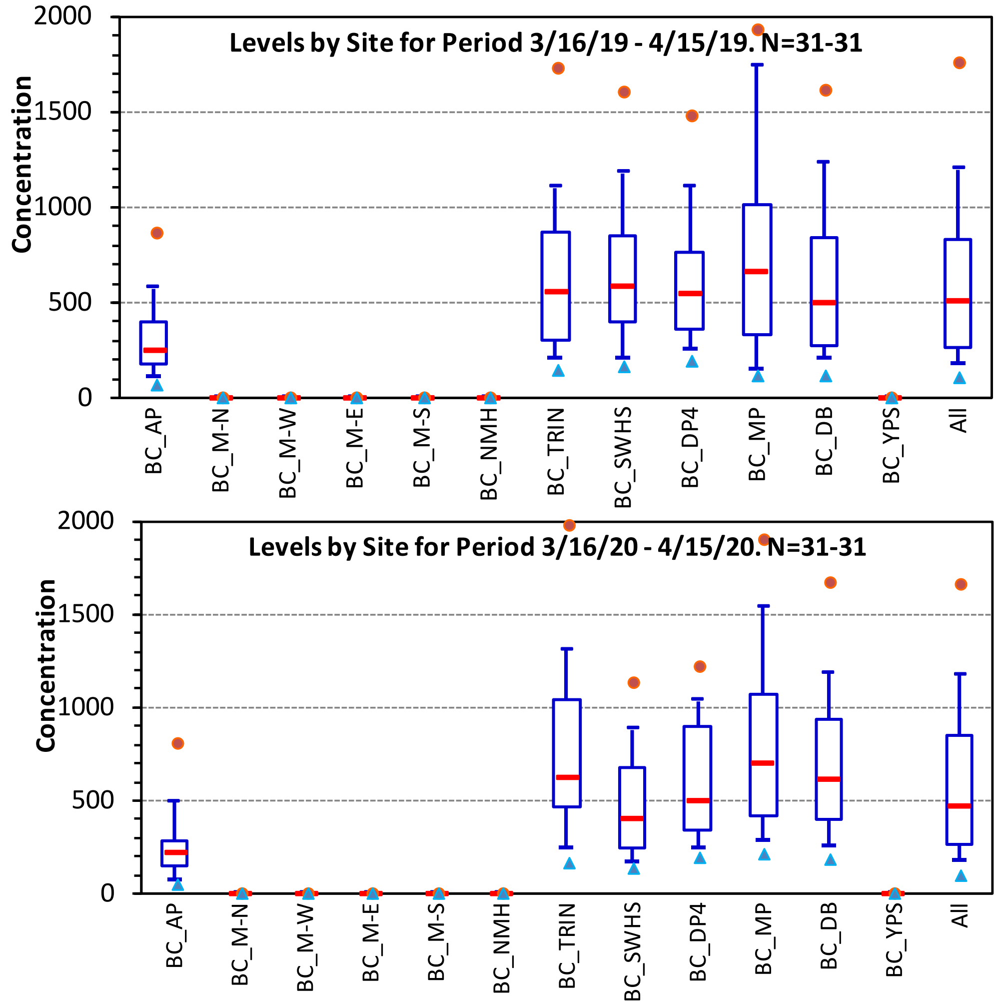


7 BC

The following table and plots show daily 24-hr average levels of black carbon (BC) from the Aethalometers measured from mid-March to mid-April in 2019 and 2020. BC is an indicator of diesel exhaust, and to an extent, wood burning and other poorly controlled combustion. BC levels went down at the Allen Park and SW High School sites, but up at the Trinity and Dearborn site; the overall change across the 6 sites was 3% down, a negligible amount. Peak levels did not decrease.

Figure 14. Left top: Table showing statistics of daily 24-hr average concentrations (ng/m^3) including mean and standard deviation, number of observations (NOBs) and percentage change. Right: Daily 24-hr average levels at each site, including 2nd, 10th, 25th, median, 75th, 90th, and 98th percentile concentrations.

	3/16/19 - 4/15/19			3/16/20 - 4/15/20			Change
	Mean	SD	NOBs	Mean	SD	NOBs	(%)
BC_AP	312	219	31	267	204	31	-16
BC_M-N			0			0	
BC_M-W			0			0	
BC_M-E			0			0	
BC_M-S			0			0	
BC_NMH			0			0	
BC_TRIN	634	461	31	772	501	31	20
BC_SWHS	659	381	31	480	309	31	-31
BC_DP4	617	364	31	610	325	31	-1
BC_MP	776	555	31	795	525	31	2
BC_DB	629	440	31	697	427	31	10
BC_YPS			0			0	
All	605	404	16	604	382	16	-3
All but SWHS	596	407	14	624	394	14	2



As shown in the trend plots below, both 2019 and 2020 data show considerable fluctuation. There is not clear trend. The increase during the week of 4-1-20 is likely due to frequent nocturnal inversions, as noted earlier.

Figure 15. Left: BC trend plots for first quarter of 2019 levels showing levels at each site as well as median (purple line) and 2-week running median (dashed red line); Bottom shows weekly summary showing 2nd, 10th, 25th, median, 75th, 90th, and 98th percentile concentrations of daily 24-hr average data over the week (starting with the date indicated. Right: Trend plots for first quarter of 2020.

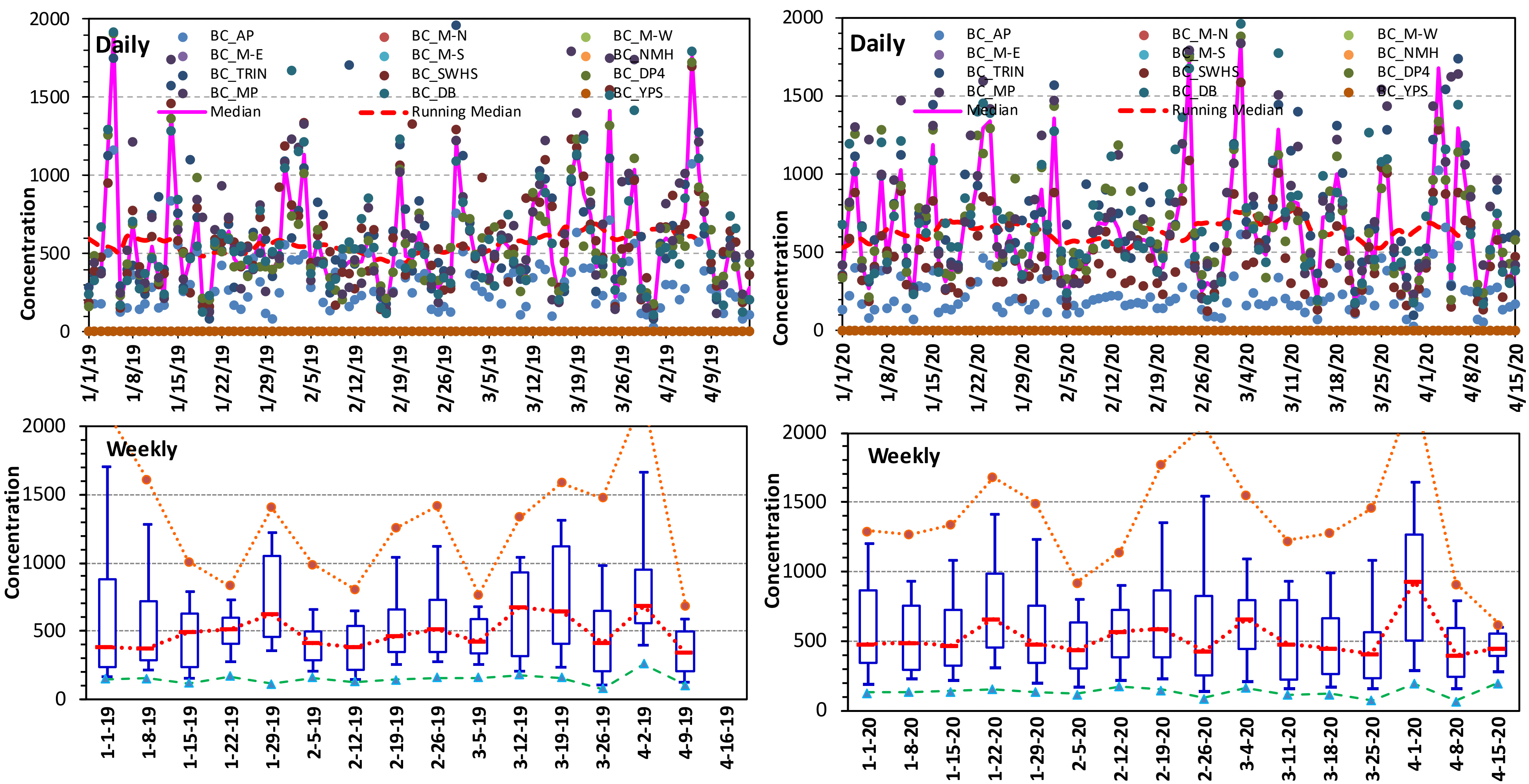


Figure 16. Pollution roses, time of day, and day of week plots. BC data show some directional influences, largely at sites near highways. In 2020, the monitor at Allen Park shows relatively low levels and little time-of-day or day-of-week influence compared to monitoring sites in SW Detroit. Also, in 2020, decreases at the SW High School are notable.