2020 Air Monitoring Data Analysis for the Austin-Round Rock-Georgetown Metropolitan Statistical Area

Prepared by the Capital Area Council of Governments

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EXECUTIVE SUMMARY

The purpose of this project is to analyze ground-level ozone (O_3) data collected in 2020 in the Austin-Round Rock-Georgetown Metropolitan Statistical Area (MSA), which consists of Bastrop, Caldwell, Hays, Travis, and Williamson Counties. The report uses data from 11 different O_3 monitoring stations and two National Weather Service (NWS) stations in the MSA, comparing the 2020 data with CAPCOG's most recent O_3 "conceptual model," which evaluated data from 2010-2015[1], and similar reports that analyzed yearly monitoring data in 2016 - 2019. Some of the most noteworthy findings of this report include the following:

- In 2020, there were only two days that measured O_3 greater than 70 parts per billion (ppb), and the 4th-highest maximum daily 8-hour averages (MDA8) for O_3 were lower than in 2019 region-wide. These lower O_3 concentrations are likely attributable primarily to lower solar radiation, but also can be partly explained by lower NO_X emissions.
- Since the region's main Continuous Air Monitoring Station (CAMS) 3 was inactive for the majority of the year, the region's O_3 design value lowered 4 ppb since data from the other regulatory monitor, CAMS 38, had to be used, which historically records lower O_3 concentrations than CAMS 3.
- On the two days when MDA8 O_3 exceeded 70 ppb, the areas to the southeast of the MSA were the most prevalent upwind areas, similar to previous year's patterns. Within the region, Hays County and Bastrop County were upwind of the region's monitors that recorded 8-hour O_3 greater than 70 ppb on both days when this occurred.

This report includes:

- General summaries of O_3 data in the region from 2020 compared to 2010-2019 (Section 2);
- Analysis of the temporal profiles and features of O_3 in the region in from 2010-2020 (Section 3);
- Investigations of potential relationships between meteorology and O_3 pollution from 2010-2020 (Section 4);
- Analysis of correlations between O_3 pollution and ambient $PM_{2.5}$ and NO_2 concentrations from 2010-2020 (Section 5);
- Analysis of spatial patterns in regional O_3 pollution, and investigation of relationships between emissions and ambient O_3 concentrations in the region in from 2010-2020 (Section 6); and
- Analysis of the potential changes in NO_X emissions between 2010-2020 that could explain changes in the O_3 levels observed within the region in 2020 compared to prior years (Section 7).

[1] Available upon request from CAPCOG

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LIST OF ACRONYMS

AQI: Air Quality Index
CAPCOG: Capital Area Council of Governments
CAMS: Continuous Air Monitoring Station
CASAC: Clean Air Scientific Committee
CEMS: Continuous Emissions Monitoring Systems
C.I.: Confidence Interval
CO: Carbon Monoxide
EPA: U.S. Environmental Protection Agency
FEM: Federal Equivalent Method
FRM: Federal Reference Method
HC: Hydrocarbon
LEADS: Leading Environmental Analysis & Display System
MDA1: Maximum Daily 1-hour Average
MDA8: Maximum Daily 8-Hour Average
$\mu g/m_3$: Micrograms per cubic meter
mph: Miles per hour
MSA: Metropolitan Statistical Area
NAAQS: National Ambient Air Quality Standards
NAM: North American Mesoscale
NO: Nitrogen oxide
NO_2: Nitrogen dioxide
NO_X: Nitrogen oxides (including NO and NO_2)
NWS: National Weather Service
O_3: Ozone
PM: Particulate matter
$PM_{2.5}$: Particulate matter with a diameter of 2.5 microns or less
PM_{10}: Particulate matter with a diameter of 10 microns or less
ppb: Parts per billion
ppm: Parts per million
ppm-hrs.: Parts per million – hours
RH: Relative Humidity
RRF: Relative Response Factor
SO_2: Sulfur dioxide
SR: Solar Radiation
TCEQ: Texas Commission on Environmental Quality
VOC: Volatile Organic Compound
WS: Wind Speed

1 INTRODUCTION

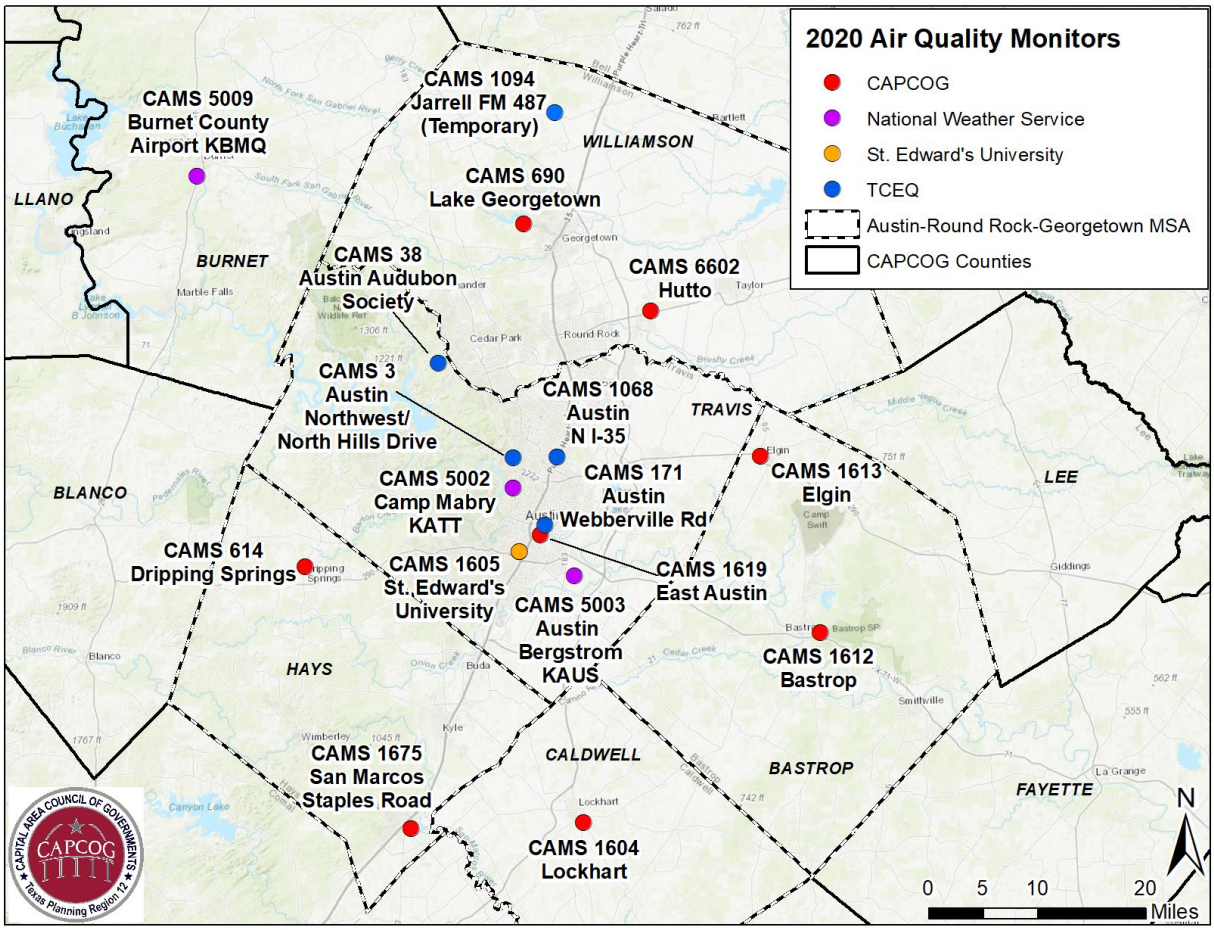
The purpose of this project is to analyze 2020 ambient air monitoring data collected in the Austin-Round Rock-Georgetown Metropolitan Statistical Area (MSA) that consists of Bastrop, Caldwell, Hays, Travis, and Williamson Counties, including comparing it with data from prior years dating back to 2010. This includes a 2016 conceptual model that covers data from 2010-2015, as well as year-specific data analysis reports for 2016, 2017, 2018, and 2019. The primary focus of this report is ground-level O_3.

1.1 AIR QUALITY MONITORING NETWORK

A map of the continuous air monitoring stations (CAMS) used for monitoring air pollution and meteorology in the region in 2020 is shown below.

- Blue circles are Texas Commission on Environmental Quality (TCEQ) stations that collected regulatory air pollution and meteorological data in 2020.
    - CAMS 3 collected hourly O_3, continuous fine particulate matter ($PM_{2.5}$), nitrogen oxide (NO), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) data and meteorological data. However, CAMS 3 needed to be re-located to another location at the site due to construction. Therefore, CAMS 3 was not active for the majority of the year and all of the O_3 season.
    - CAMS 38 collected O_3 data, non-continuous samples of particulate matter 10 micrometers or smaller (PM_{10}) and meteorological data.
    - CAMS 171 collected $PM_{2.5}$ (continuous and non-continuous), PM_{10} (non-continuous), hydrocarbon (HC, non-continuous), and meteorological data.
    - CAMS 1068 is TCEQ's "near-road" monitor and includes carbon monoxide (CO), NO, NO_2, NO_X, $PM_{2.5}$ (continuous and non-continuous) and meteorological data.
- Red circles are non-regulatory Capital Area Council of Governments (CAPCOG) stations
    - All stations collected O_3 and meteorological data.
    - CAMS 1619 (East Austin) is a new station in 2020 that replaced CAMS 1603 (Gorzycki Middle School).
- Purple circles are National Weather Service (NWS) monitors that collected meteorological data.
- The gold circle is a non-regulatory station owned by St. Edward's University that collected O_3 and meteorological data.

Figure 1-1. 2020 Air Quality Monitors in the Austin-Round Rock-Georgetown MSA and CAPCOG Counties



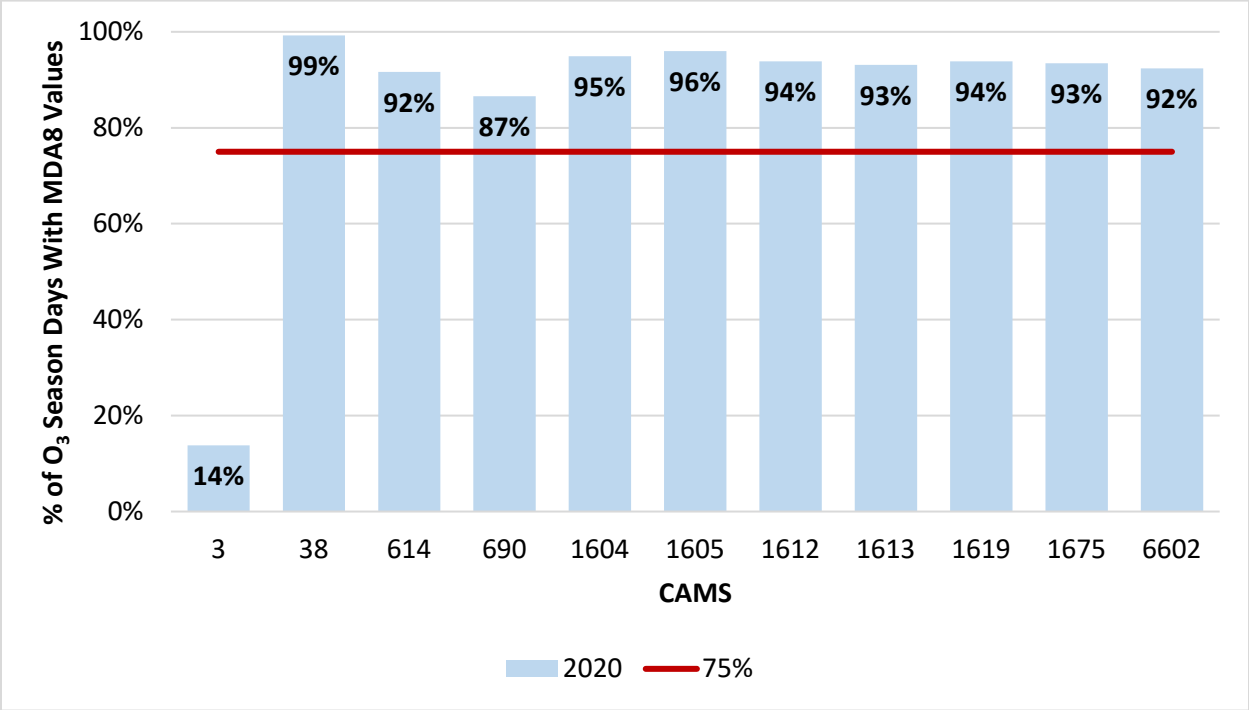
TCEQ's monitoring stations are "regulatory" because they equipped with Federal Reference Method (FRM) monitoring equipment in accordance with federal regulations. Therefore, the TCEQ monitors are used as the basis for assessing the region's compliance with the National Ambient Air Quality Standards (NAAQS). CAPCOG's monitoring stations are "non-regulatory" because they are not FRM nor Federal Equivalent Method (FEM). However, they do use Environmental Protection Agency (EPA)-approved and previously TCEQ-approved sampling methods in a research capacity. Data used for this analysis were obtained from TCEQ's Leading Environmental Analysis & Display System (LEADS®) data system.

1.2 Availability and Completeness Statistics of O_3 Monitors

In order to provide perspective on the overall availability of maximum daily 8-hour average (MDA8) O_3 values for analysis, the following figure shows the percentage of O_3 season MDA8 values available for each monitoring station in 2020. TCEQ's CAMS 3 paused data collection on February 17, 2020, and it resumed data collection on October 22, 2020. TCEQ's CAMS 38 operated for all of 2020. CAPCOG's eight CAMS collected data from mid-February to mid-November, and the St. Edwards University CAMS collected data from January 1, 2020, to November 19, 2020. For regulatory purposes, the EPA requires at least 75% data completeness during an area's official O_3 season for a monitor's data to be used for a valid design value calculation. The region's official O_3

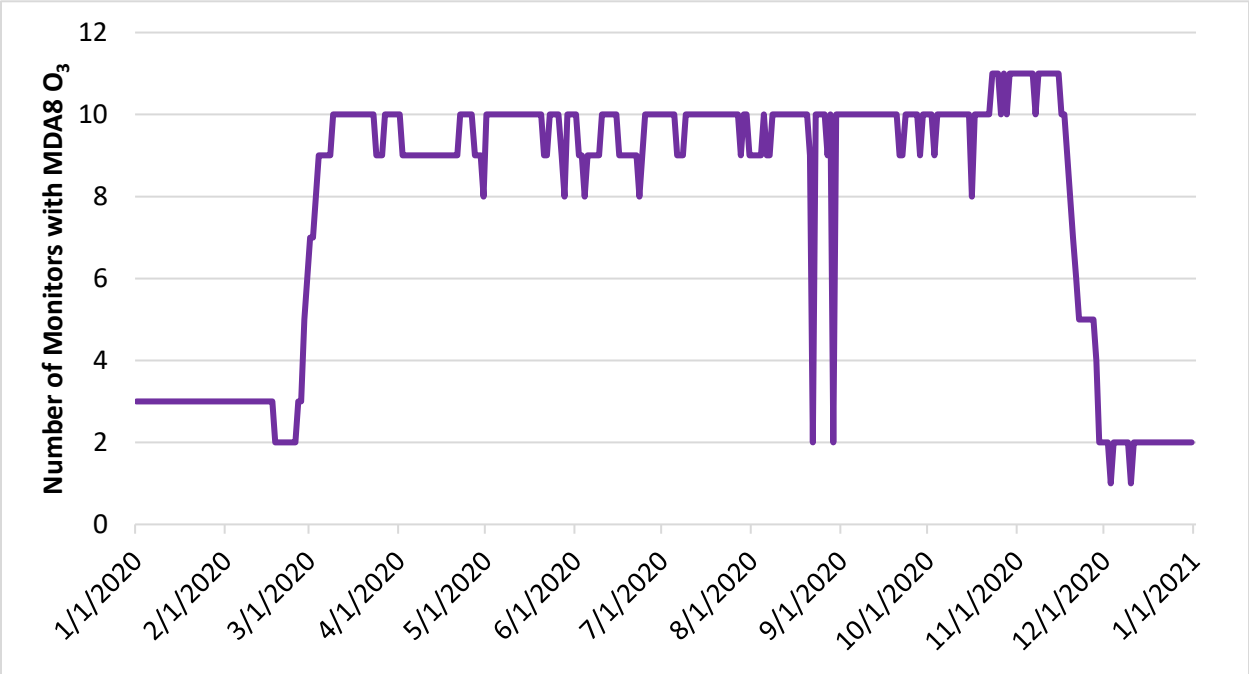
season is March 1 – November 30, so the figure below represents the percentage of total possible MDA8 O_3 values available during those 275 days.

Figure 1-2. CAMS MDA8 O_3 Value Data Completeness for the 2020 O_3 Season by Site



The following figure shows a summary of the number of O_3 monitors with MDA8 values used in this analysis by day of the year in 2020.

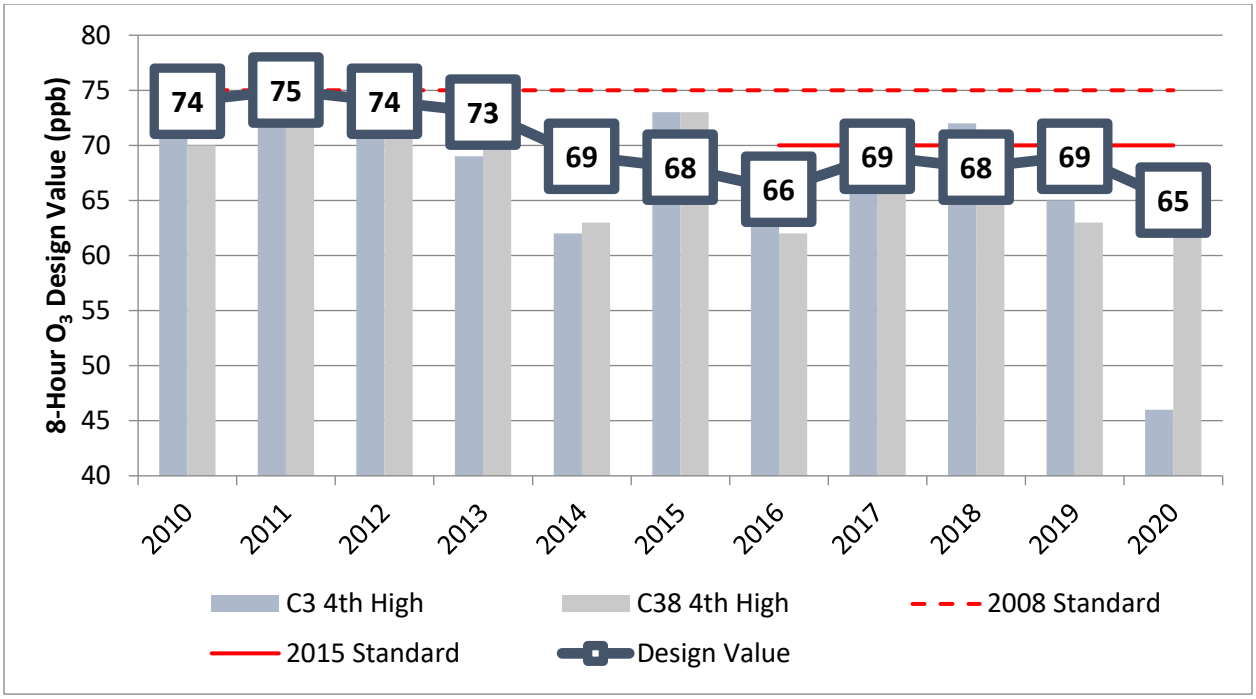
Figure 1-3. Number of Monitors with Recorded MDA8 O_3 Values by Date in 2020



1.3 O_3 NAAQS Attainment Status

Through the end of 2020, the region's O_3 levels continue to be attaining the 2015 O_3 NAAQS of 0.070 parts per million (ppm). Figure 1-4 below shows the trend in the Austin-Round Rock-Georgetown MSA's 8-hour O_3 design values from 2010-2020 compared to the 2008 and 2015 8-hour O_3 NAAQS, along with the 4th-highest MDA8 O_3 at each regulatory O_3 station. MDA8 is the daily maximum 8-hour concentration for a given calendar day that is the highest of the twenty-four possible 8-hour average concentrations computed for that day.

Figure 1-4. Austin-Round Rock-Georgetown MSA 8-Hour O3 Design Value and 4th-Highest MDA O3 Trend 2010-2020



The design value decreased 4 ppb from 2019 to 2020. This was not due to large improvements in air quality, rather it is due to the region's primary O_3 monitor, CAMS 3, being offline for the majority of the year. As displayed in Table 1-2 in the previous section, CAMS 3 was only operational for the first few months of 2020 and the last few months of 2020. Therefore, the 2020 design value for the MSA was calculated using CAMS 38 data which historically records lower concentrations than CAMS 3. Looking at CAMS 38 design value for 2017-2019, it was 66 ppb. Therefore, comparing the CAMS 38 2017-2019 design value of 66 ppb and the CAMS 38 2018-2020 design value of 65 ppb, it decreased by 1 ppb which is what would have been expected for the design value at CAMS 3 if it were operational for all of 2020.

1.3.1 CAMS 3 Re-Location and Effect on the O_3 Design Value

Due to construction at the area of the CAMS 3 monitoring site at Murchison Middle School, CAMS 3 was re-located to another location on the school property during 2020. CAMS 3 data collection was paused in February, and the data collection did not resume until October. Therefore, before CAMS 3 was re-located, it collected data from January 1, 2020 – February 17, 2020. After the re-location at the same property, CAMS 3 restarted data collection on October 16, 2020, for $PM_{2.5}$, and October 22, 2020, for the other pollutants. As a result of the CAMS 3 re-location, the primary O_3 monitor for the region was offline for 89% of the region's ozone season in 2020. Therefore, throughout this report, the data analysis results for CAMS 3 will be skewed lower than expected.

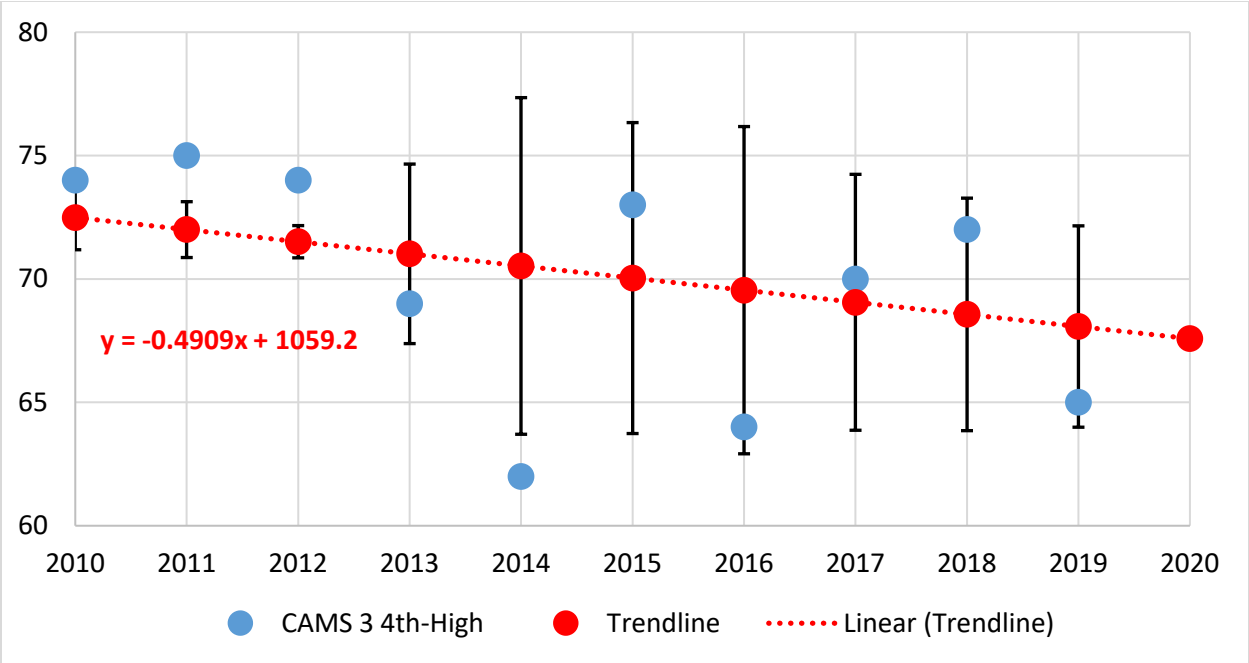
The image below shows the original location of CAMS 3, known as Austin Northwest, and the new location of CAMS 3, known as Austin North Hills Drive. The new location of CAMS 3 is 526 ft. to the west of the original location of CAMS 3.

Figure 1-5. CAMS 3 Old and New Location

Figure 1-6 below shows the 4th highest MDA8 O_3 values at CAMS 3 from 2010-2019, and it compares these values to the trendline and the 95% confidence range[2]. Using the trendline equation in Figure 1-4, the fourth highest MDA8 value at CAMS 3 would have been expected to be 67 ppb for 2020, if CAMS 3 had been collecting data for all of 2020. Therefore, the design value for 2018-2020 for CAMS 3 would have been expected to be 68 ppb. The difference between the 2017-2019 actual design value for CAMS 3 of 69 ppb and the 2018-2020 theoretical design value of 68 ppb for CAMS 3 is 1 ppb, which is in line with the decrease seen with the CAMS 38 design value. While the regional design value was expected to improve in 2020, it would have been expected that estimated design value for 2018-2020 would have decreased by 1 ppb instead of the 4 ppb decrease that actually occurred due to the lack of CAMS 3 data for 2020.

[2] 95% confidence interval range is based on the standard deviation for the 3-year design value period associated with that year. So, the standard deviation applicable to the 2019 data reflected 2017-2019 data.

Figure 1-6. CAMS 3 4th-Highest MDA8 O_3 Values, Trendline, and 95% Confidence Intervals, 2010-2020



1.4 Overview of Findings from the 2010-2015 O_3 Conceptual Model

Some of the more significant findings from the 2010-2015 O_3 Conceptual Model included the following:

- MDA8 O_3 levels >70 ppb occurred as early as March and as late as October and occurred most frequently in August.
- MDA8 O_3 levels ≥55 ppb occurred as early as February and as late as November.
- Start hours for MDA8 O_3 >70 ppb were as early as 9 am and as late as 1 pm within the Austin-Round Rock-Georgetown MSA.
- MDA8 O_3 >70 ppb tended to form in the region when:
    - Mid-day wind speed was low – typically less 7 miles per hour (mph) or less;
    - Mid-day temperatures were high – typically 90 degrees Fahrenheit or higher;
    - Diurnal temperature changes were large – typically 23 degrees or more;
    - Mid-day relative humidity averages were low – typically 30% or less; and
    - Mid-day solar radiation averages were high – typically over 1.18 langleys/minute.
- MDA8 O_3 ≥55 ppb tended to form in the region when:
    - Mid-day wind speed was low – typically less than 9 mph;
    - Mid-day temperatures were high – typically 82 degrees Fahrenheit or higher;
    - Diurnal temperature changes were large – typically more than 33 degrees;
    - Mid-day RH averages were low – typically 30% or less; and
    - Mid-day solar radiation averages were high – typically over 1.11 langleys/minute.
- There were statistically significant multi-pollutant correlations between high MDA8 O_3 levels and high 24-hour $PM_{2.5}$ concentrations.
- Regression analyses of high MDA8 O_3 levels at CAMS 3 and CAMS 38 showed that the following factors were statistically significant in high MDA8 O_3 levels between 2010-2015 at a significance level of 0.05:
    - Average wind speeds between 12 pm and 4 pm
    - Average temperature between 12 pm and 4 pm
    - Diurnal temperature change

  - Average relative humidity between 12 pm and 4 pm
  - Solar radiation between 12 pm and 4 pm (at CAMS 38 only)
  - Day = Sunday
  - Year = 2013 (coefficient = -2.42 ppb for CAMS 3 and – 1.62 ppb for CAMS 38)
- When MDA8 O_3 was >70 ppb, "background" MDA8 values for the region were typically 59-61 ppb, with local emissions contributing the balance.
- MDA8 O_3 levels >70 ppb were 15-60 times more influenced by anthropogenic NO_X emissions than by anthropogenic Volatile Organic Compounds (VOC) emissions.

Substantial and long-term downward trends in mobile source NO_X emissions resulted in significant decreases in regional MDA8 O_3 levels between 2010 and 2015 and were expected to continue to drive MDA8 O_3 levels down in 2016 and beyond.

1.5 Key Questions for this Analysis

Some of the key questions for this analysis are:

- Were the conditions for high MDA8 O_3 levels in 2020 similar to the conditions that were typical of high O_3 levels in 2010-2018?
- Did factors that lead to high MDA8 O_3 levels in the region from 2010-2019 occur with any greater or less frequency in 2020?

2 Analysis of Daily Maximum 8-Hour O_3 Data and Seasonal O_3 Exposure

This section provides general data on the MDA8 O_3 levels measured in the region in 2020. This includes an analysis of days when MDA8 O_3 levels were >70 ppb, 55-70 ppb, and <55 ppb, which corresponds to the 2015 O_3 NAAQS O_3 Air Quality Index (AQI) values of "unhealthy for sensitive groups" (71-85 ppb), "moderate" (55-70 ppb), and "good" (<55 ppb). The highest MDA8 O_3 value recorded in the region in 2020 was 78 ppb, meaning there were no days considered "unhealthy" for the general population. Data is analyzed both monitor-by-monitor and region-wide. For the regional analysis, the highest MDA8 O_3 value recorded in the region would determine that day's classification.

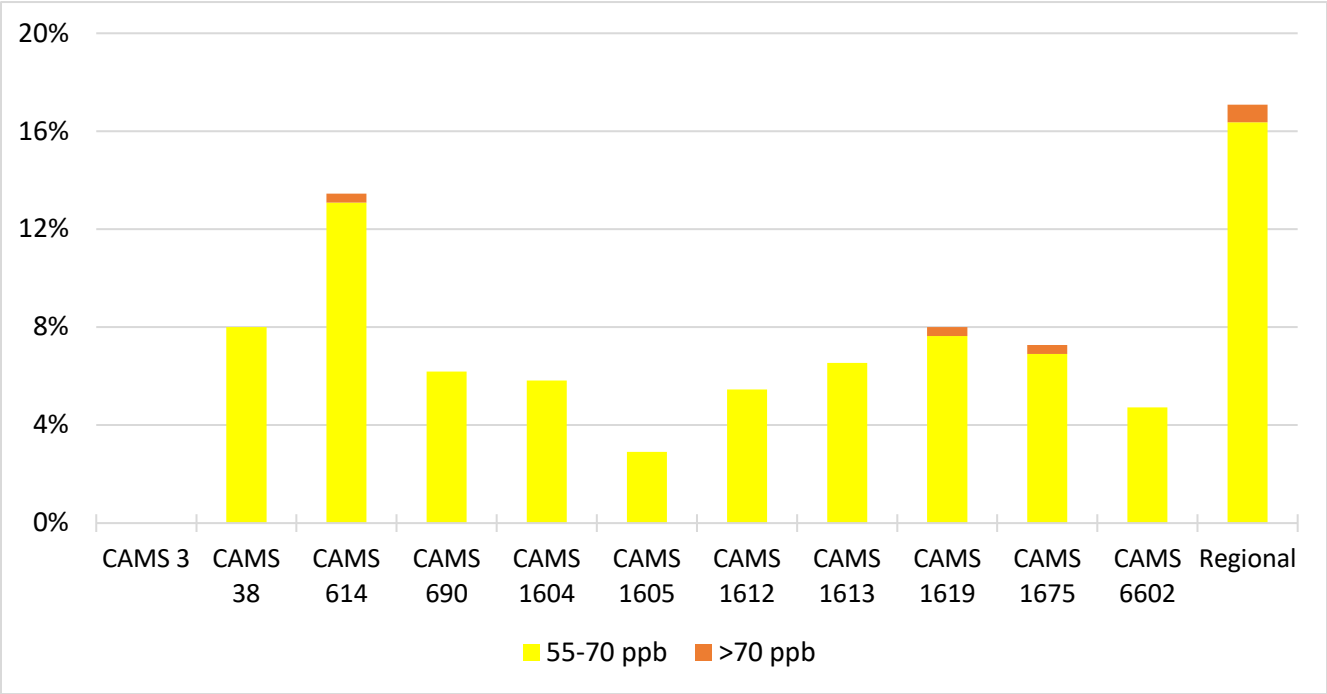
Table 2-1. Summary of AQI for O_3

AQI Level	AQI Number	O_3 (8-Hr., ppb)
Good	0-50	0-54
Moderate	51-100	55-70
Unhealthy for Sensitive Groups	101-150	71-85
Unhealthy	151-200	86-105
Very Unhealthy	201-300	106-200
Hazardous	301-500	201-600

2.1 High O_3 Measurements by Monitoring Station

The following figure shows the percentage of total number of MDA8 O_3 values that were 55-70 ppb and >70 ppb for each monitoring station and region-wide during the official O_3 season in 2020 (March-November). There were 2 days in 2020 with MDA8 O_3 levels measured above 70 ppb. MDA8 O_3 was measured at 55 ppb or above on 16.4% of days in the O_3 season.

Figure 2-1. Percentage of O_3 Season Days when Monitored MDA8 O_3 was 55-70 ppb or >70 ppb, 2020



The following tables provide more detailed data on the number of days that each monitor measured MDA8 O_3 values >70 ppb, 55-70 ppb, and <55 ppb in each year from 2010-2019. Summaries of the total number of observations and the regional peak are also included.

Table 2-2. Days with MDA8 O_3 >70 ppb by Monitoring Station and Year, 2010-2020

CAMS	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
3	8	13	6	1	0	8	1	3	6	0	0	**46**
38	3	6	6	3	0	7	0	1	1	1	0	**28**
614	4	9	6	0	0	5	0	1	3	1	1	**30**
690	1	6	8	9	0	5	0	3	3	0	0	**35**
1604	n/a	n/a	n/a	n/a	0	0	0	2	0	0	0	**2**
1605	n/a	n/a	n/a	n/a	n/a	n/a	0	0	0	0	0	**0**
1612	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	0	**0**
1613	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	0	**0**
1619	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	1	**1**
1675	n/a	2	6	3	0	3	0	0	6	0	1	**21**
6602	n/a	13	0	1	0	4	0	0	1	0	0	**19**
Regional	11	20	12	10	0	12	1	7	10	2	2	**87**

Table 2-3. Days with MDA8 O_3 55-70 ppb by Monitoring Station and Year, 2010-2020

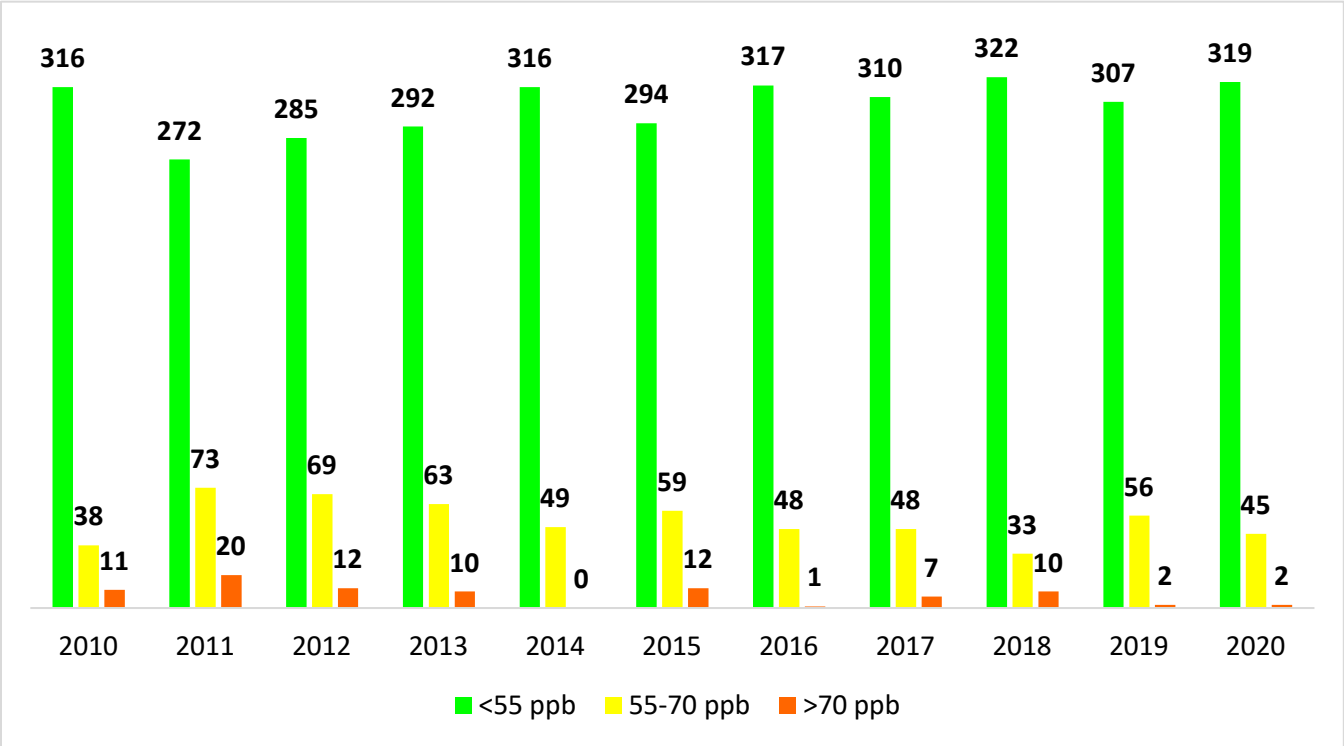
CAMS	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
3	32	57	45	49	28	49	34	31	26	28	0	**379**
38	30	65	54	44	36	47	28	32	25	26	22	**409**
614	26	69	38	19	24	45	22	25	31	30	36	**365**
690	17	64	43	45	29	40	20	41	31	38	17	**385**
1604	n/a	n/a	n/a	n/a	21	31	23	34	16	12	16	**153**
1605	n/a	n/a	n/a	n/a	n/a	n/a	2	12	16	6	8	**44**
1612	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	7	15	**22**
1613	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	15	18	**33**
1619	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	21	**21**
1675	n/a	16	41	28	17	41	16	23	24	28	19	**253**
6602	n/a	41	31	38	0	34	15	27	23	14	13	**236**
Regional	38	73	69	63	49	59	48	48	33	56	45	**581**

Table 2-4. Days with MDA8 O_3 <55 ppb by Monitoring Station and Year, 2010-2020

CAMS	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
3	316	267	298	310	329	302	329	323	327	323	115	**3,239**
38	326	286	297	300	315	296	334	323	331	325	342	**3,475**
614	152	138	164	178	170	188	243	233	245	231	215	**2,157**
690	179	136	145	158	177	198	250	219	241	207	222	**2,132**
1604	n/a	n/a	n/a	n/a	163	217	240	219	257	248	245	**1,589**
1605	n/a	n/a	n/a	n/a	n/a	n/a	318	295	322	286	316	**1,537**
1612	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	236	247	**483**
1613	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	249	240	**489**
1619	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	236	**236**
1675	n/a	26	168	184	176	205	250	227	247	228	239	**1,950**
6602	n/a	117	168	174	0	164	257	211	250	236	241	**1,818**
Regional	316	272	285	292	316	294	317	310	322	307	319	**3,350**

The following figure shows the number of days when the regional peak MDA8 value for O_3 was <55 ppb, 55-70 ppb, and >70 ppb by year.

Figure 2-2.Number of Days when Regional Peak MDA8 O_3 was <55 ppb, 55-70 ppb, and >70 ppb by Year



In 2020, there were an equal number of "unhealthy for sensitive groups" days (days >70 ppb) as in 2019. However, there were more days that were "moderate", between 55-70 ppb, in 2020 than in 2019.

2.2 Ten Highest MDA8 O_3 Values

Compliance with the 2015 O_3 NAAQS is based on the average of the yearly 4th high MDA8 O_3 values over three years. EPA's modeling guidance recommends the use of the top 10 modeled MDA8 O_3 values in baseline and future analysis years for calculating relative response factors (RRFs). These averages of the top 10 days tend to be very close to the 4th-highest MDA8 O_3 values. Therefore, the following tables present the top 10 days measured at each monitoring station for each year, as well as the average of the top 4 days and the average of the top 10 days. The table also indicates whether the 2020 values were lower than, higher than, or within the 95% confidence intervals (C.I.) for 2010-2012, 2013-2015, 2014-2016, 2015-2017, and 2016-2018, and 2017-2019. Since CAMS 1619 was established in 2020, it's table only contains data for 2020. Additionally, since CAMS 1612 and CAMS 1613 were established in 2019, only 2019 and 2020 data are available.

Table 2-5. CAMS 3 Top 10 Measured MDA8 O_3 Values by Year

Rank	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2020 in C.I. for 2010-2012	2020 in C.I. for 2013-2015	2020 in C.I. for 2014-2016	2020 in C.I. for 2015-2017	2020 in C.I. for 2016-2018	2020 in C.I. for 2017-2019
1	77	82	94	79	69	85	72	71	75	69	52	Low	Low	Low	Low	Low	Low
2	76	79	87	70	65	83	67	71	74	66	49	Low	Low	Low	Low	Low	Low
3	75	78	80	69	63	82	66	71	72	66	49	Low	Low	Low	Low	Low	Low
4	74	75	74	69	62	73	64	70	72	65	46	Low	Low	Low	Low	Low	Low
5	73	75	73	68	62	73	64	69	71	63	46	Low	Low	Low	Low	Low	Low
6	72	74	71	68	62	73	63	68	71	62	46	Low	Low	Low	Low	Low	Low
7	72	74	68	67	61	72	63	67	70	62	46	Low	Low	Low	Low	Low	Low
8	71	74	68	67	61	71	62	67	69	62	45	Low	Low	Low	Low	Low	Low
9	69	73	67	66	61	70	62	64	66	62	45	Low	Low	Low	Low	Low	Low
10	68	73	67	65	60	69	61	63	66	61	45	Low	Low	Low	Low	Low	Low
Avg. Top 4	76	79	84	72	65	81	67	71	73	66	49	Low	Low	Low	Low	Low	Low
Avg. Top 10	73	76	75	69	63	75	64	68	71	63	46	Low	Low	Low	Low	Low	Low

Since CAMS 3 was offline for the majority of the year, the data recorded in 2020 is not consistent with the past years of data.

Table 2-6. CAMS 38 Top 10 Measured MDA8 O_3 Values by Year

Rank	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2020 in C.I. for 2010-2012	2020 in C.I. for 2013-2015	2020 in C.I. for 2014-2016	2020 in C.I. for 2015-2017	2020 in C.I. for 2016-2018	2020 in C.I. for 2017-2019
1	76	78	80	74	68	82	69	73	74	74	65	Low	Low	Yes	Low	Low	Low
2	72	76	78	73	63	81	65	68	70	65	64	Low	Yes	Yes	Yes	Low	Low
3	71	73	78	72	63	80	64	67	70	65	63	Low	Yes	Yes	Yes	Low	Low
4	70	73	76	70	63	73	62	67	70	63	63	Low	Yes	Yes	Yes	Yes	Yes
5	69	71	74	68	63	71	61	66	69	62	61	Low	Low	Yes	Yes	Yes	Low
6	68	71	72	68	62	71	61	66	67	62	61	Low	Low	Yes	Yes	Low	Low
7	66	69	70	68	62	71	61	65	66	62	61	Low	Low	Yes	Yes	Low	Low
8	65	69	70	68	62	69	60	63	66	61	60	Low	Low	Yes	Yes	Yes	Low
9	65	68	69	67	61	68	60	63	65	60	59	Low	Low	Yes	Low	Low	Low
10	64	68	69	66	61	67	60	63	64	60	59	Low	Low	Yes	Low	Low	Low
Avg. Top 4	72	75	78	72	64	79	65	69	71	66	63	Low	Low	Yes	Yes	Low	Low
Avg. Top 10	69	72	74	69	63	73	62	66	68	63	61	Low	Low	Yes	Yes	Low	Low

Table 2-7. CAMS 614 Top 10 Measured MDA8 O_3 Values by Year

Rank	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2020 in C.I. for 2010-2012	2020 in C.I. for 2013-2015	2020 in C.I. for 2014-2016	2020 in C.I. for 2015-2017	2020 in C.I. for 2016-2018	2020 in C.I. for 2017-2019
1	80	86	77	69	70	79	66	72	77	74	72	Low	Yes	Yes	Yes	Yes	Yes
2	78	83	76	69	64	76	66	68	71	67	68	Low	Yes	Yes	Yes	Yes	Yes
3	73	79	73	68	63	72	66	67	71	67	67	Low	Yes	Yes	Yes	Yes	Yes
4	72	77	73	67	63	71	65	67	69	64	66	Low	Yes	Yes	Yes	Yes	Yes
5	70	77	73	64	62	71	64	66	69	64	65	Low	Yes	Yes	Yes	Yes	Yes
6	70	76	71	64	61	70	63	66	68	62	64	Low	Yes	Yes	Yes	Yes	Yes
7	69	74	70	62	61	70	61	65	68	62	64	Low	Yes	Yes	Yes	Yes	Yes
8	67	71	70	62	61	69	61	63	66	62	63	Low	Yes	Yes	Yes	Yes	Yes
9	66	71	68	62	61	69	61	62	65	62	63	Low	Yes	Yes	Yes	Yes	Yes
10	64	70	68	59	61	68	59	62	65	61	63	Low	Yes	Yes	Yes	Yes	Yes
Avg. Top 4	76	81	75	68	65	75	66	69	72	68	68	Low	Yes	Yes	Yes	Yes	Yes
Avg. Top 10	71	76	72	65	63	72	63	66	68.9	64	65	Low	Yes	Yes	Yes	Yes	Yes

Table 2-8. CAMS 690 Top 10 Measured MDA8 O_3 Values by Year

Rank	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2020 in C.I. for 2010-2012	2020 in C.I. for 2013-2015	2020 in C.I. for 2014-2016	2020 in C.I. for 2015-2017	2020 in C.I. for 2016-2018	2020 in C.I. for 2017-2019
1	71	79	81	89	70	83	70	75	77	70	69	Low	Low	Yes	Yes	Low	Low
2	70	79	81	79	69	79	68	73	73	67	68	Low	Low	Yes	Yes	Low	Yes
3	66	77	78	78	66	78	66	73	73	67	64	Low	Low	Yes	Low	Low	Low
4	65	73	73	75	66	75	61	70	69	67	64	Low	Low	Yes	Yes	Yes	Low
5	65	71	73	74	65	73	60	69	69	66	63	Low	Low	Yes	Yes	Yes	Low
6	65	71	71	73	63	67	60	68	67	64	61	Low	Low	Yes	Yes	Yes	Low
7	64	70	71	72	62	66	60	67	67	63	61	Low	Yes	Yes	Yes	Yes	Low
8	62	70	71	71	62	65	59	67	66	62	61	Low	Yes	Yes	Yes	Yes	Low
9	61	69	69	71	62	65	58	67	65	62	60	Low	Low	Yes	Yes	Yes	Low
10	59	69	69	70	61	64	58	66	63	61	58	Low	Low	Yes	Yes	Yes	Low
Avg. Top 4	68	77	78	80	68	79	66	73	73	67	66	Low	Low	Yes	Yes	Low	Low
Avg. Top 10	65	73	74	75	65	72	62	70	69	64	62	Low	Low	Yes	Yes	Low	Low

Table 2-9. CAMS 1604 Top 10 Measured MDA8 O_3 Values by Year

Rank	2014	2015	2016	2017	2018	2019	2020	2020 in C.I. for 2014-2016	2020 in C.I. for 2015-2017	2020 in C.I. for 2016-2018	2020 in C.I. for 2017-2019
1	66	69	63	74	68	66	66	Yes	Yes	Yes	Yes
2	65	68	62	74	67	61	64	Yes	Yes	Yes	Yes
3	64	67	62	70	66	61	62	Yes	Yes	Yes	Yes
4	64	67	60	67	66	61	59	Low	Low	Low	Low
5	61	65	59	65	65	59	59	Yes	Low	Low	Low
6	61	64	59	64	64	58	58	Low	Low	Low	Low
7	61	64	59	64	64	57	58	Low	Low	Low	Yes
8	60	63	58	64	63	57	57	Low	Low	Low	Low
9	60	63	57	63	63	56	56	Low	Low	Low	Low
10	59	63	57	63	61	56	56	Low	Low	Low	Yes
Avg. Top 4	65	68	62	71	67	62	62	Yes	Yes	Yes	Yes
Avg. Top 10	62	65	60	67	65	59	59	Low	Low	Low	Yes

Table 2-10. CAMS 1605 Top 10 Measured MDA8 O_3 Values by Year

Rank	2016	2017	2018	2019	2020	2019 in C.I. for 2016-2018	2020 in C.I. for 2017-2019
1	56	66	70	60	66	Yes	Yes
2	56	64	70	59	60	Yes	Yes
3	53	62	66	59	58	Yes	Low
4	52	61	66	58	56	Yes	Low
5	52	60	64	56	55	Yes	Low
6	51	59	64	55	55	Yes	Yes
7	51	58	64	54	55	Yes	Yes
8	51	57	64	53	55	Yes	Yes
9	51	56	63	53	54	Yes	Yes
10	50	55	63	53	54	Yes	Yes
Avg. Top 4	54	63	68	59	60	Yes	Yes
Avg. Top 10	52	60	65	56	56	Yes	Yes

Table 2-11. CAMS 1612 Top 10 Measured MDA8 O_3 Values by Year

Rank	2019	2020
1	63	68
2	61	63
3	60	62
4	59	59
5	59	59
6	57	58
7	55	58
8	54	58
9	54	58
10	54	56
Avg. Top 4	60	63
Avg. Top 10	57	59

Table 2-12. CAMS 1613 Top 10 Measured MDA8 O_3 Values by Year

Rank	2019	2020
1	64	68
2	63	63
3	61	62
4	60	61
5	59	59
6	59	59
7	58	58
8	57	58
9	56	58
10	56	57
Avg. Top 4	62	63
Avg. Top 10	59	60

Table 2-13. CAMS 1619 Top 10 Measured MDA8 O_3 Values by Year

Rank	2020
1	73
2	66
3	64
4	63
5	62
6	62
7	62
8	60
9	60
10	59
Avg. Top 4	66
Avg. Top 10	63

Table 2-14. CAMS 675/1675 Top 10 Measured MDA8 O_3 Values by Year

Rank	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2020 in C.I. for 2010-2012	2020 in C.I. for 2013-2015	2020 in C.I. for 2014-2016	2020 in C.I. for 2015-2017	2020 in C.I. for 2016-2018	2020 in C.I. for 2017-2019
1	72	86	81	82	68	76	65	69	84	66	78	Yes	Yes	High	High	Yes	Yes
2	71	82	75	74	65	73	64	67	82	66	65	Low	Low	Yes	Yes	Yes	Yes
3	69	79	74	72	62	73	63	66	76	64	62	Low	Low	Yes	Yes	Yes	Yes
4	68	78	72	70	61	70	62	63	74	63	62	Low	Yes	Yes	Yes	Yes	Yes
5	67	77	72	69	61	70	61	62	72	62	60	Low	Low	Yes	Yes	Yes	Yes
6	67	75	71	67	61	69	60	61	72	62	59	Low	Low	Yes	Yes	Yes	Yes
7	67	75	70	67	60	67	60	61	70	61	59	Low	Low	Yes	Yes	Yes	Yes
8	64	73	69	66	60	67	60	60	69	60	59	Low	Low	Yes	Yes	Yes	Yes
9	64	72	69	66	60	66	59	60	68	59	59	Low	Low	Yes	Yes	Yes	Yes
10	64	72	68	65	59	66	59	60	66	59	59	Low	Low	Yes	Yes	Yes	Yes
Avg. Top 4	70	81	76	75	64	73	64	66	79	64	66	Low	Yes	Yes	Yes	Yes	Yes
Avg. Top 10	67	86	72	70	62	70	61	63	73	62	62	Low	Yes	Yes	Yes	Yes	Yes

Table 2-15. CAMS 6602 Top 10 Measured MDA8 O_3 Values by Year

Rank	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2020 in C.I. for 2010-2012	2020 in C.I. for 2013-2015	2020 in C.I. for 2014-2016	2020 in C.I. for 2015-2017	2020 in C.I. for 2016-2018	2020 in C.I. for 2017-2019
1	80	70	77	n/a	77	62	68	71	62	65	Low	Low	Yes	Yes	Yes	Yes
2	80	70	70	n/a	75	59	67	70	62	63	Low	Yes	Yes	Yes	Yes	Yes
3	79	69	70	n/a	72	58	66	68	60	63	Low	Low	Yes	Yes	Yes	Yes
4	75	69	69	n/a	71	58	65	68	60	61	Low	Low	Yes	Yes	Yes	Yes
5	74	69	65	n/a	70	58	63	66	60	61	Low	Yes	Yes	Yes	Yes	Yes
6	72	67	64	n/a	69	57	63	65	60	61	Low	Yes	Yes	Yes	Yes	Yes
7	72	66	63	n/a	68	57	62	65	59	60	Low	Yes	Yes	Yes	Yes	Yes
8	72	64	63	n/a	65	57	62	63	58	60	Low	Yes	Yes	Yes	Yes	Yes
9	71	64	63	n/a	64	56	61	62	58	58	Low	Low	Yes	Yes	Yes	Yes
10	71	63	63	n/a	62	56	60	61	58	57	Low	Low	Yes	Yes	Yes	Low
Avg. Top 4	79	70	72	n/a	74	59	67	69	61	63	Low	Low	Yes	Yes	Yes	Yes
Avg. Top 10	75	67	67	n/a	69	58	64	66	59	60	Low	Low	Yes	Yes	Yes	Yes

2.3 Three-Year Averages of 4th-Highest MDA8 O_3

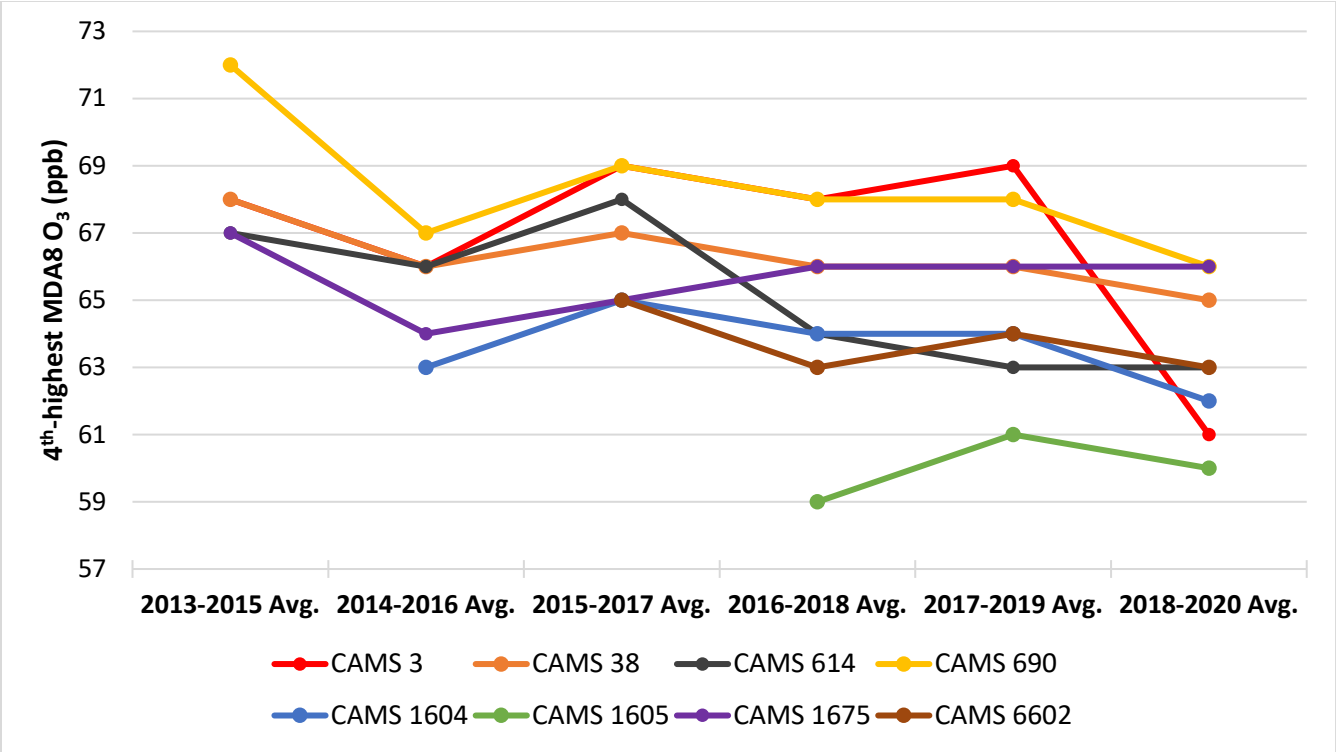
The following table shows the average of the 4th-highest MDA8 O_3 values at all of the monitoring stations used in this report for 2013-2020. Consistent with the data-handling conventions for the 2015 O_3 NAAQS, values beyond the units' digit are truncated. These three-year averages can be considered as the design values for each monitoring site.

Table 2-16. 4th-highest MDA8 O_3 values at Regional O_3 Monitors, 2013-2020 (ppb)

CAMS	2013	2014	2015	2016	2017	2018	2019	2020	2013-2015 Avg.	2014-2016 Avg.	2015-2017 Avg.	2016-2018 Avg.	2017-2019 Avg.	2018-2020 Avg.
3	69	62	73	64	70	72	65	46	68	66	69	68	69	61
38	70	63	73	62	67	70	63	63	68	66	67	66	66	65
614	67	63	71	65	67	60	64	66	67	66	68	64	63	63
690	75	66	75	61	70	69	67	64	72	67	69	68	68	66
1604	n/a	64	67	60	67	66	61	59	n/a	63	65	64	64	62
1605	n/a	n/a	n/a	52	61	66	58	56	n/a	n/a	n/a	59	61	60
1612	n/a	n/a	n/a	n/a	n/a	n/a	59	59	n/a	n/a	n/a	n/a	n/a	n/a
1613	n/a	n/a	n/a	n/a	n/a	n/a	60	61	n/a	n/a	n/a	n/a	n/a	n/a
1619	n/a	n/a	n/a	n/a	n/a	n/a	n/a	63	n/a	n/a	n/a	n/a	n/a	n/a
1675	70	61	70	62	63	74	63	62	67	64	65	66	66	66
6602	69	n/a	71	58	65	68	60	61	n/a	n/a	65	63	64	63

Since CAMS 3 was offline for the majority of the year, CAMS 3 did not rank as the number one monitor for the highest three-year average as it has in the past. CAPCOG's CAMS 690 and CAMS 1675 both had a 4th-highest MDA8 O_3 average for 2018-2020 of 66 ppb. The graph below displays the three-year average of 4th-highest MDA8 O_3 for the regional monitors, excluding CAMS 1612, CAMS 1613, and CAMS 1619 since they do not have a 2018-2020 average.

Figure 2-3. Three-Year Averages of the 4th-highest MDA8 O_3 value for Regional Monitors (ppb)

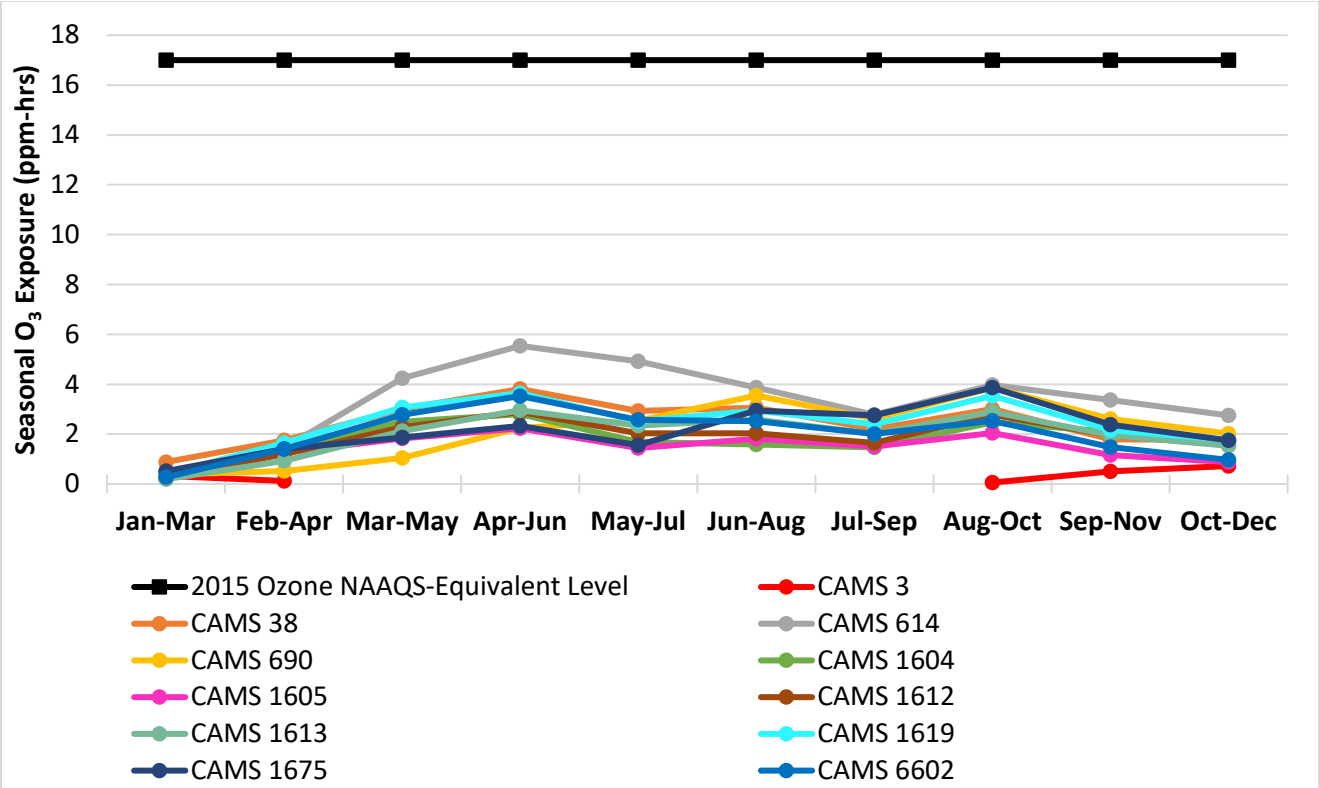


Most of the O_3 monitors in the region averaged a lower three-year average in 2018-2020 from the previous three-year average, while two monitors had the same average as the previous one. Excluding CAMS 3, the average decrease in the individual monitor's design value from 2017-2019 to 2018-2020 was 1.4 ppb. Therefore, this average decrease across the regional monitors further supports the discussion in Section 1.3.1 regarding CAMS 3 offline status in 2020 and its effect on the regional design values. While regional air quality was expected to improve in 2020, the decrease in the regional design value would have been around 1 ppb, not 4 ppb, which is in line with the trend from the individual monitors

2.4 Seasonal O_3 Exposure

While EPA set the 2015 secondary O_3 NAAQS identical to the 2015 primary O_3 NAAQS, the preamble to the rulemaking states that, "the requisite protection will be provided by a standard that generally limits cumulative seasonal exposure to 17 ppm-hours (ppm-hrs.) or lower, in terms of a three-year W126 index." EPA did not set a separate secondary NAAQS because, "such control of cumulative seasonal exposure will be achieved with a standard set at a level of 0.070 ppm, and the same indicator, averaging time, and form as the current standard." The region's peak seasonal O_3 exposure levels were well below the 17 ppm-hrs. level that EPA referenced in the final 2015 O_3 NAAQS rulemaking. The figure below shows the seasonal exposure levels at each monitoring station for each 3-month period during the year.

Figure 2-4. Weighted Seasonal O3 Exposure by Monitoring Station and 3-month period, 2020 (W126 ppm-hrs.)



3 Temporal Analysis

In the 2010-2015 Conceptual Model for the region, CAPCOG included a number of temporal analyses of O_3 in the region. CAPCOG performed similar analyses of the 2016-2020 data for most of these analyses, including:

- The earliest and latest dates of the year when high O_3 levels were recorded;
- The distribution of high O_3 days by month;
- The distribution of high O_3 days by day of the week; and
- The distribution of high O_3 days by start time for MDA8 O_3.

CAPCOG compared the 2020 data to the 2010-2019 data in order to evaluate whether there was evidence of a difference in the temporal patterns of 2020's regional MDA8 O_3 values.

3.1 Earliest and Latest Dates for High O_3

One of the key issues for CAPCOG to understand is when are the earliest and latest dates in the year that high MDA8 O_3 levels were recorded. Since CAPCOG only operates its monitors seasonally and TCEQ operates theirs year-round, CAPCOG needs to understand the appropriate start and end dates for its monitoring activities. "High O_3" levels for this analysis include:

- Days when the highest MDA8 O_3 value recorded in the region was ≥55 ppb
- Days when the highest MDA8 O_3 value recorded in the region was >70 ppb
- Days that were among the four highest MDA8 O_3 values at the region's regulatory monitoring stations (i.e., considered in determining whether the area is in compliance with the NAAQS)
- Days that were among the 10 highest MDA8 O_3 values at the region's regulatory monitoring stations (i.e., would be potentially used for attainment modeling using EPA's most recent draft modeling guidance if the values were ≥60 ppb)

The following table summarizes the earliest and latest calendar dates that met these criteria for 2010-2020.

Table 3-1. Earliest and Latest Dates for High MDA8 O_3 in the CAPCOG Region

MDA8 O_3	2010-2015	2016	2017	2018	2019	2020
Regional Peak ≥55 ppb	2/10 – 11/8	2/11 – 10/27	2/22 – 10/26	3/13 – 8/23	3/17 – 11/18	4/1 – 11/18
Regional Peak >70 ppb	3/25 – 10/17	10/3 – 10/3	5/6 – 9/13	4/28 – 8/3	7/26 – 9/6	5/18 – 8/18
CAMS 3 Top 4	4/13 – 10/24	2/12 – 10/3	5/6 – 9/1	5/7 – 8/2	3/22 – 9/6	N/A
CAMS 3 Top 10	3/13 – 10/25	2/12 – 10/3	4/7 – 9/13	4/28 – 8/3	3/21 – 10/5	N/A
CAMS 38 Top 4	5/2 – 10/24	2/12 – 10/2	5/6 – 9/13	4/28 – 8/3	4/9 – 9/6	5/1 – 8/18
CAMS 38 Top 10	3/13 – 10/26	2/12 – 10/2	4/7 – 9/13	4/24 – 8/3	3/22 – 10/6	5/1 – 10/13

Since CAMS 3 was offline for the majority of the year, the highest values and their occurrence dates are not consistent with previous years. Therefore, the CAMS 3 dates are not applicable (N/A) for Table 3-1. The 2020 data for "moderate" O_3 levels (≥55 ppb) was not in line with previous years since "moderate" levels were not recorded until April when in the past February and March have seen such levels. However, the 2020 data for "moderate" levels was consistent in that such levels were recorded as late as November, which was observed in 2019 as well. CAPCOG's monitoring program typically runs through November 15th, so, this data point may prompt a re-evaluation of the timeframe for CAPCOG to conduct monitoring in the future.

3.2 High O_3 Days by Month

The following tables show the number of days when MDA8 O_3 values were 55-70 ppb and >70 ppb by month between 2010-2020.

Figure 3-1. Percentage of Days with MDA8 O_3 Values of 55-70 ppb by Month

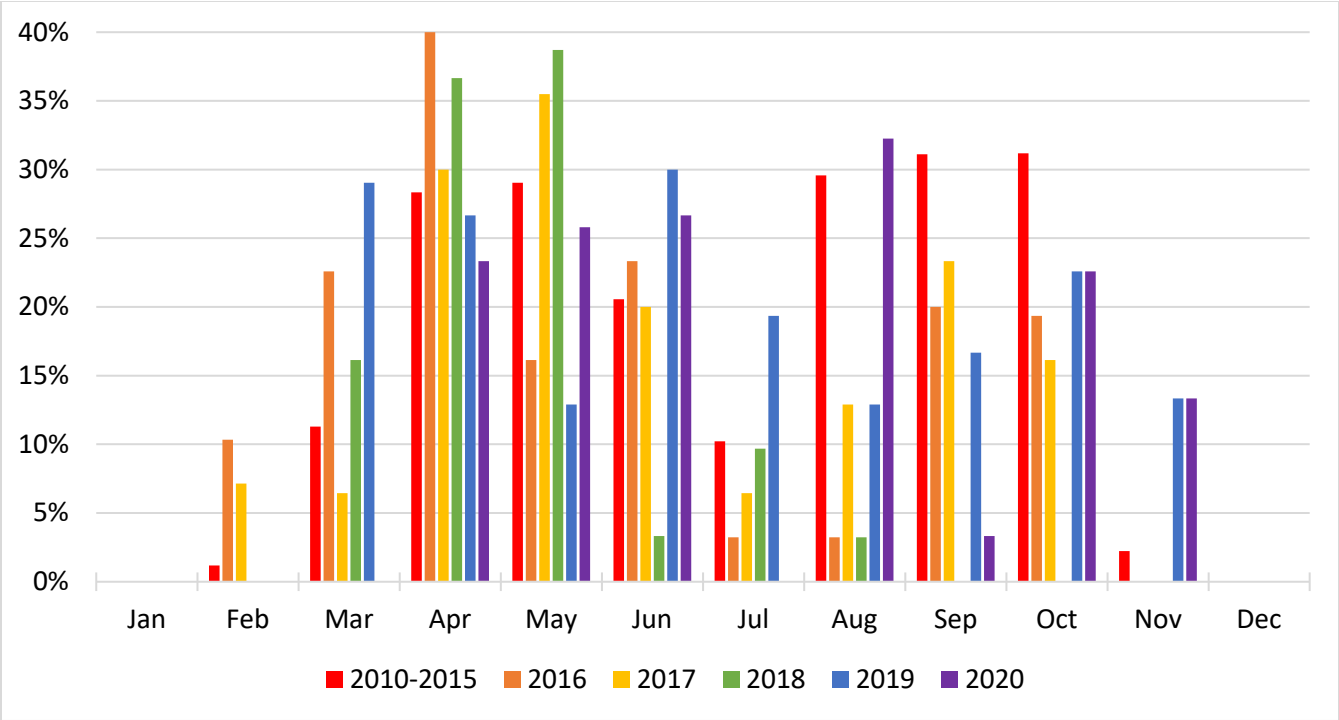
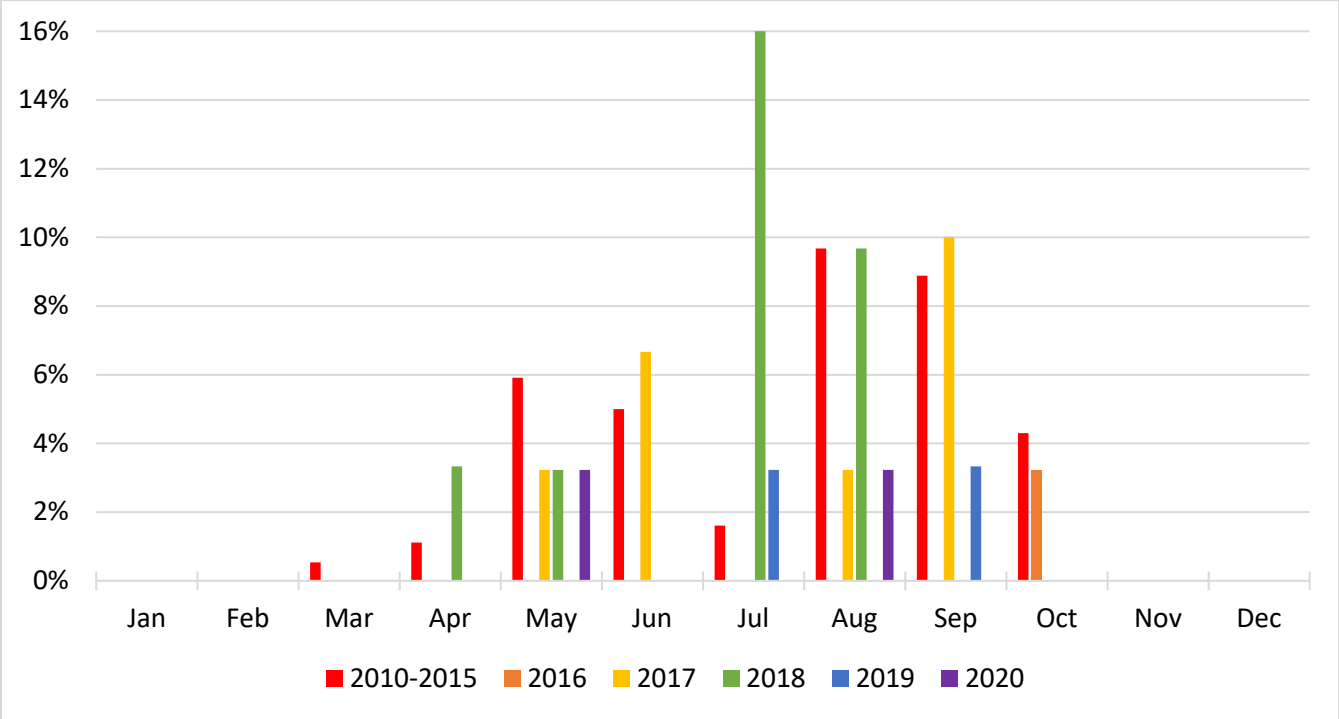


Figure 3-2. Percentage of Days with MDA8 O_3 Values of >70 ppb by Month



The lack of high O_3 data (>70 ppb) in 2020 is notable, especially compared to multiple high days in the past. MDA8 O_3 levels exceeded 70 ppb twice in 2020, which is in line with data from 2019. In the past years, MDA8 O_3 values reached 55 ppb or higher in February and March. However, MDA8 O_3 values in 2020 did not reach 55 ppb until April. On other hand, the latest MDA8 O_3 values for 2020 were recorded in November which is consistent with 2019.

3.3 High O_3 Days by Day of the Week

CAPCOG analyzed the frequency of high O_3 days by day of the week. The following figures show the percentage of days when the highest MDA8 O_3 levels in the region were ≥55 ppb and >70 ppb.

Figure 3-3. Distribution of MDA8 O_3 55 ppb or Above by Day of the Week

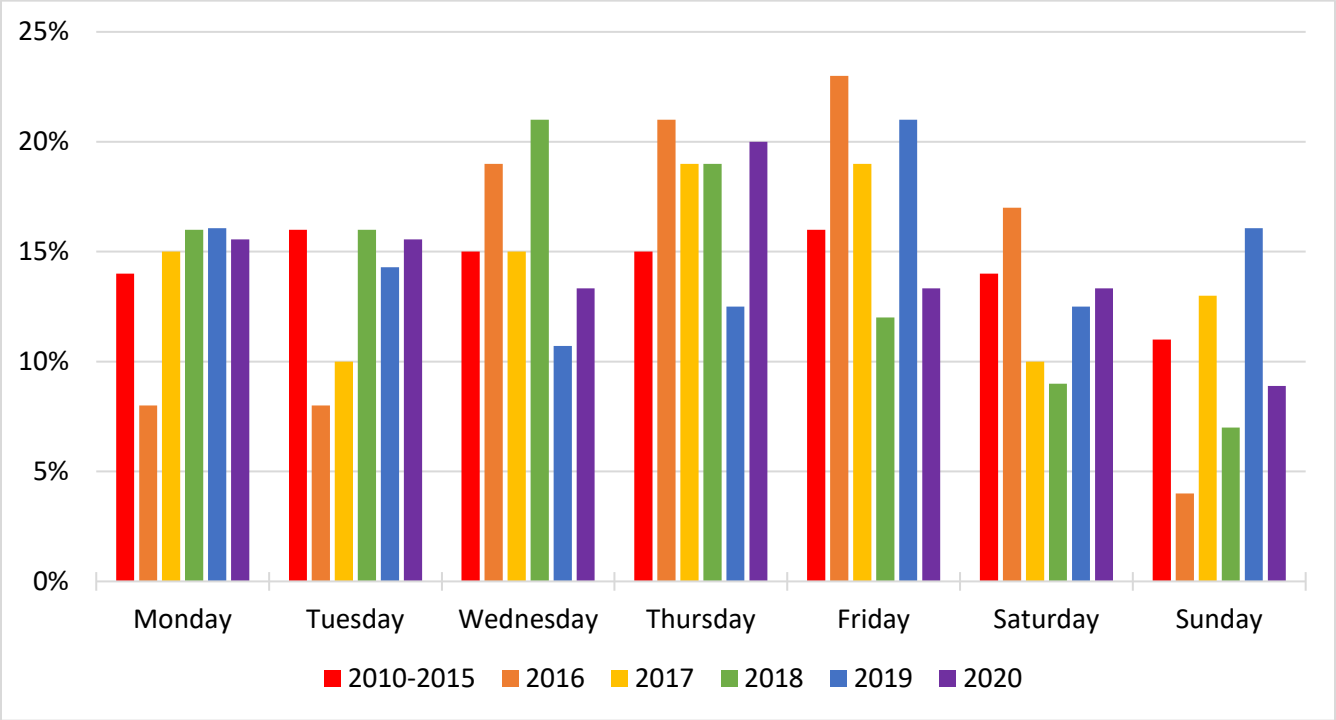
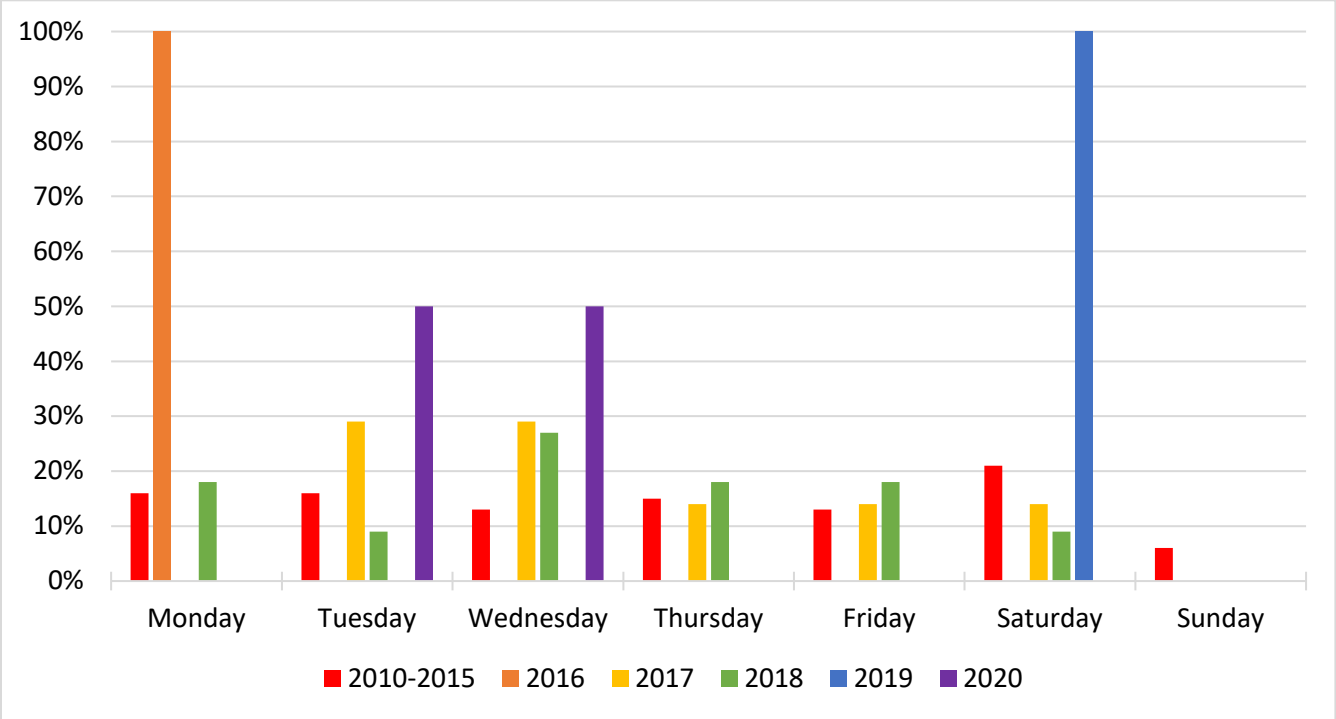


Figure 3-4. Distribution of MDA8 O_3 above 70 by Day of the Week

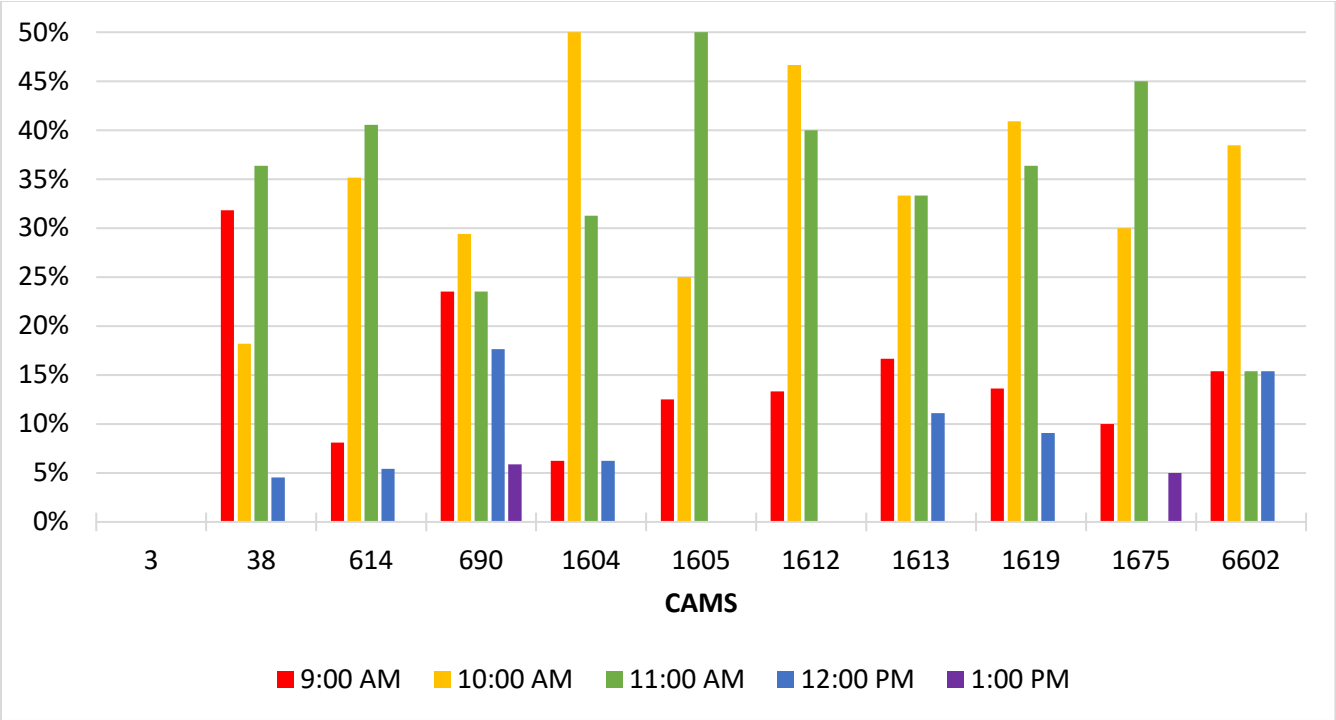


In 2020, the daily distribution for O_3, that was ≥55 ppb, indicates that moderate levels of O_3 occurred on all days of the week, with Thursday having a slightly larger percentage. There were only 2 days in 2020 that experienced O_3 greater than 70 ppb, and those days occurred on Tuesday and Wednesday. As evident in Figure 3-4, high O_3 days can occur any day of the week.

3.4 Start Hour for MDA8 O_3 ≥ 55 ppb

One of the temporal factors evaluated in the most recent conceptual model was the distribution of start hours for high MDA8 O_3 values. The following figure shows these distributions for each monitoring station in 2020. As the figure shows, 10 am and 11 am were the most common start hours for MDA8 O_3 values that are ≥55 ppb at all monitoring stations. Since CAMS 3 was not operational for the majority of the year, it did not measure MDA8 O_3 values that are ≥55 ppb, so this analysis is not applicable for CAMS 3.

Figure 3-5. Distribution of Start Hour for MDA8 O_3 ≥55 ppb by Monitoring Station, 2020



In the figures below, CAPCOG compared the distribution of start hours in 2020 to what was observed in 2010-2019 for MDA8 O_3 ≥55 ppb at each monitor. The individual monitor trends follow the pattern of the most frequent start hour at 10 am or 11 am. As mentioned previously, there is no analysis for CAMS 3 due to the lack of data.

Figure 3-6. Start Hour for MDA8 O_3 ≥55 ppb at CAMS 38, 2010-2020

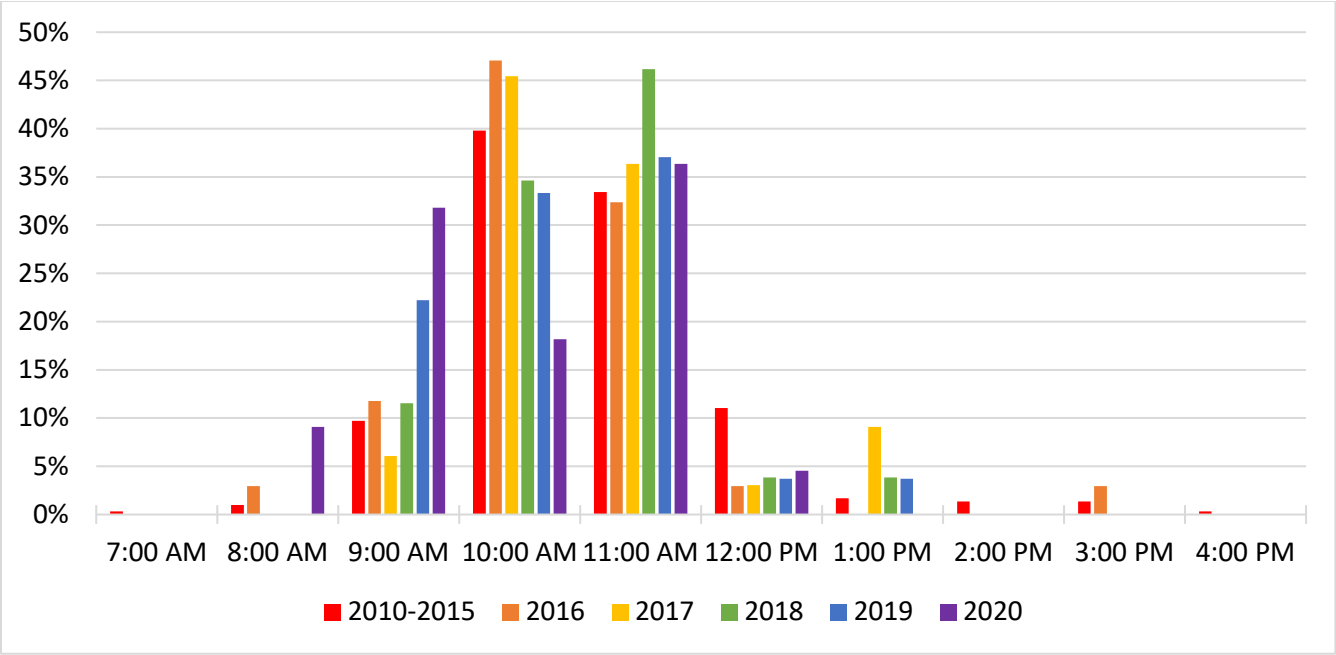


Figure 3-7. Start Hour for MDA8 O_3 ≥55 ppb at CAMS 614, 2010-2020

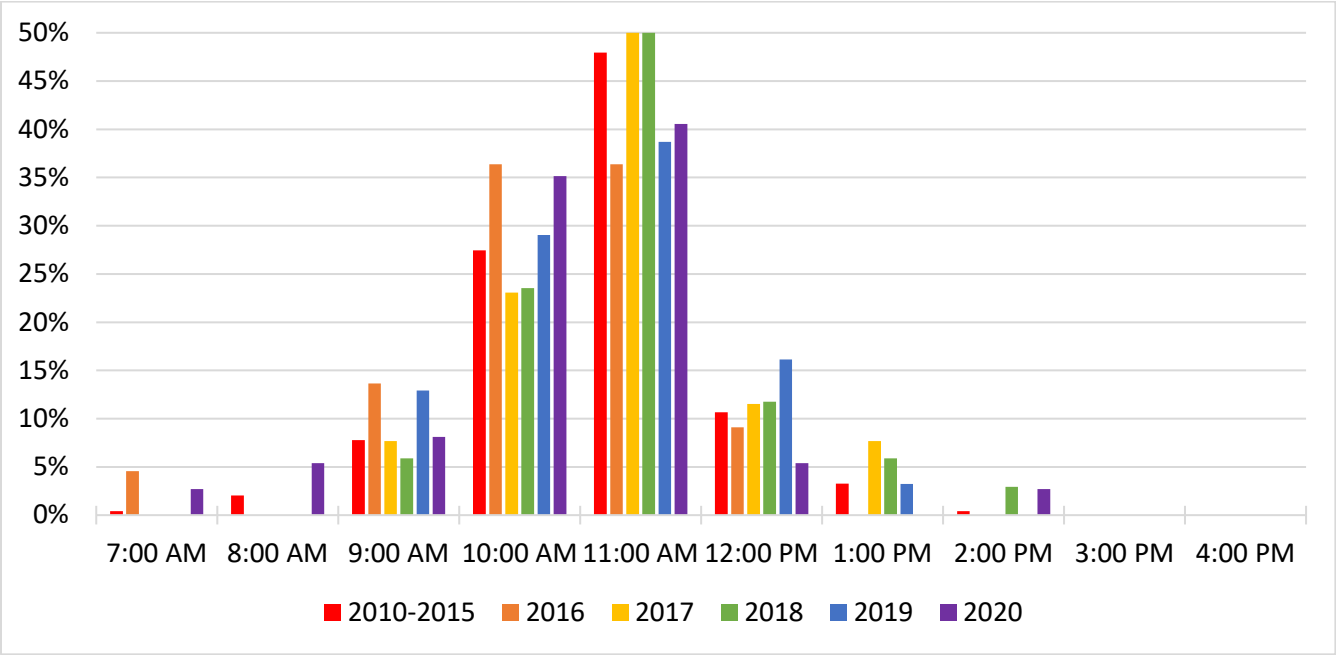


Figure 3-8. Start Hour for MDA8 O_3 ≥55 ppb at CAMS 690, 2010-2020

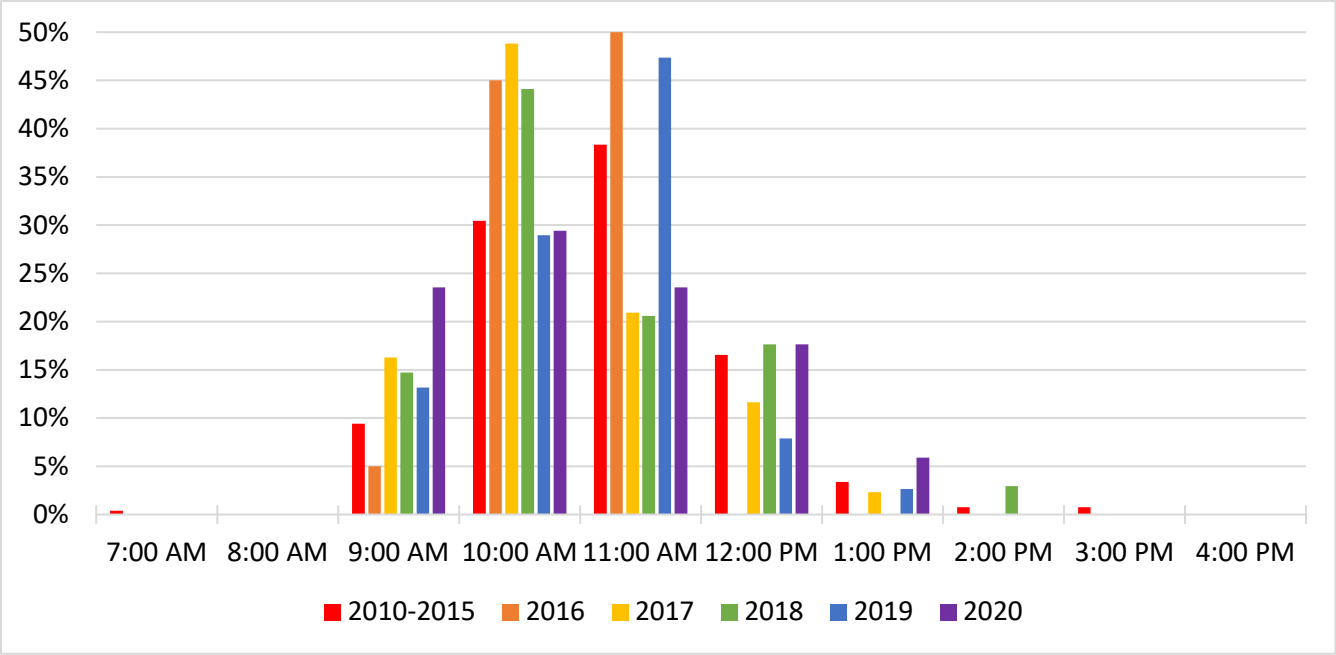


Figure 3-9. Start Hour for MDA8 O_3 ≥55 ppb at CAMS 1604, 2010-2020

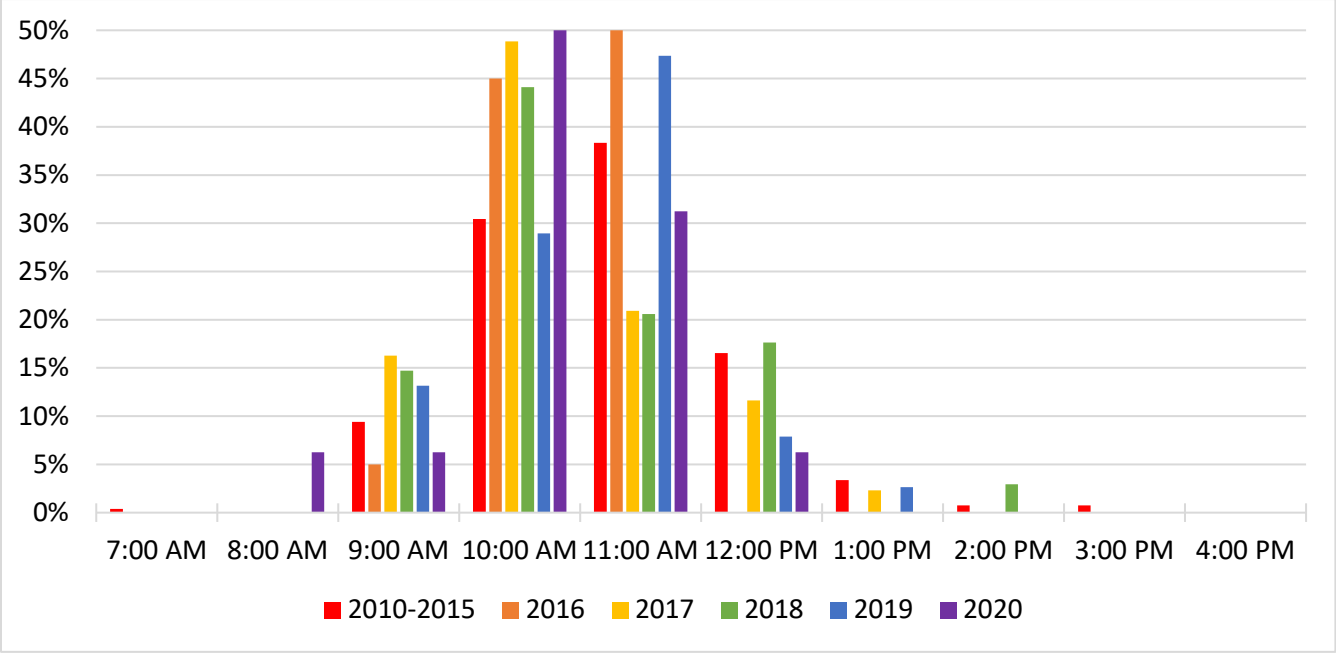


Figure 3-10. Start Hour for MDA8 O_3 ≥55 ppb at CAMS 1612, 2019-2020

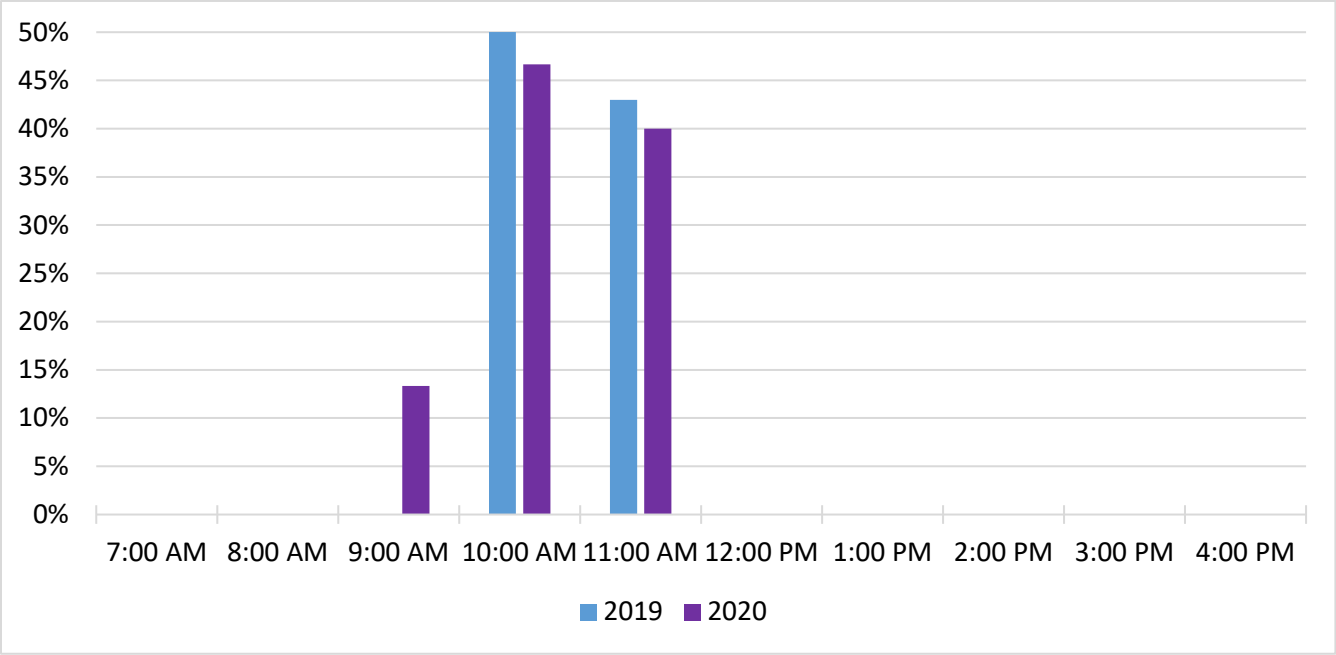


Figure 3-11. Start Hour for MDA8 O_3 ≥55 ppb at CAMS 1613, 2019-2020

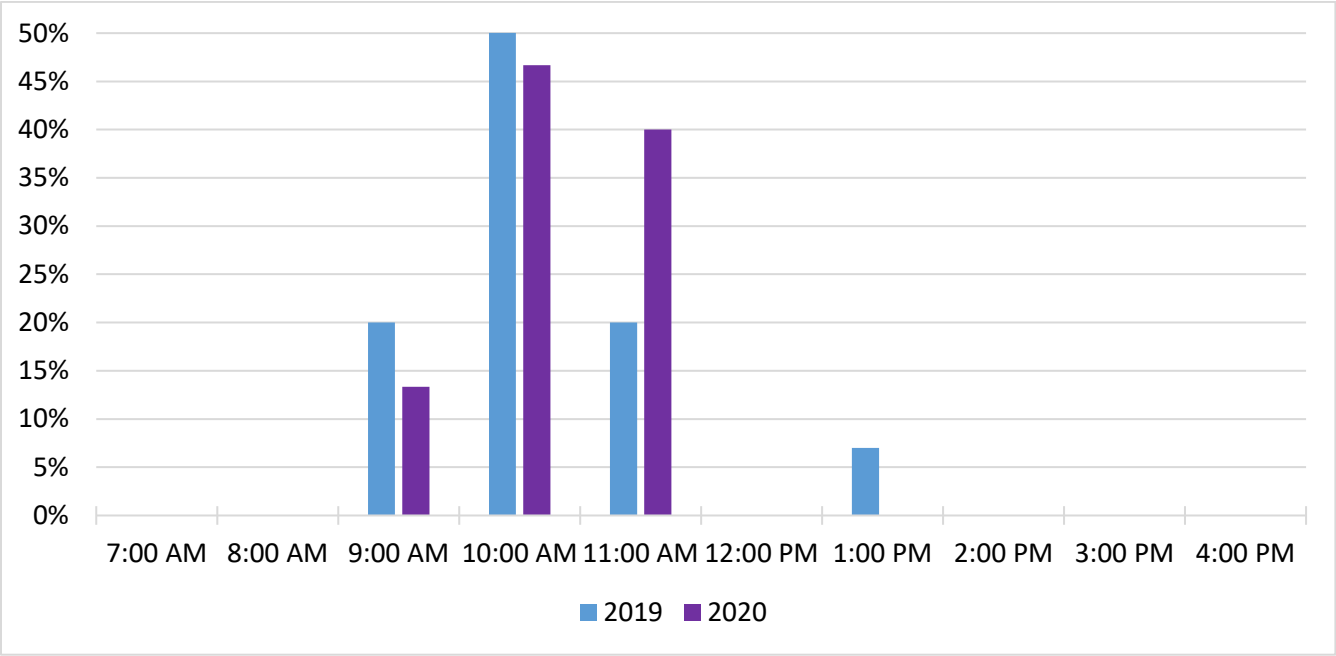


Figure 3-12. Start Hour for MDA8 O_3 ≥55 ppb at CAMS 1619, 2020

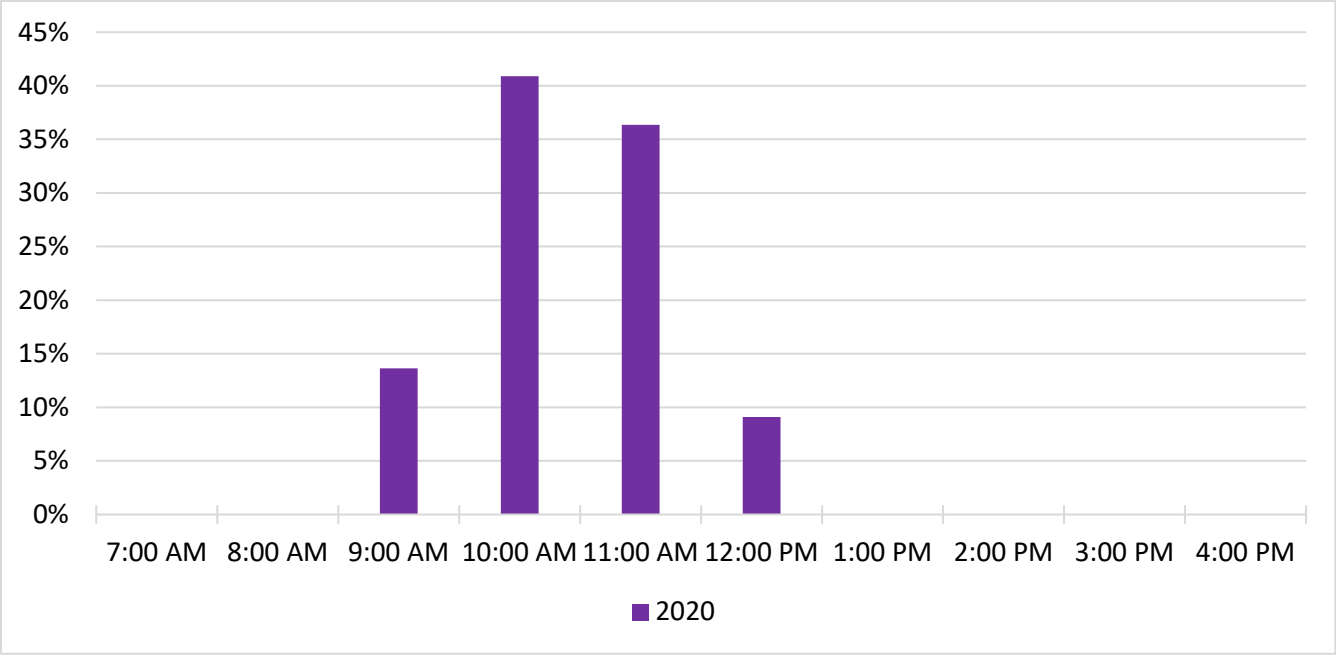


Figure 3-13. Start hour for MDA8 O_3 ≥55 ppb at CAMS 1675, 2010-2020

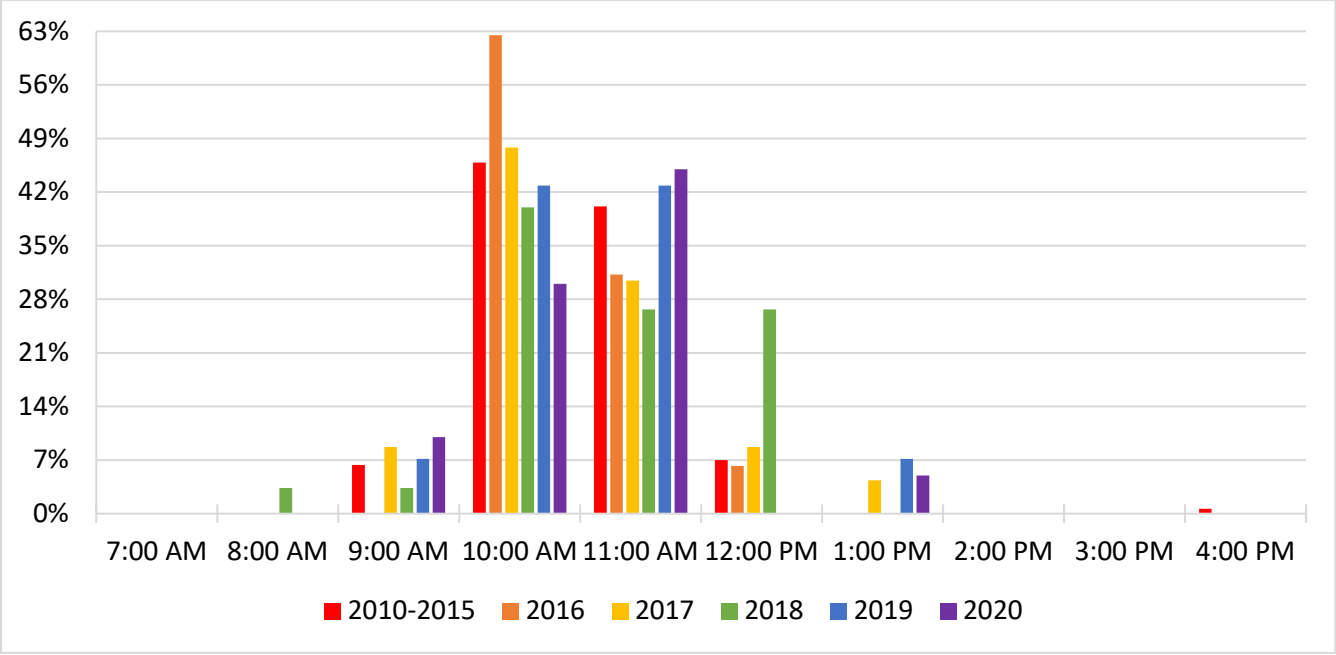
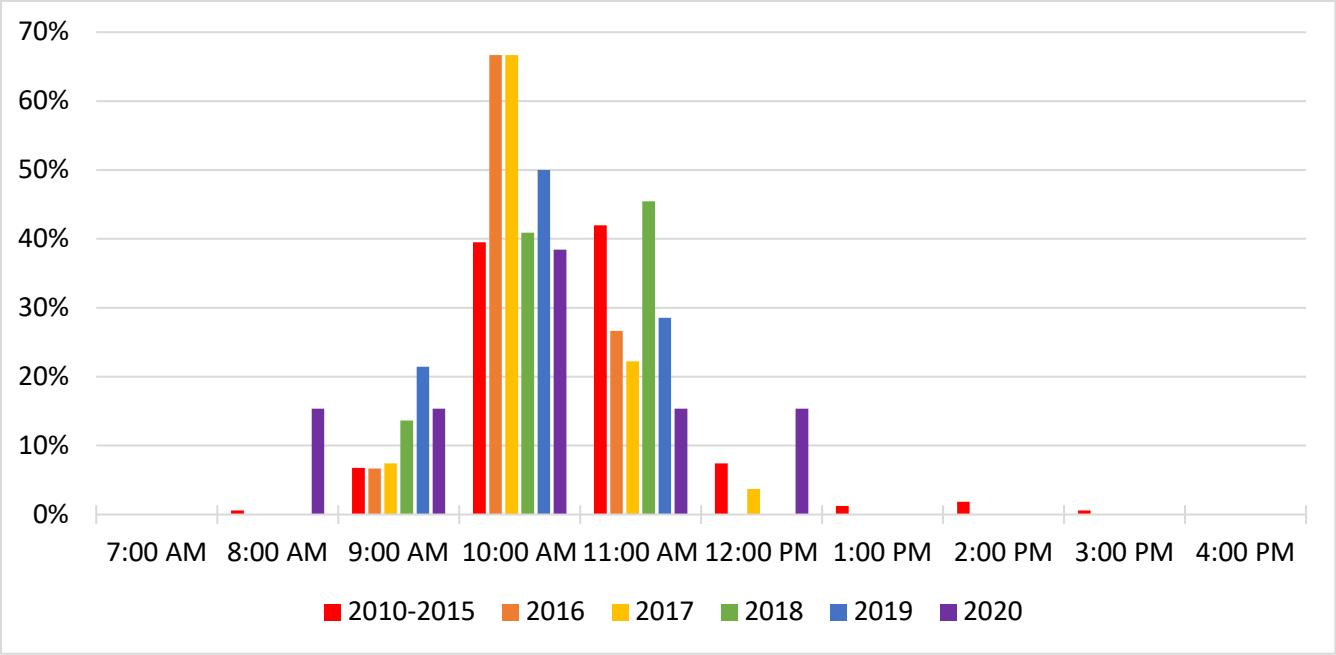


Figure 3-14. Start Hour for MDA8 O_3 ≥55 ppb at CAMS 6602, 2010-2020



4 METEOROLOGICAL FACTORS

In the most recent conceptual model for the region covering 2010-2015, CAPCOG evaluated a variety of potential meteorological factors that could influence the MDA8 O_3 values throughout the region, including:

- Average wind speed (WS) between 12 pm and 4 pm at each monitoring station;
- Average temperature between 12 pm and 4 pm at each monitoring location;
- Diurnal temperature changes at each monitoring location;
- Average relative humidity (RH) between 12 pm and 4 pm at all monitoring locations;
- Average solar radiation (SR) between 12 pm and 4 pm at each monitoring location; and
- Wind back trajectories on MDA8 O_3 values >70 ppb.

CAPCOG used the 12 pm – 4 pm time frame based on these being the four hours with the highest average 1-hour O_3 levels on days when MDA8 O_3 levels were >70 ppb at CAMS 3 between 2010-2015. Also, CAPCOG included the 8 am – 12 pm period for wind direction (WD) based on this time frame including all of the start hours for MDA8 O_3 values >70 ppb at CAMS 3 and CAMS 38 between 2010-2015.

In CAPCOG's most recent conceptual model, CAPCOG used groupings of >70 ppb, 55-70 ppb, and <55 ppb. CAPCOG used confidence interval tests and chi-squared (χ^2) tests of independence in order to determine whether there were significant statistical differences between the actual distribution and the expected distribution given the data for all days.

For this section, CAPCOG analyzed:

- MDA8 O_3 at CAMS 38 for 2020 and CAMS 3 for 2010-2019
- Wind speed and temperature data at CAMS 38 for 2020 and CAMS 3 for 2010-2019
- Relative humidity (RH) data at Camp Mabry (CAMS 5002) due to lack of RH data at CAMS 38
- Solar radiation data at CAMS 38 (only monitoring station that includes solar radiation measurements)

For these analyses, CAMS 3 data have been used in the past due to it being the region's primary O_3 monitor. However, since CAMS 3 was not collecting data for the majority of 2020, the CAMS 38 data are used. Since CAMS 3 and CAMS 38 have shown similar relationships in the past, the CAMS 3 data are presented for 2010-2019 to use in comparison for the 2020 data from CAMS 38.

4.1 WIND SPEED

CAPCOG's most recent O_3 conceptual model showed that average wind speeds between 12 pm-4 pm had a negative correlation with MDA8 O_3. In CAPCOG's 2010-2015 Conceptual Model, CAPCOG analyzed the data for 12-4 pm in order to limit the analysis to just the hours that typically included the peak O_3 concentrations for the day. The regression analyses that CAPCOG conducted on the relationship between O_3, meteorological factors, day of week, and year at CAMS 3 and CAMS 38, showed similar statistical impacts of wind speed on MDA8 O_3 values: -0.18 ppb/mph at CAMS 3 and -0.20 ppb/mph at CAMS 38.

Given this relationship, CAPCOG conducted a variety of statistical analyses to evaluate whether the 2020 wind speeds were statistically different from wind speeds observed 2010-2019 and the relationship between O_3 and wind speed observed between 2010-2019.

4.1.1 Comparison of Relationship between Wind Speed and MDA8 O_3 in 2020 to 2010-2019

The figures below show the relationship between observed wind speeds and observed MDA8 O_3 values at CAMS 3 for 2010-2019 and CAMS 38 for 2020. All trend lines have a small slope which show that there is not a strong negative or positive relationship. 2020 follows the relationship seen in the 2016-2018 which shows a slight positive relationship in wind speed to MDA8 O_3.

Figure 4-1. Scatter Plot of 12 pm – 4 pm Wind Speed at CAMS 3 v. MDA8 O_3 at CAMS 3, 2010-2015

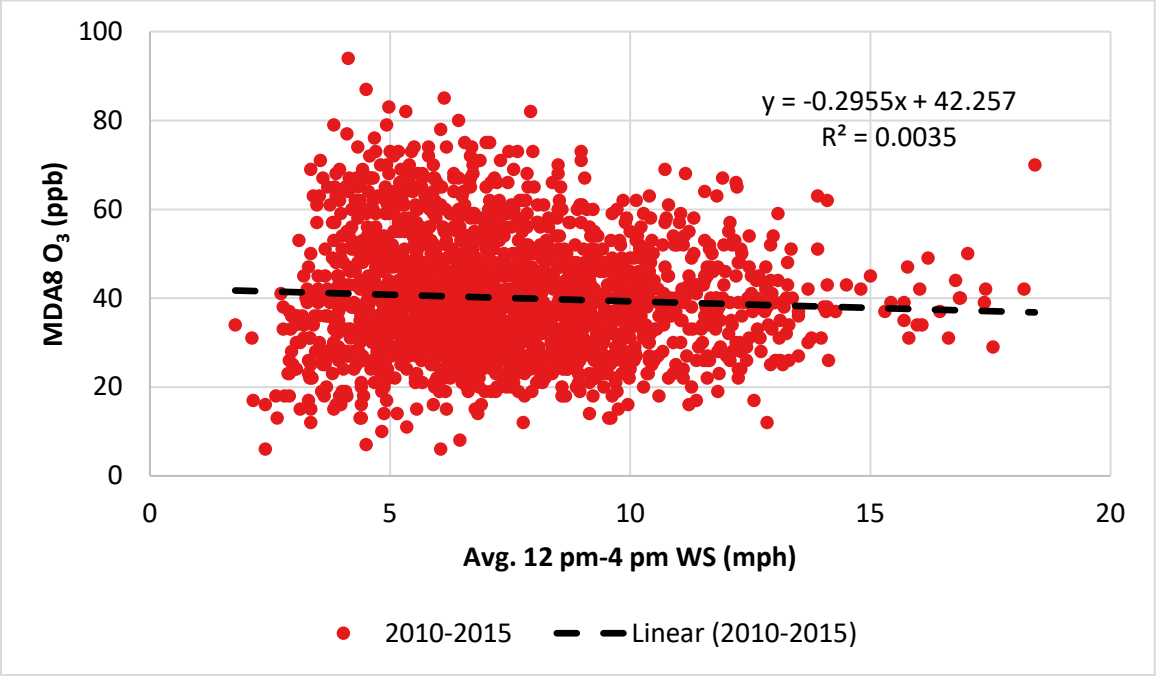


Figure 4-2. Scatter Plot of 12 pm – 4 pm Wind Speed at CAMS 3 v. MDA8 O_3 at CAMS 3, 2016

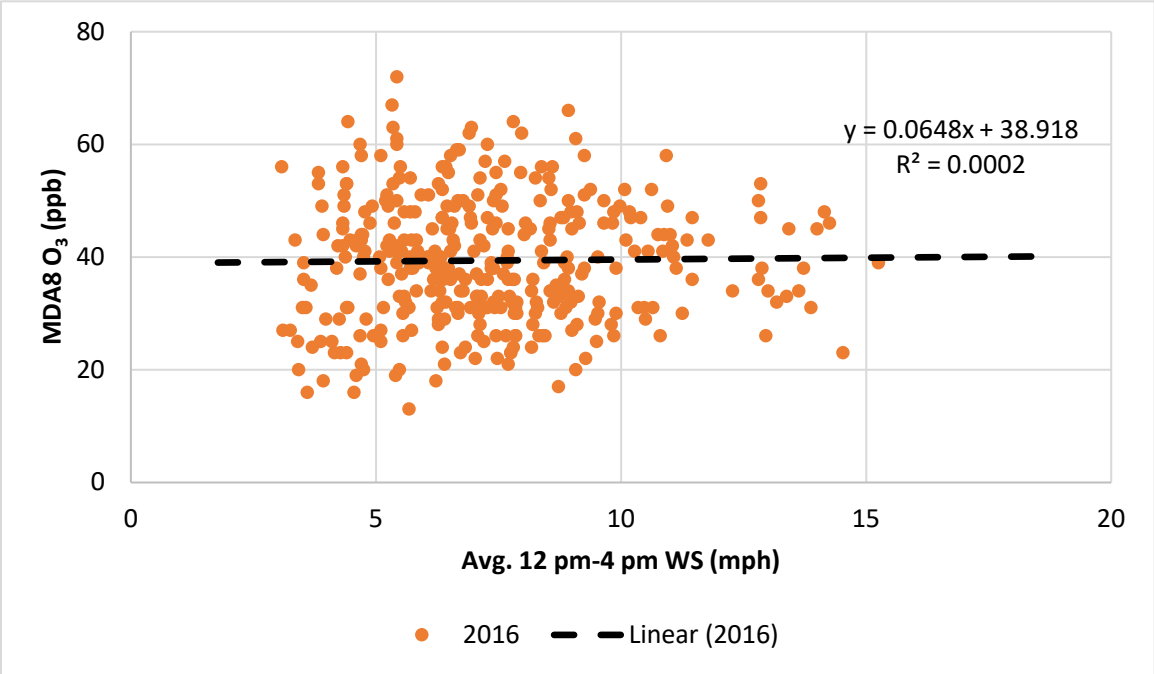


Figure 4-3. Scatter Plot of 12 pm – 4 pm Wind Speed at CAMS 3 v. MDA8 O_3 at CAMS 3, 2017

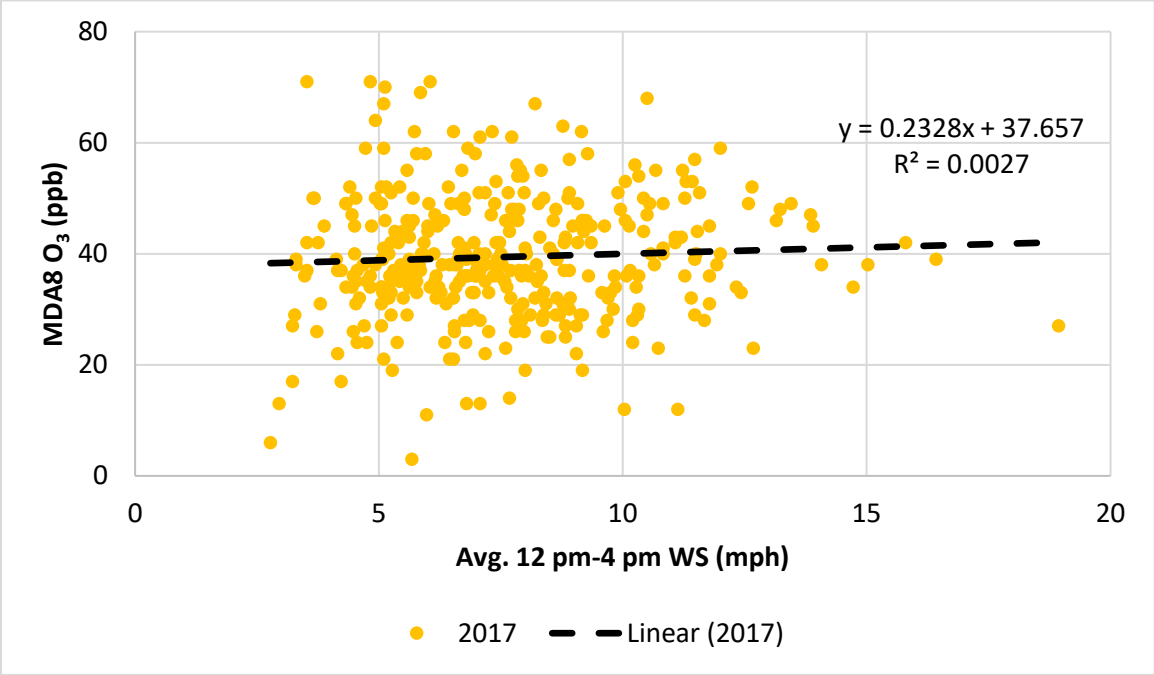


Figure 4-4 Scatter Plot of 12 pm – 4 pm Wind Speed at CAMS 3 v. MDA8 O_3 at CAMS 3, 2018

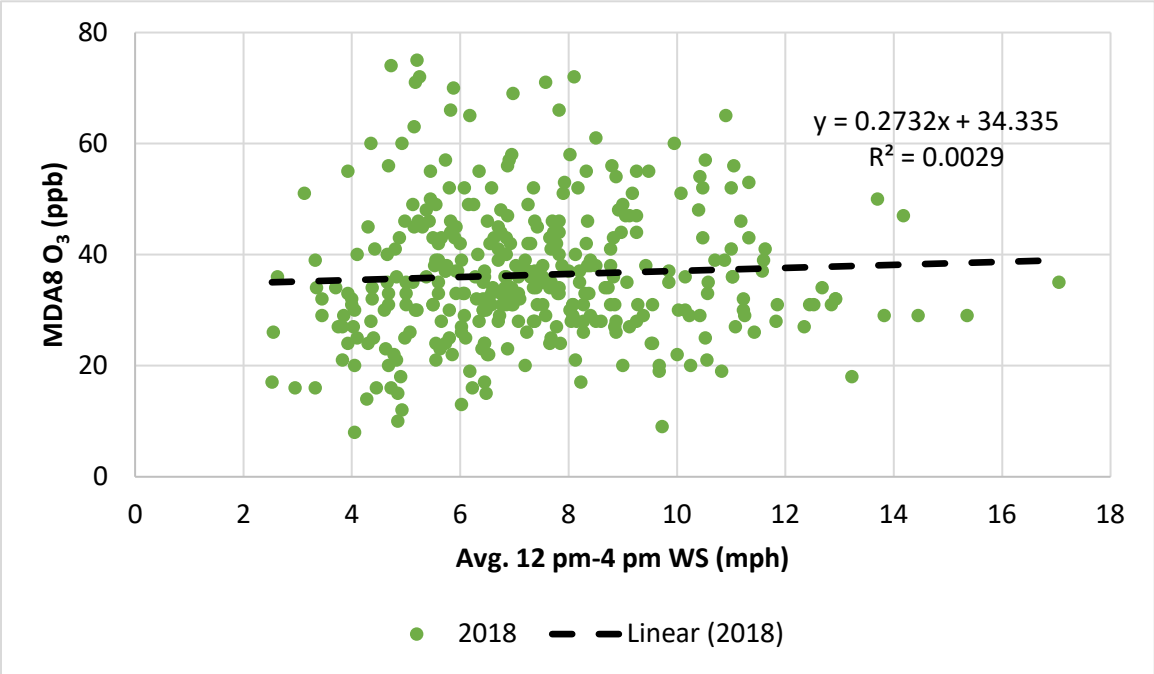


Figure 4-5. Scatter Plot of 12 pm – 4 pm Wind Speed at CAMS 3 v. MDA8 O_3 at CAMS 3, 2019

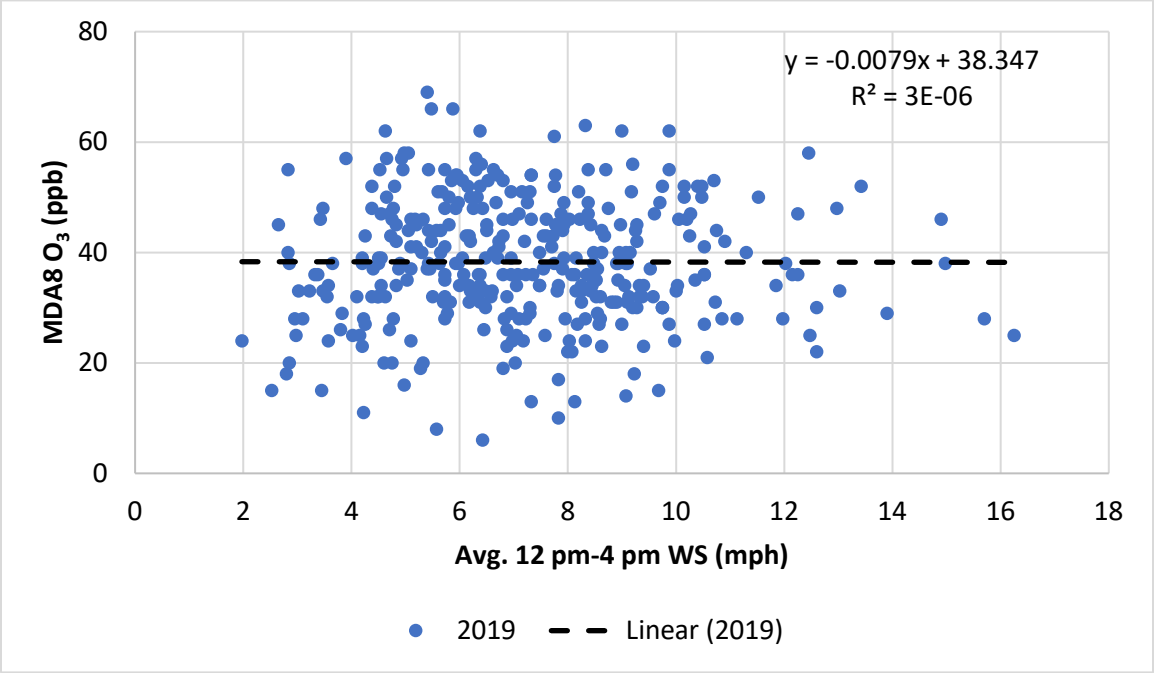
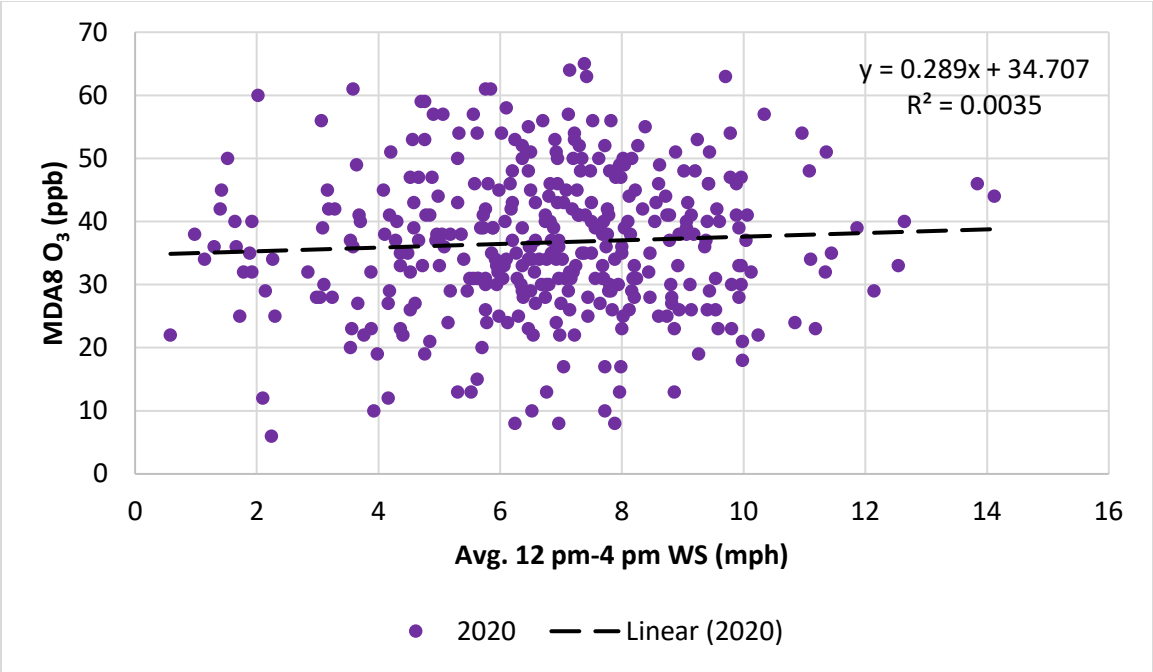
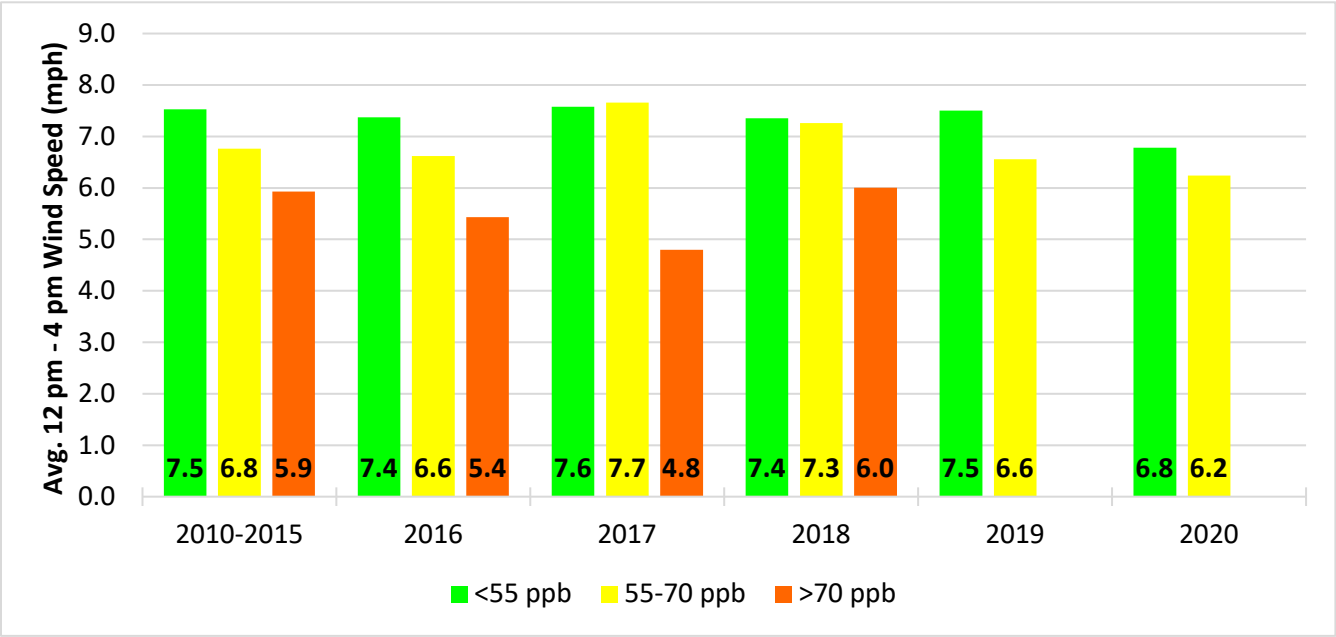


Figure 4-6. Scatter Plot of 12 pm – 4 pm Wind Speed at CAMS 38 v. MDA8 O3 at CAMS 38, 2020



The figure below shows a comparison of the typical wind speeds for the days when MDA8 O_3 values were <55 ppb, 55-70 ppb, and >70 ppb at CAMS 38 in 2020 compared to data from CAMS 3 for 2010-2019. Since there were no days with MDA8 O_3 that were >70 ppb at CAMS 38 in 2020 nor CAMs 3 in 2019, the figure below does not contain the average wind speed for that interval.

Figure 4-7. Typical Wind Speed 12 pm – 4 pm on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 3, 2010-2019, and CAMS 38, 2020

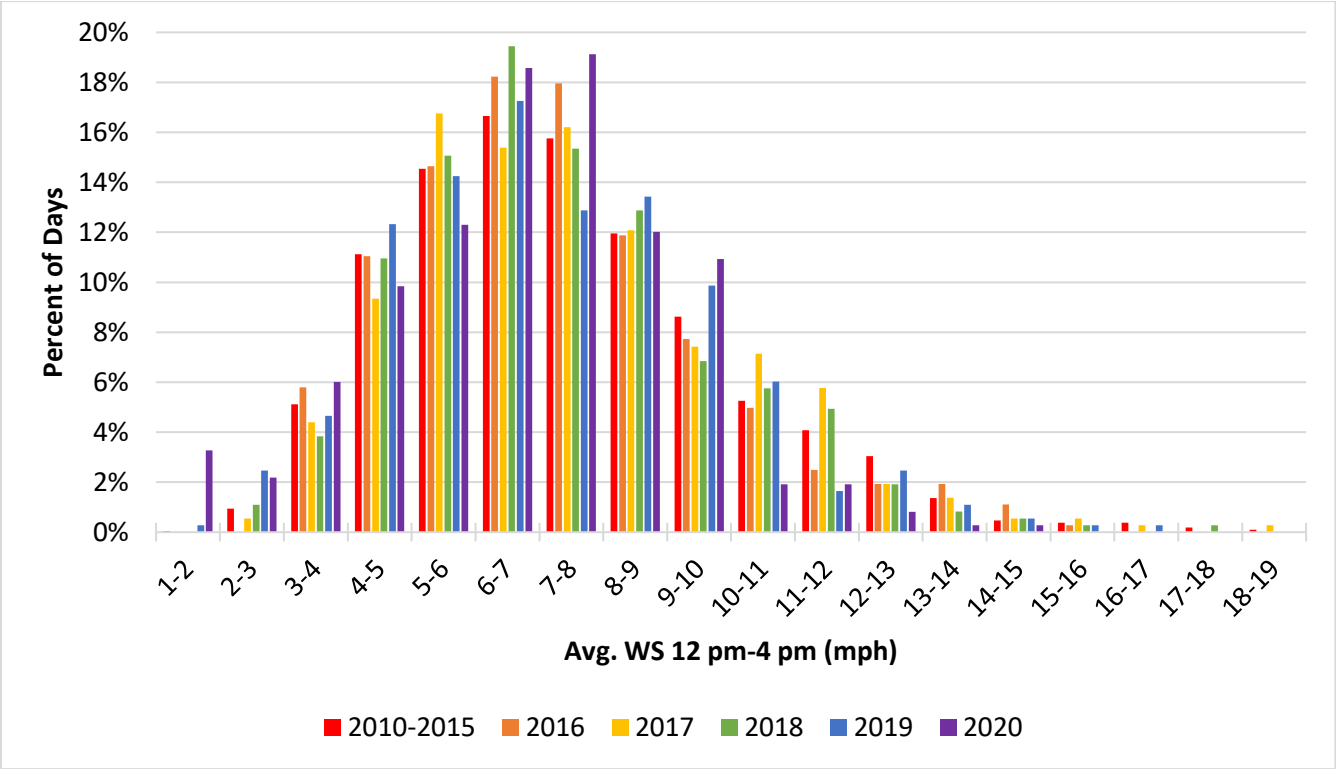


The average wind speed and O_3 concentration relationship for 2020 followed the observed pattern from the past that indicates that lower wind speeds can allow for higher O_3 formation. Although, 2020 data observed at CAMS 38 showed lower average wind speeds overall than in the previous years.

4.1.2 Comparison of 2020 Wind Speeds to 2010-2019 Wind Speeds

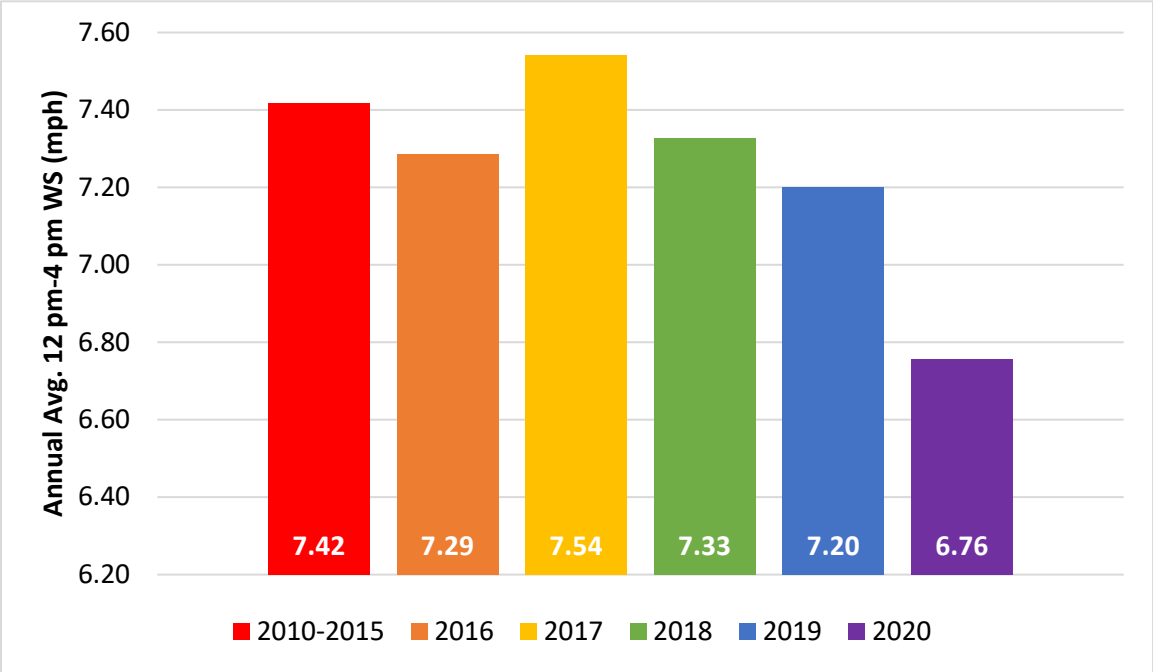
The figure below shows the distribution of daily average wind speeds between 12 pm-4 pm at CAMS 3 for 2010-2019 and CAMS 38 for 2020.

Figure 4-8. Histogram of 12 pm – 4 pm Wind Speeds at CAMS 3, 2010-2029, and CAMS 38, 2020



CAPCOG also tested whether there was a significant difference in the annual average of these daily 12 pm-4 pm wind speed averages. The following figure shows the average for 2010-2020. The graph shows that the average annual wind speed at CAMS 38 for 2020 was lower than the windspeed at CAMS 3 for 2010-2019.

Figure 4-9. Annual Average 12 pm-4 pm Wind Speed at CAMS 3, 2010-2019, and CAMS 38, 2020



4.2 Temperature

CAPCOG's most recent O_3 conceptual model showed that average temperatures between 12 pm-4 pm had a positive correlation with MDA8 O_3. In CAPCOG's 2010-2015 Conceptual Model, CAPCOG analyzed the data from 12 pm-4 pm in order to limit the analysis to just the hours that are typically included the peak O_3 concentrations for the day. The regression analyses that CAPCOG conducted on the relationship between O_3, meteorological factors, day of week, and year at CAMS 3 and CAMS 38, showed similar significant statistical impacts of temperature on MDA8 O_3 values: +0.18 ppb/°F at CAMS 3 and +0.19 ppb/°F at CAMS 38.

Given this relationship, CAPCOG conducted a variety of statistical analyses to evaluate whether the 2020 temperatures were statistically different from temperatures observed 2010-2019 or if the relationship between O_3 and temperature was statistically different than the relationship observed 2010-2019.

4.2.1 Comparison of Relationship between Temperature and MDA8 O_3 in 2019 to 2010-2018

The figures below show a scatter plot with MDA8 O_3 values and average temperatures for 12 pm-4 pm at CAMS 3 for 2010-2019. As the figures show, the 2019 data was consistent in showing a positive correlation between these two factors.

Figure 4-10. Scatter Plot of 12 pm – 4 pm Temperature at CAMS 3 v. MDA8 O_3 at CAMS 3, 2010-2015

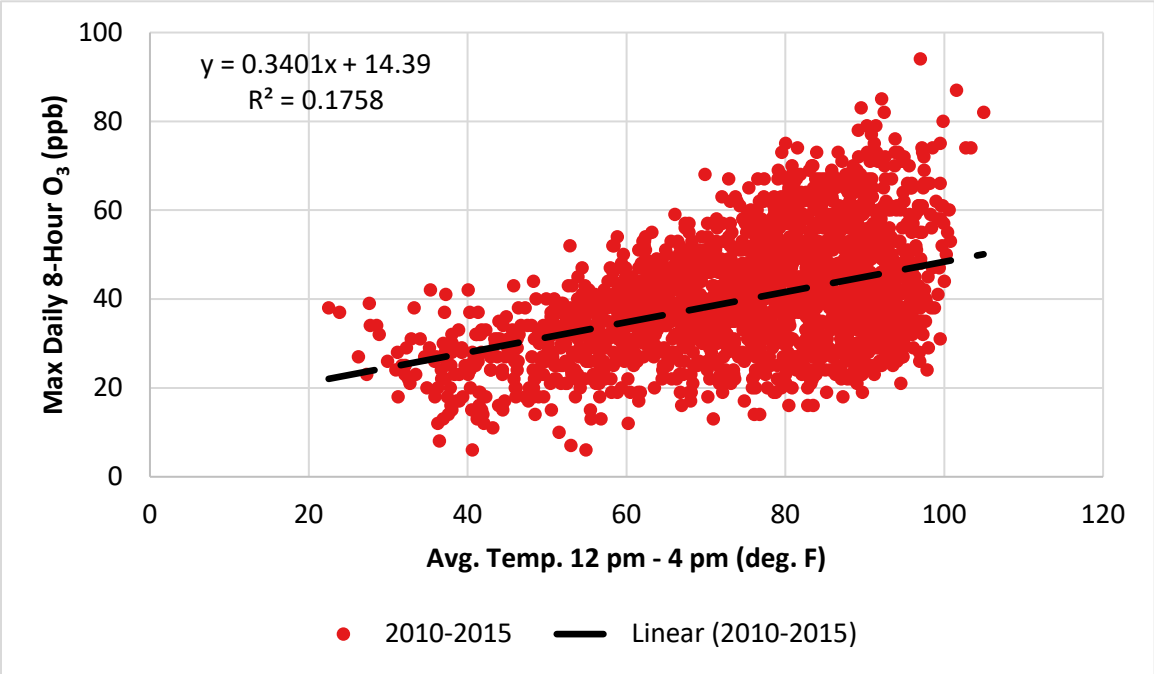


Figure 4-11. Scatter Plot of 12 pm – 4 pm Temperature at CAMS 3 v. MDA8 O_3 at CAMS 3, 2016

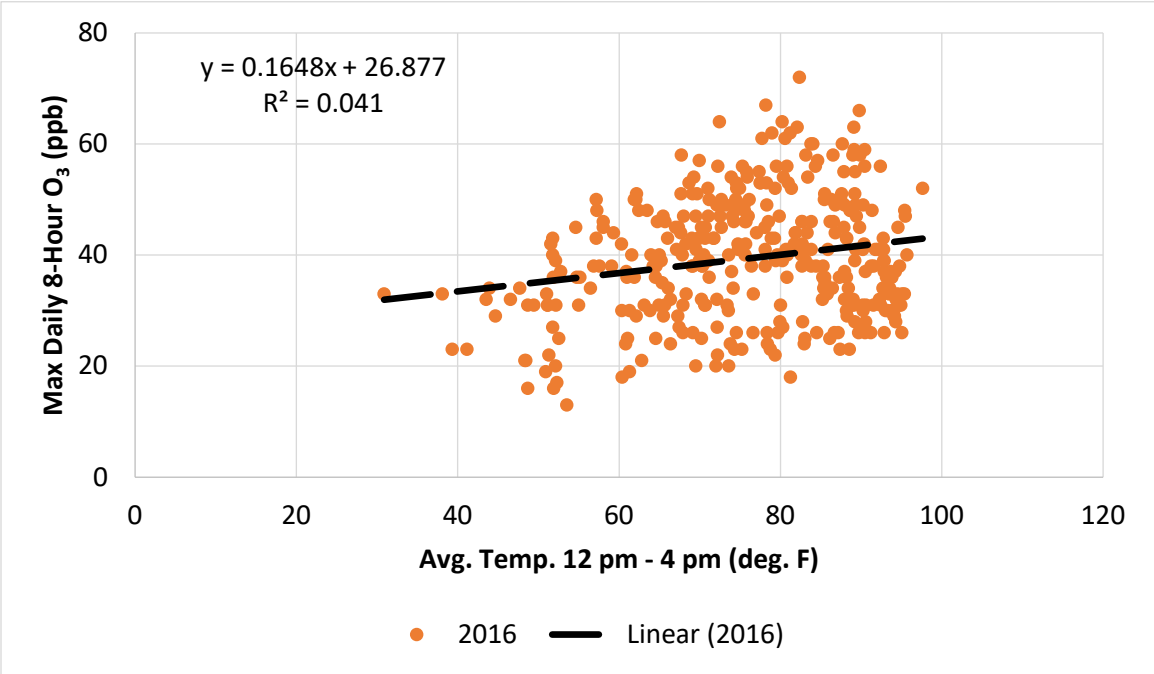


Figure 4-12. Scatter Plot of 12 pm – 4 pm Temperature at CAMS 3 v. MDA8 O_3 at CAMS 3, 2017

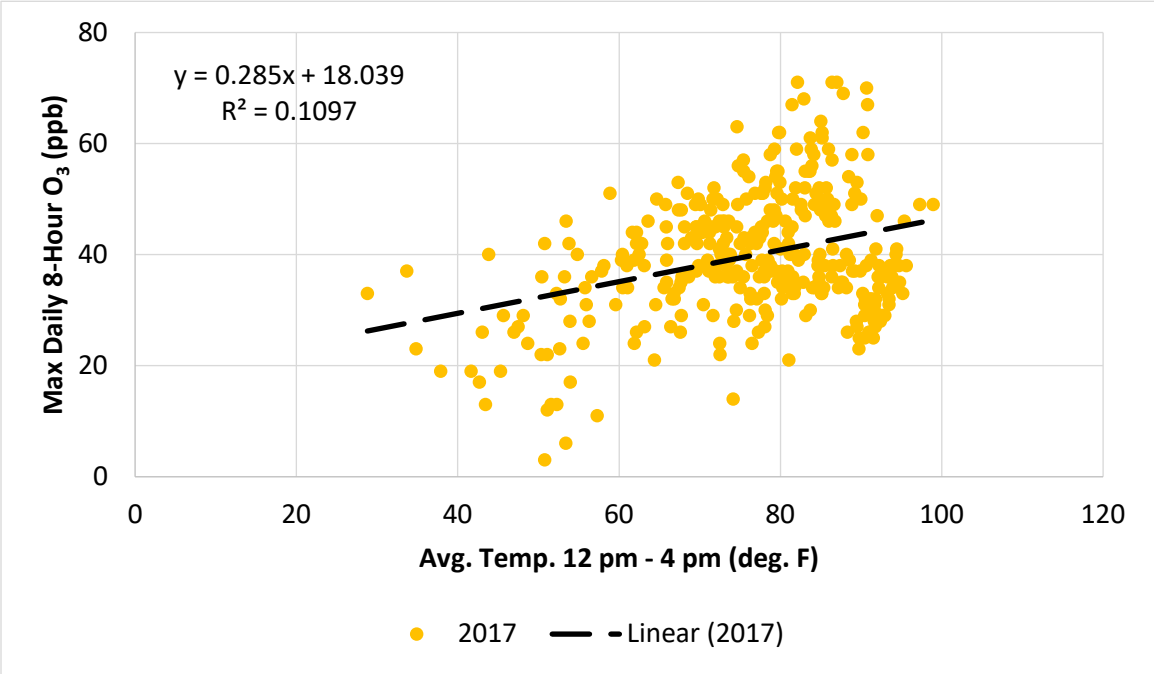


Figure 4-13. Scatter Plot of 12 pm – 4 pm Temperature at CAMS 3 v. MDA8 O_3 at CAMS 3, 2018

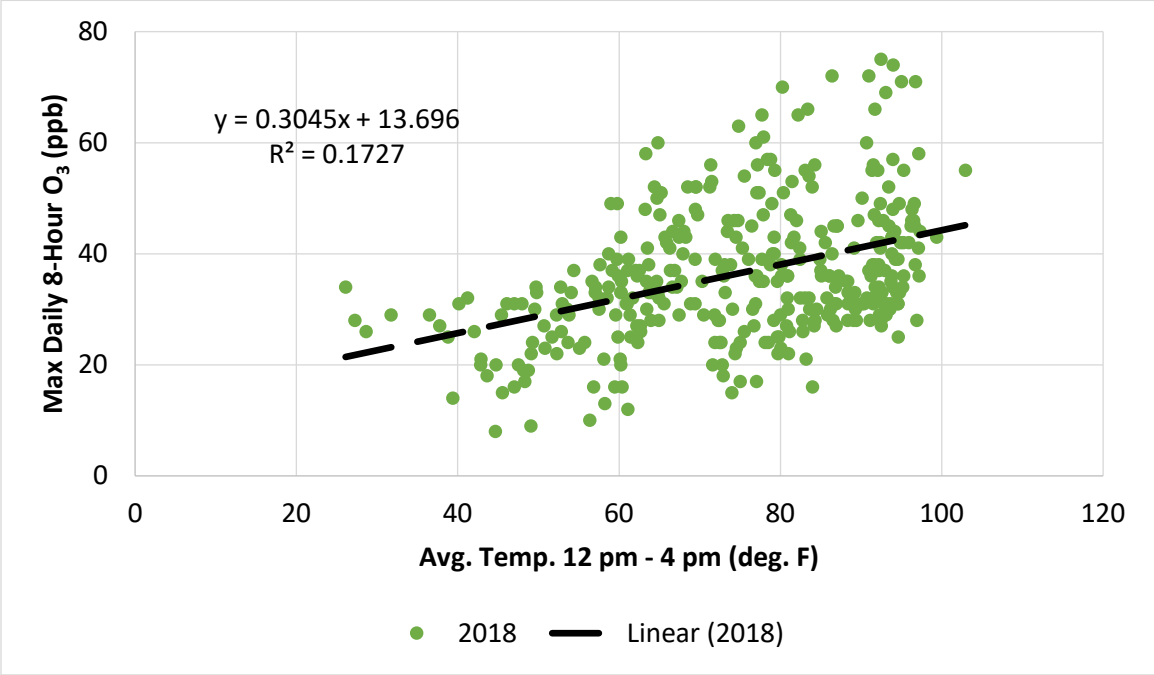


Figure 4-14. Scatter Plot of 12 pm – 4 pm Temperature at CAMS 3 v. MDA8 O_3 at CAMS 3, 2019

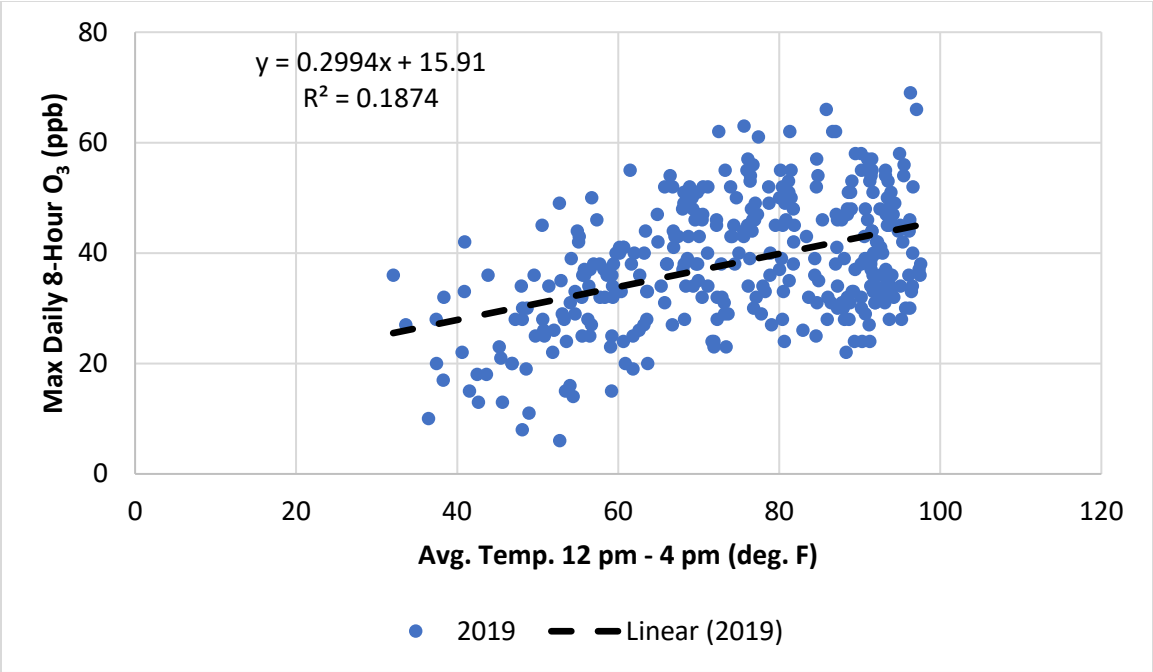
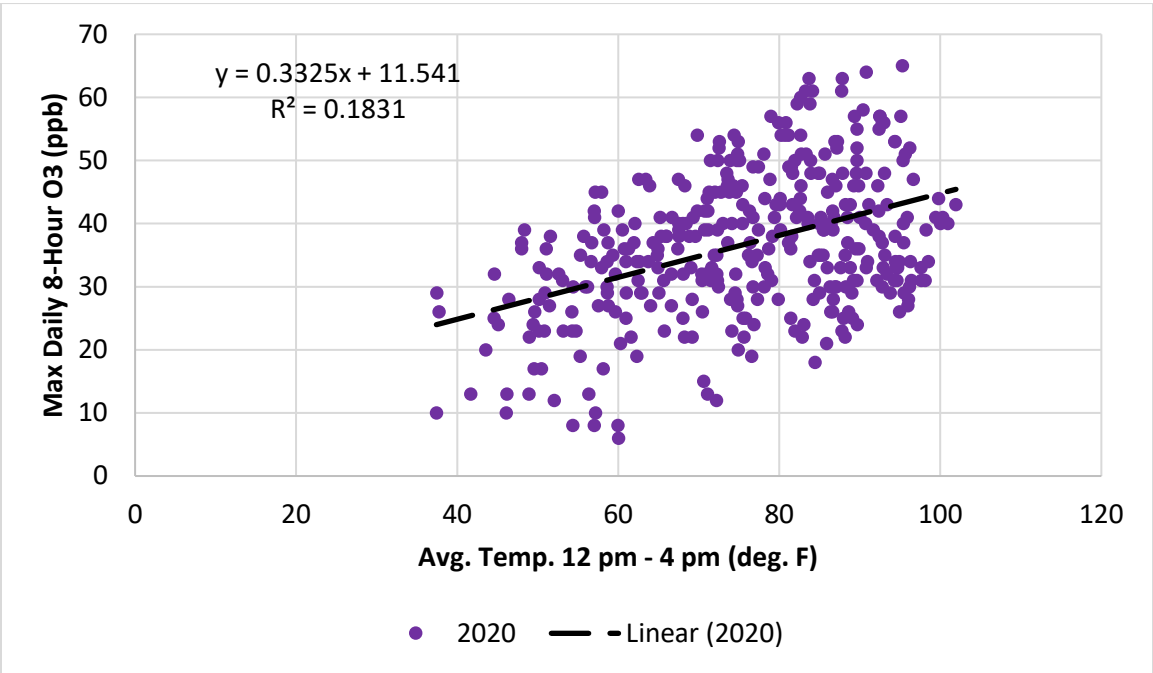
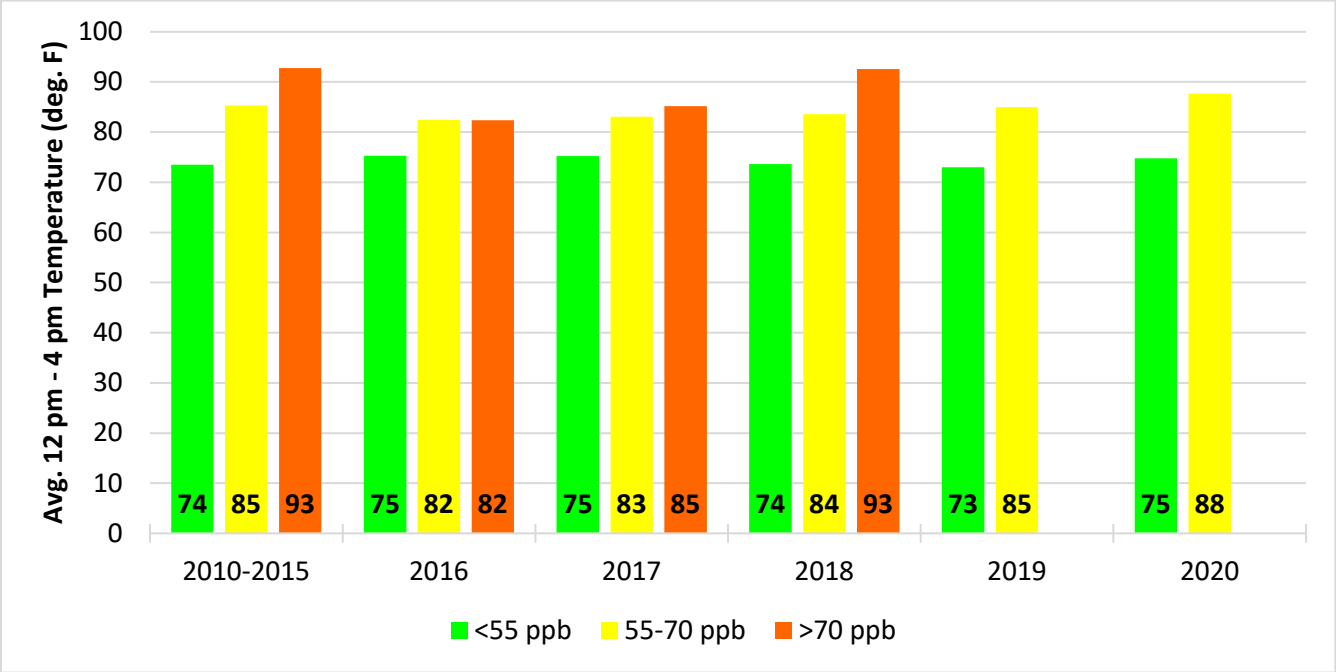


Figure 4-15. Scatter Plot of 12 pm – 4 pm Temperature at CAMS 38 v. MDA8 O3 at CAMS 38, 2020



The figure below shows a comparison of the temperature for the days when MDA8 O_3 values were <55 ppb, 55-70 ppb, and >70 ppb at CAMS 38 in 2020 compared to data from CAMS 3 for 2010-2019. Since there were no days with MDA8 O_3 that were >70 ppb at CAMS 38 in 2020 nor CAMs 3 in 2019, the figure below does not contain the average wind speed for that interval.

Figure 4-16. Typical Temperature 12 pm – 4pm on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 3, 2010-2019, and CAMS 38, 2020

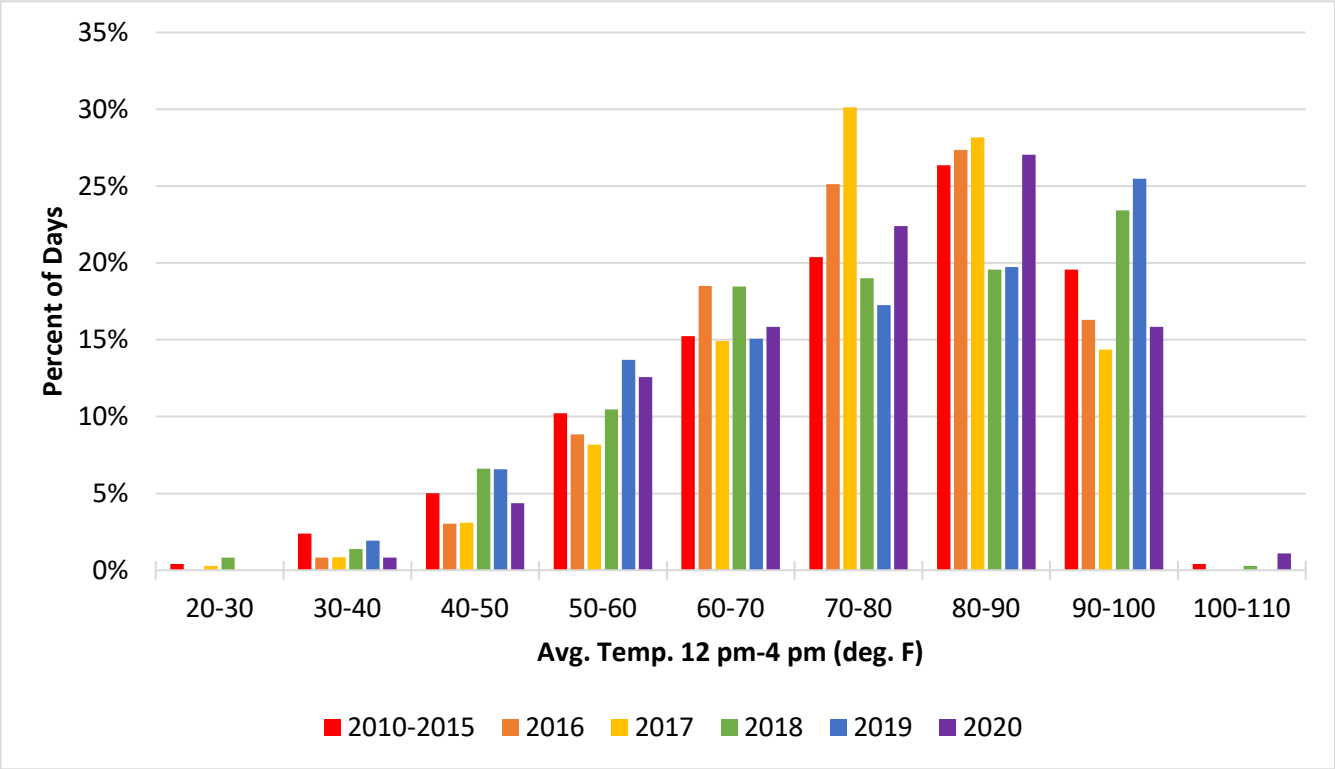


The average temperature and O_3 concentration relationship for 2020 follows the relationship from the previous years. This relationship indicates that higher temperatures can allow for higher O_3 formation.

4.2.2 Comparison of 2020 Temperatures to 2010-2019 Temperatures

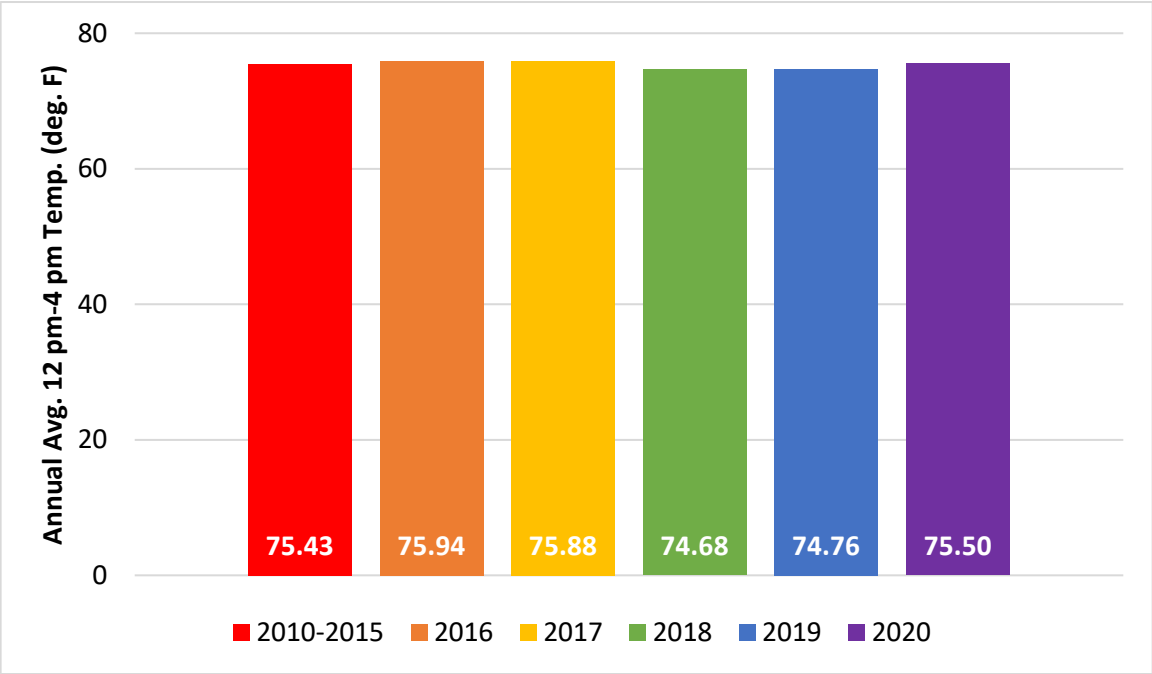
The figure below shows a histogram of the distribution of daily average temperatures between 12 pm-4 pm at CAMS 3 and CAMS 38.

Figure 4-17. Histogram of 12 pm – 4 pm Temperatures at CAMS 3, 2010-2019, and CAMS 38, 2020



CAPCOG also analyzed whether there was a significant difference in the annual average of these daily 12 pm-4 pm temperature averages. The following figure shows the average from 2010-2019 for CAMS 3 and from 2020 for CAMS 38. The annual average 12-4 pm temperature for 2020 was not significantly different than in the past.

Figure 4-18. Annual Average 12 pm-4 pm Temperature at CAMS 3, 2010-2019, and CAMS 38, 2020



4.3 Diurnal Temperature Change

CAPCOG's most recent O_3 conceptual model showed that diurnal temperature change had a significant positive correlation with MDA8 O_3. In CAPCOG's 2010-2015 Conceptual Model, CAPCOG analyzed the data only for days when hourly averages were available for all 24 hours of the day in order to have the full range of data used in the analysis. The regression analyses CAPCOG conducted on the relationship between O_3, meteorological factors, day of week, and year at CAMS 3 and CAMS 38, showed similar significant statistical impacts of diurnal temperature changes on MDA8 O_3 values: +0.30 ppb/degree F at CAMS 3 and +0.30 ppb/degree F at CAMS 38.

Given this relationship, CAPCOG conducted a variety of statistical analyses to evaluate whether the 2020 diurnal temperature changes were statistically different from temperature changes observed 2010-2019 or if the relationship between O_3 and temperature change was different than the relationship observed 2010-2019.

4.3.1 Comparison of Relationship between Diurnal Temperature Change and MDA8 O_3 in 2020 to 2010-2019

The figures below show scatter plots with MDA8 O_3 values and diurnal temperature changes at CAMS 3 for 2010-2019 and CAMS 38 for 2020. As the figures show, the 2020 data was consistent in showing a positive correlation between these two factors.

Figure 4-19. Scatter Plot of Diurnal Temperature Change at CAMS 3 v. MDA8 O_3 at CAMS 3, 2010-2015

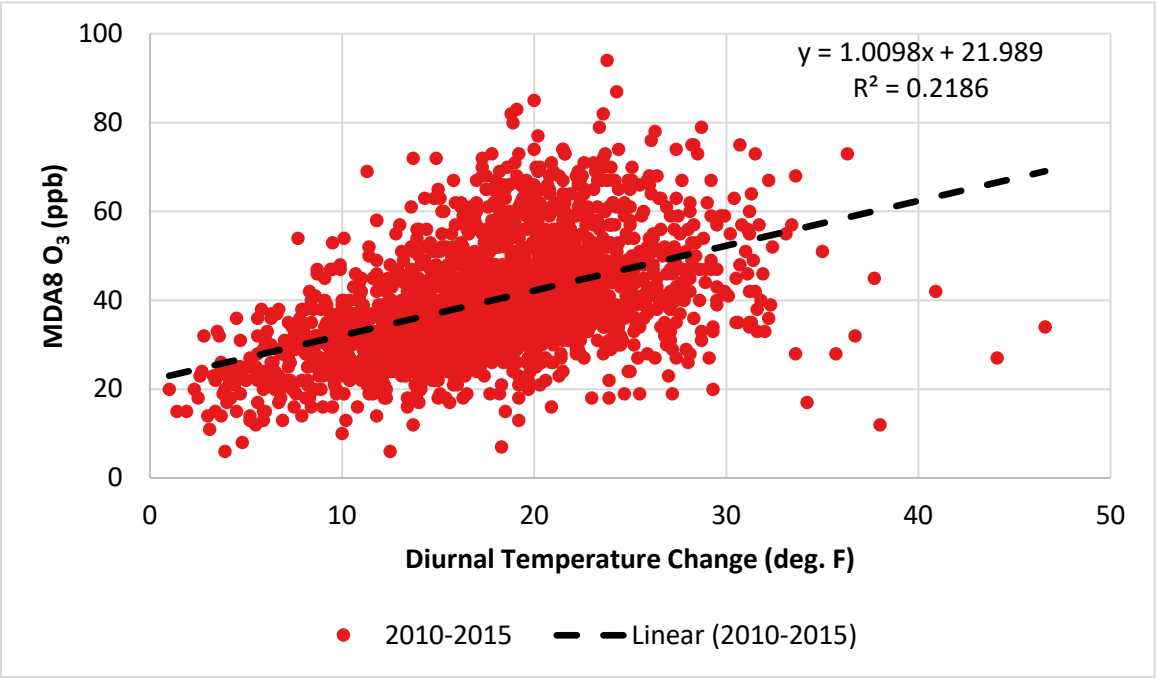


Figure 4-20. Scatter Plot of Diurnal Temperature Change at CAMS 3 v. MDA8 O_3 at CAMS 3, 2016

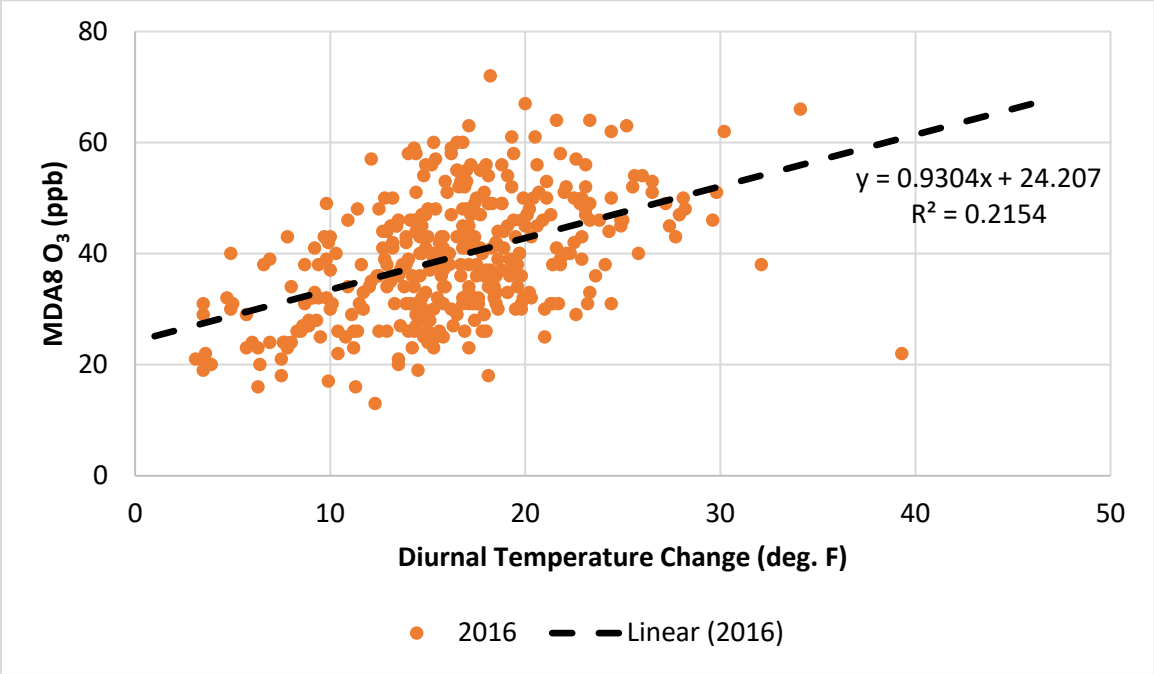


Figure 4-21. Scatter Plot of Diurnal Temperature Change at CAMS 3 v. MDA8 O_3 at CAMS 3, 2017

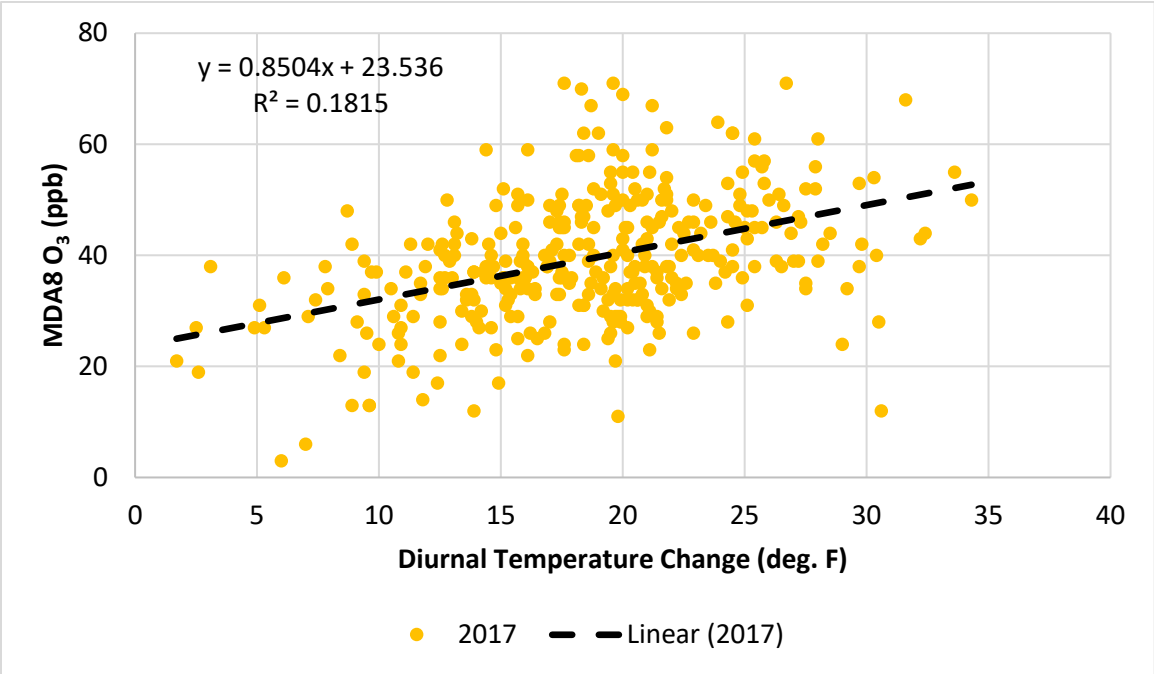


Figure 4-22. Scatter Plot of Diurnal Temperature Change at CAMS 3 v. MDA8 O_3 at CAMS 3, 2018

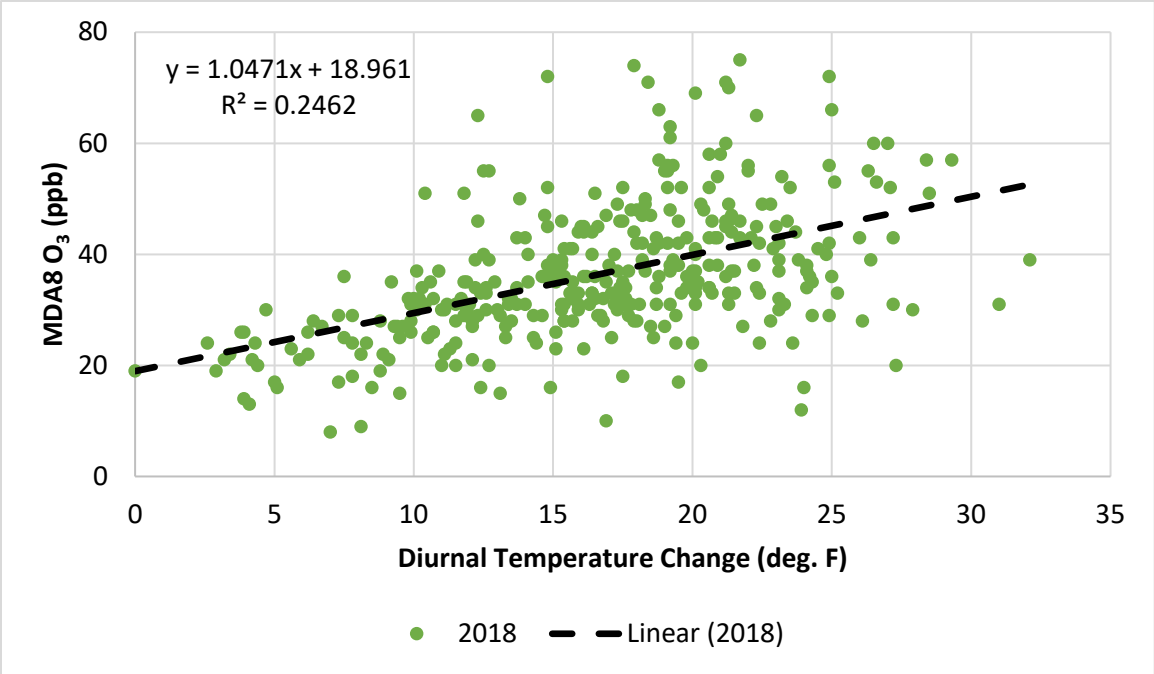


Figure 4-23. Scatter Plot of Diurnal Temperature Change at CAMS 3 v. MDA8 O_3 at CAMS 3, 2019

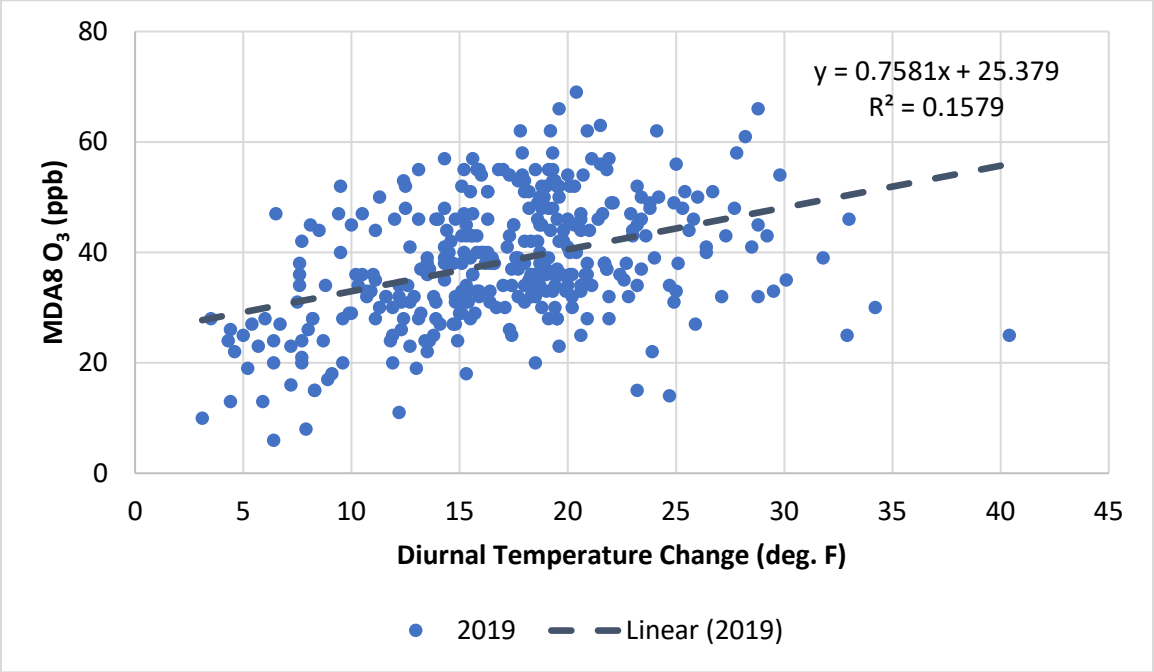
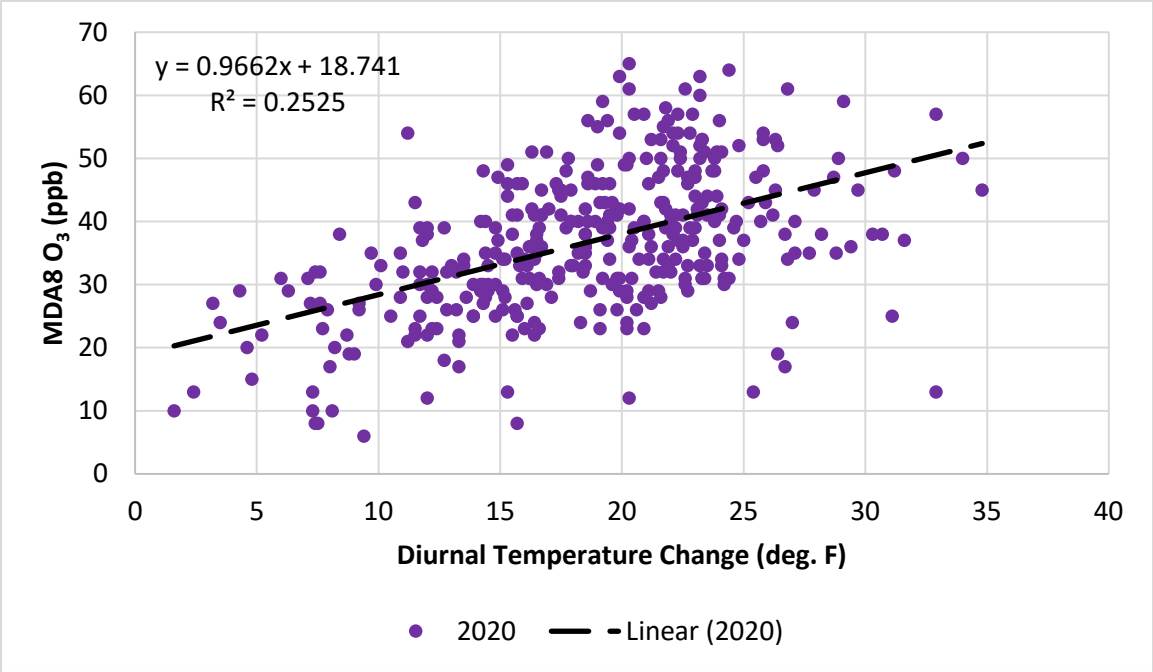
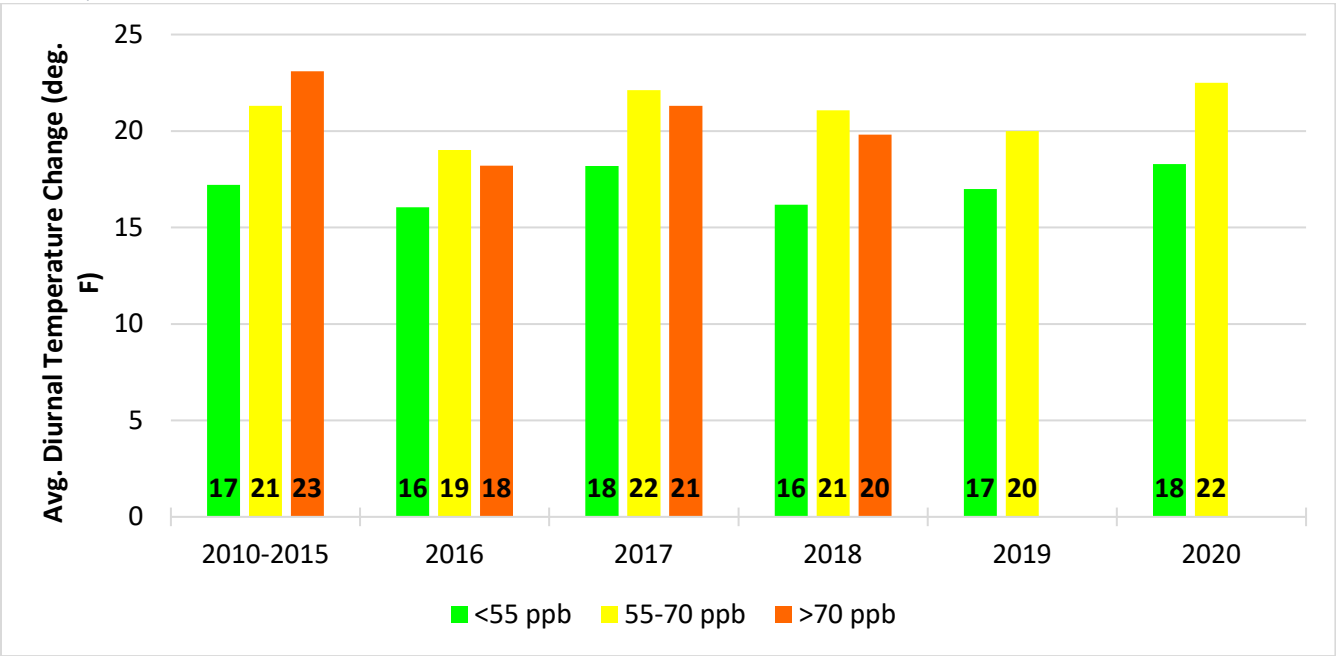


Figure 4-24. Scatter Plot of Diurnal Temperature Change at CAMS 38 v. MDA8 O_3 at CAMS 38, 2020



The figure below shows a comparison of the typical diurnal temperature changes on days <55 ppb, 55-70 ppb, and >70 ppb in 2020 relative to 2010-2019. Since there were no days with MDA8 O_3 that were >70 ppb at CAMS 3 in 2019 and at CAMS 38 in 2020, the figure below does not contain the average diurnal temperature for that interval.

Figure 4-25. Typical Diurnal Temperature Change on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 3, 2010-2019, and CAMS 38, 2020

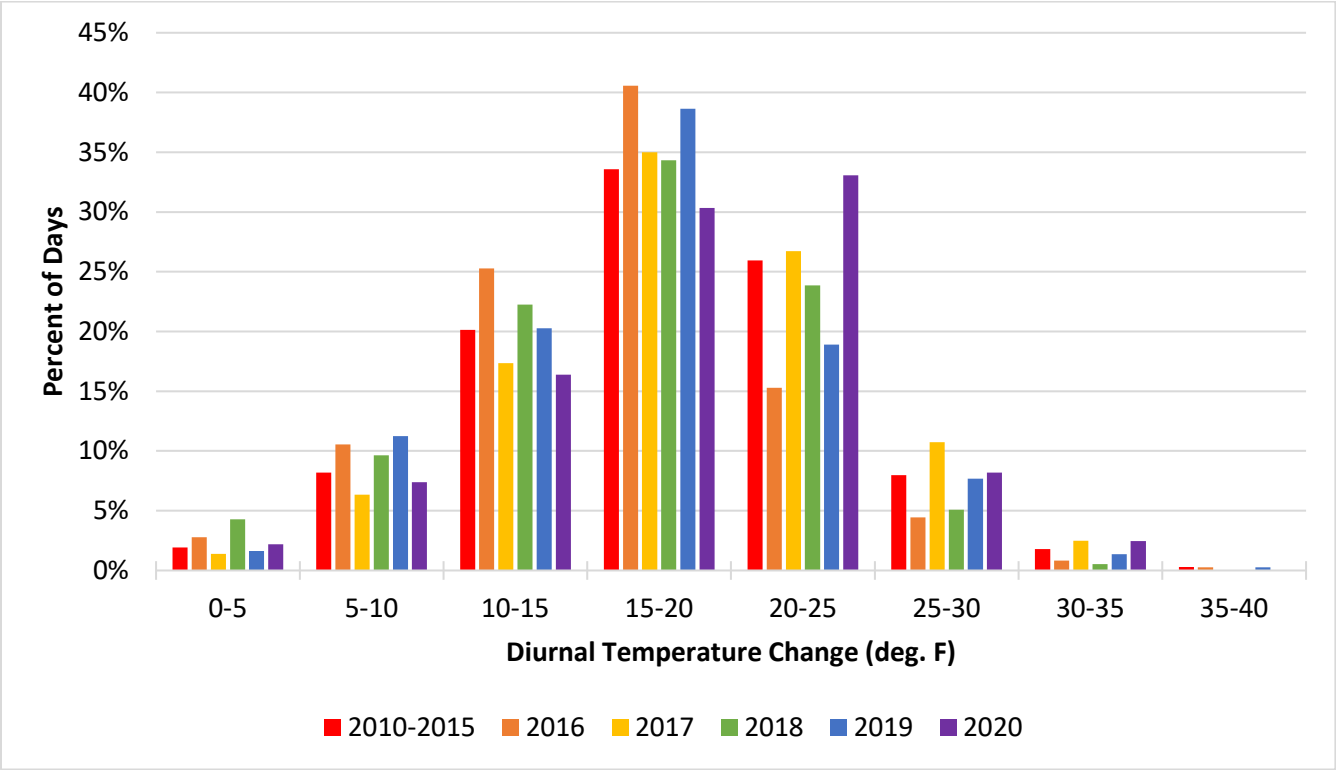


This analysis shows that MDA8 O_3 was 55 ppb or higher on days that had high diurnal temperature changes.

4.3.2 Comparison of 2020 Diurnal Temperature Changes to 2010-2019 Diurnal Temperature Changes

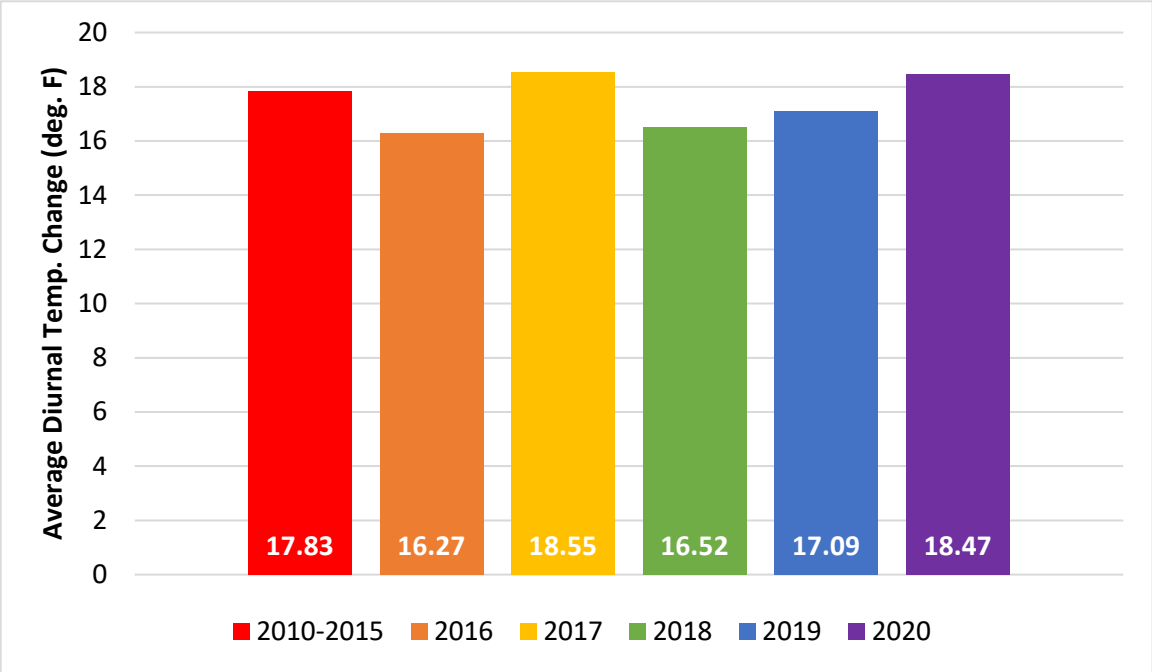
The distribution of days into 5-degree bins in the histogram below shows a similar distribution of diurnal temperature changes in 2020 compared to 2010-2019. Although, 2020 did see a higher percentage of days that were in the 20-25°F bin than in the past years.

Figure 4-26. Histogram of Diurnal Temperature Changes at CAMS 3, 2010-2019, and CAMS 38, 2020



CAPCOG also analyzed whether there was a significant difference in the annual average of diurnal temperature. The following figure shows the average from 2010-2019 for CAMS 3 and from 2020 for CAMS 38. The annual average diurnal temperature for 2020 was higher than 2019, and it was similar to levels seen in 2017.

Figure 4-24. Annual Average Diurnal Temperature Change at CAMS 3, 2010-2019, and CAMS 38, 2020



4.4 Relative Humidity

CAPCOG's most recent O_3 conceptual model showed that average relative humidity (RH) between 12 pm-4 pm had a statistically negative correlation with MDA8 O_3. Regression analyses that CAPCOG conducted for that report showed similar statistical impacts of relative humidity on MDA8 O_3 values: -0.28 ppb at CAMS 3/% RH and -0.25 ppb/% RH at CAMS 5002-Camp Mabry, which is the station closest to both sites with RH measurements.

Given this relationship, CAPCOG conducted a variety of statistical analyses to evaluate whether the 12 pm-4 pm relative humidity measurements for 2020 were statistically different from the relative humidity measurements in 2010-2019 or if the relationship between O_3 and relative humidity was different from the relationship observed 2010-2019.

4.4.1 Comparison of Relationship between Relative Humidity and MDA8 O_3 in 2020 to 2010-2019

The figures below show scatter plots with MDA8 O_3 values at CAMS 3 for the 12 pm-4 pm relative humidity data at CAMS 5002 (Camp Mabry) for 2010-2019. However, for 2020, CAPCOG used the relative humidity data from CAMS 5003 (Austin Bergstrom) because the Camp Mabry data only had a 52% data completeness for the year, with a large portion of that data loss during ozone season. Therefore, the Camp Mabry data is not representative of actual relative humidity levels for 2020. As a result, the 2020 data displays the MDA8 O_3 values at CAMS 38 for the 12 pm-4 pm relative humidity data at CAMS 5003 since CAMS 5003 collected relative humidity data for the entire year.

As the figures show, the 2020 data was consistent in showing a negative correlation between relative humidity and MDA8 O_3.

Figure 4-27. Scatter Plot of 12 pm – 4 pm Relative Humidity at Camp Mabry v. MDA8 O_3 at CAMS 3, 2010-2015

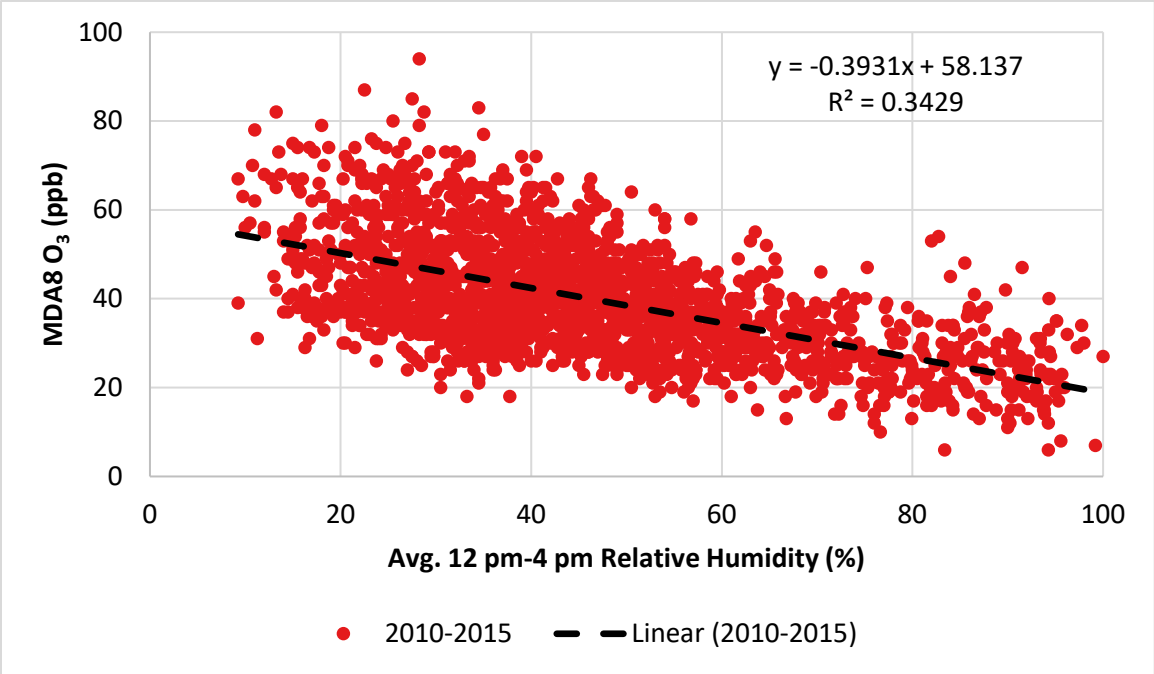


Figure 4-28. Scatter Plot of 12 pm – 4 pm Relative Humidity at Camp Mabry v. MDA8 O_3 at CAMS 3, 2016

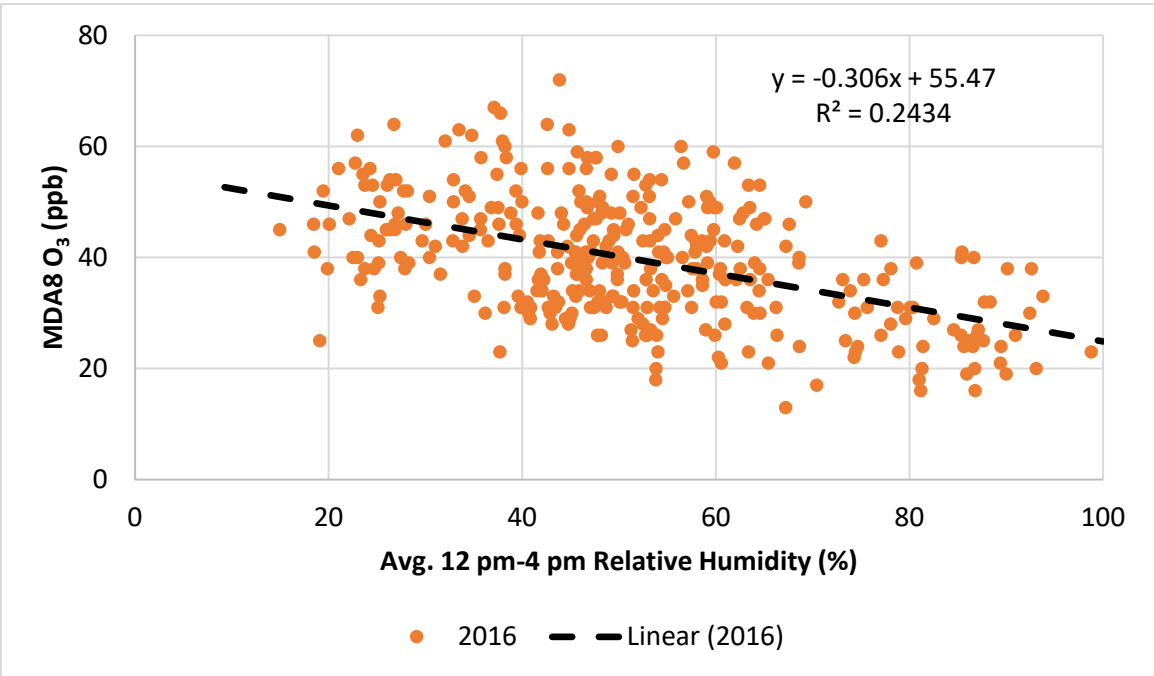


Figure 4-29. Scatter Plot of 12 pm – 4 pm Relative Humidity at Camp Mabry v. MDA8 O_3 at CAMS 3, 2017

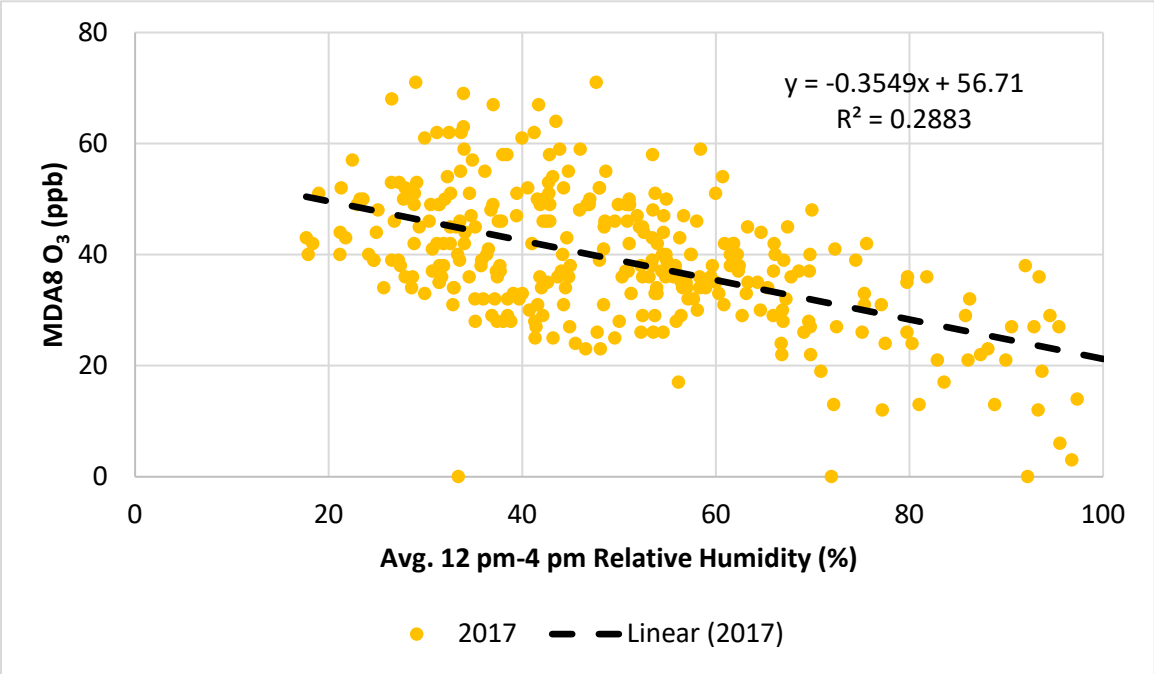


Figure 4-30. Scatter Plot of 12 pm – 4 pm Relative Humidity at Camp Mabry v. MDA8 O_3 at CAMS 3, 2018

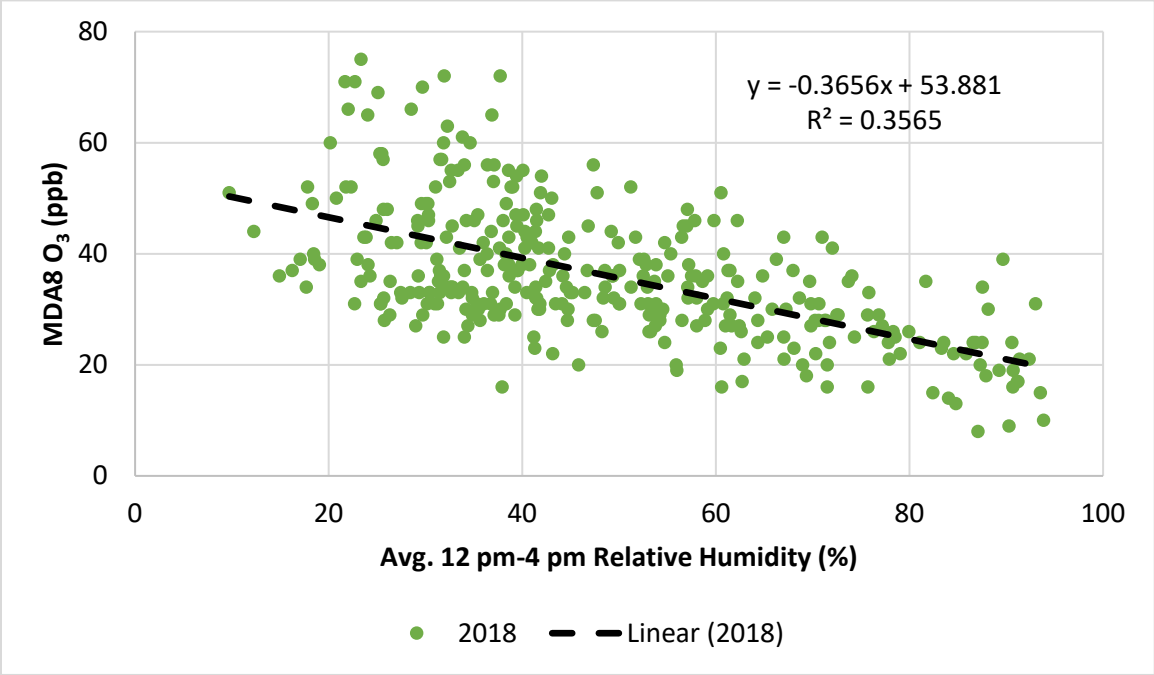


Figure 4-31. Scatter Plot of 12 pm – 4 pm Relative Humidity at Camp Mabry v. MDA8 O_3 at CAMS 3, 2019

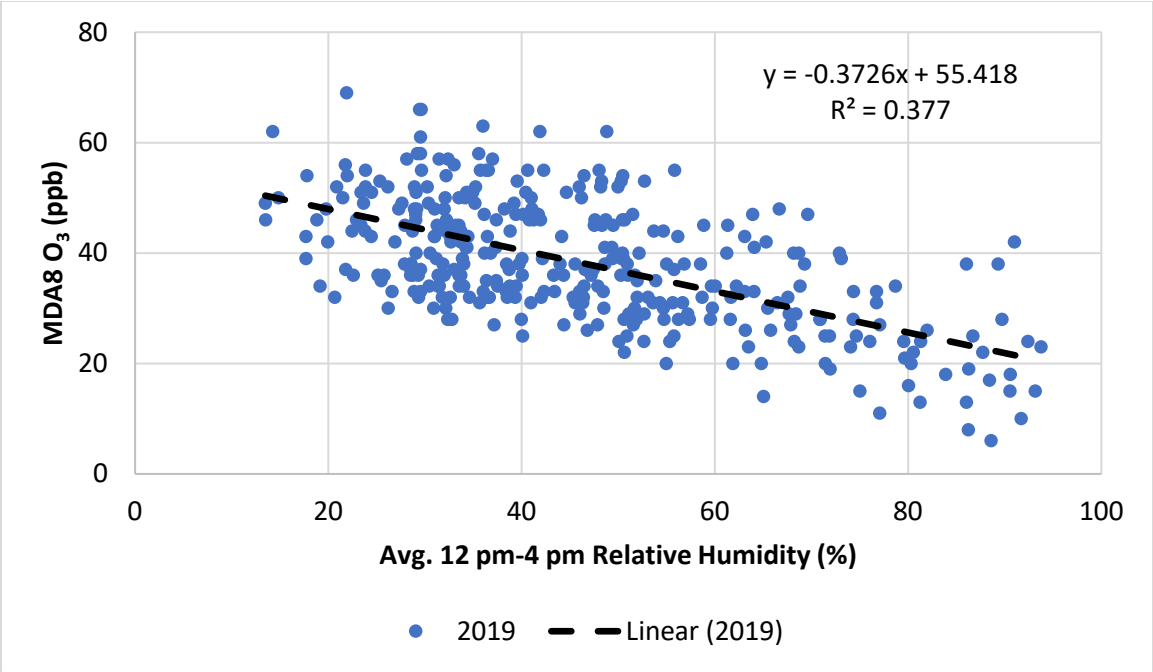
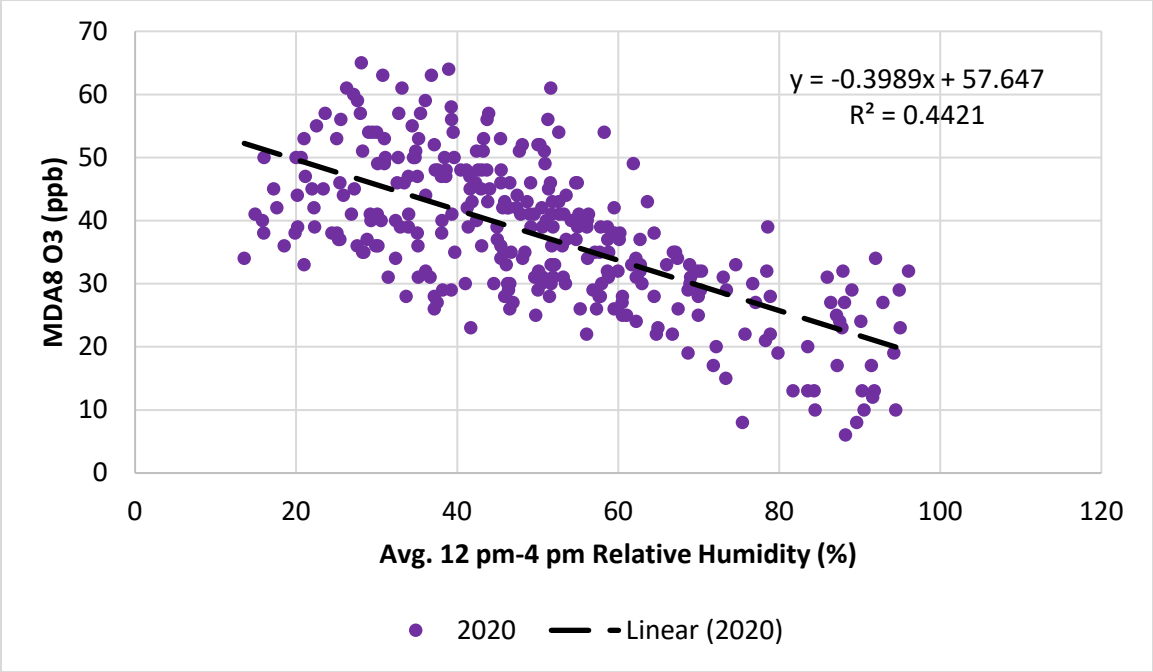


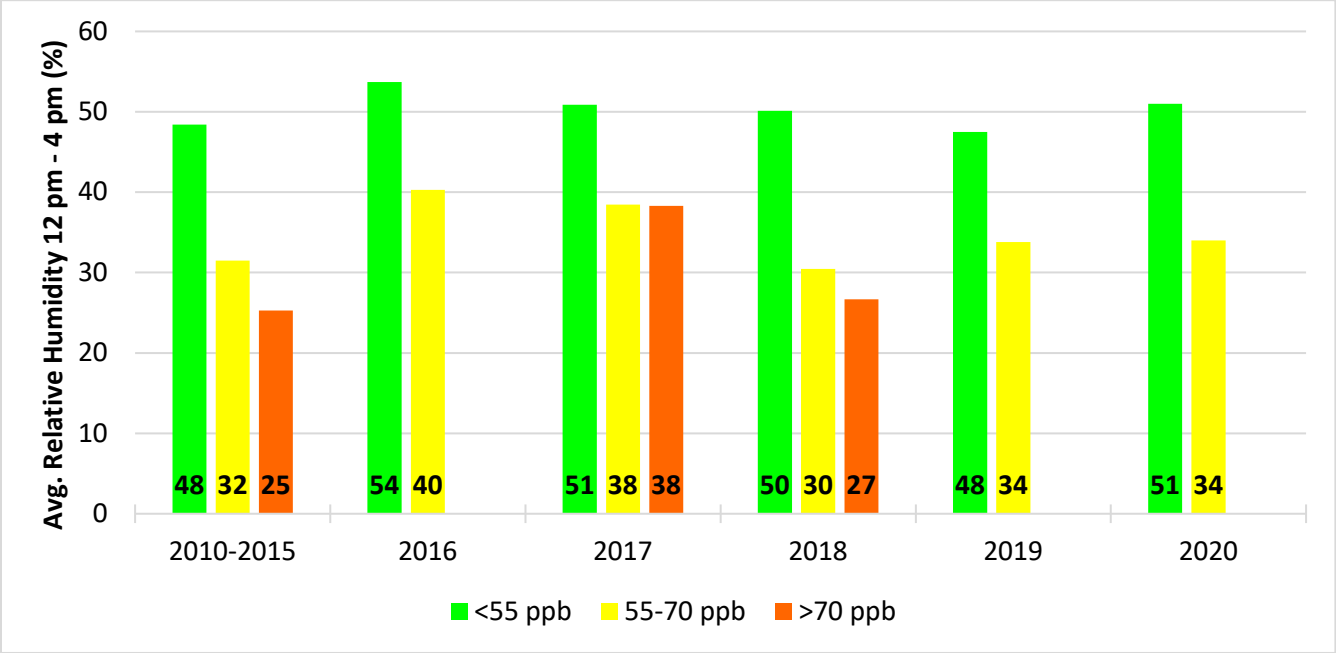
Figure 4-32. Scatter Plot of 12 pm – 4 pm Relative Humidity at Austin Bergstrom v. MDA8 O_3 at CAMS 38, 2020



The figure below shows a comparison of the typical relative humidity at Camp Mabry from 12 pm-4 pm on days when MDA8 O_3 at CAMS 3 was <55 ppb, 55-70 ppb, and >70 ppb for 2010-2019 and the typical relative humidity at Austin Bergstrom from 12 pm-4 pm on days when MDA8 O_3 at CAMS 3 was <55 ppb, 55-70 ppb, and >70 ppb

for 2020. Since there were no days with MDA8 O_3 that were >70 ppb at CAMS 3 in 2019 and at CAMS 38 in 2020, the figure below does not contain the average diurnal temperature for that interval.

Figure 4-33. Typical Relative Humidity 12 pm – 4pm at Camp Mabry on Days with MDA8 O3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 3, 2010-2019, and Typical Relative Humidity 12 pm – 4pm at Austin Bergstrom on Days with MDA8 O3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 38

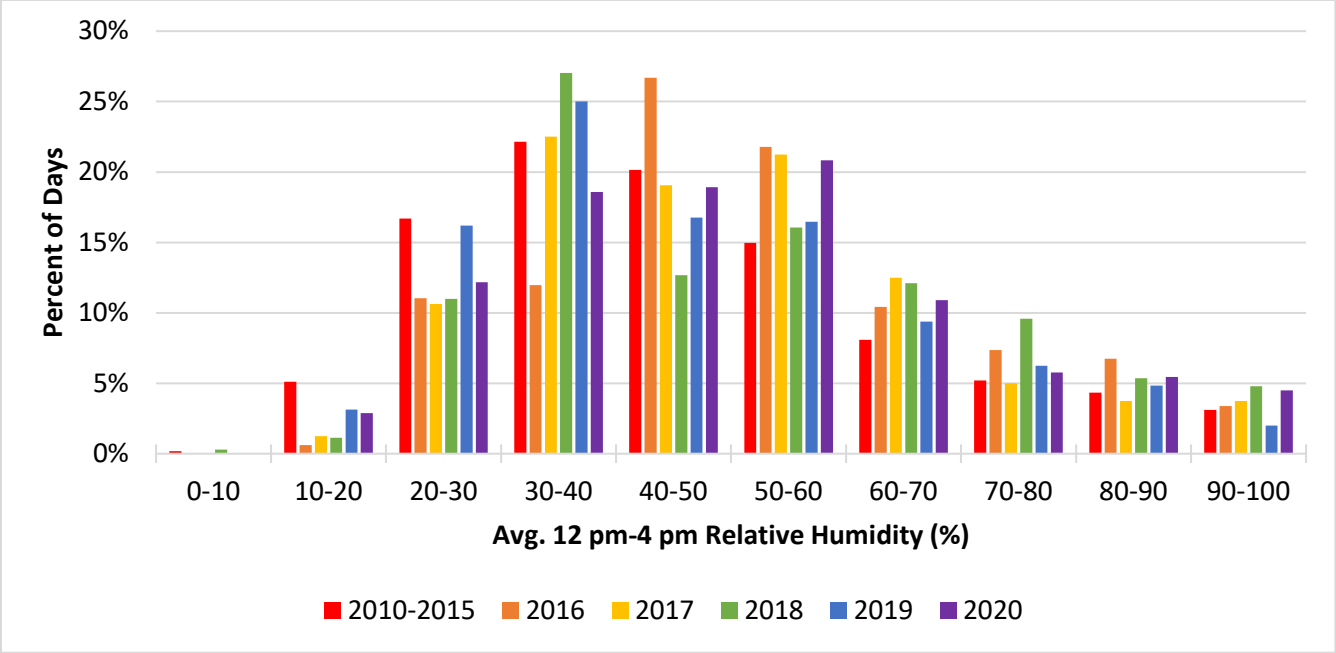


The average relative humidity and O_3 concentration relationship for 2020 follows the relationship from the previous years. This relationship indicates that high O_3 tends to form with low humidity.

4.4.2 Comparison of 2020 Relative Humidity to 2010-2019 Relative Humidity

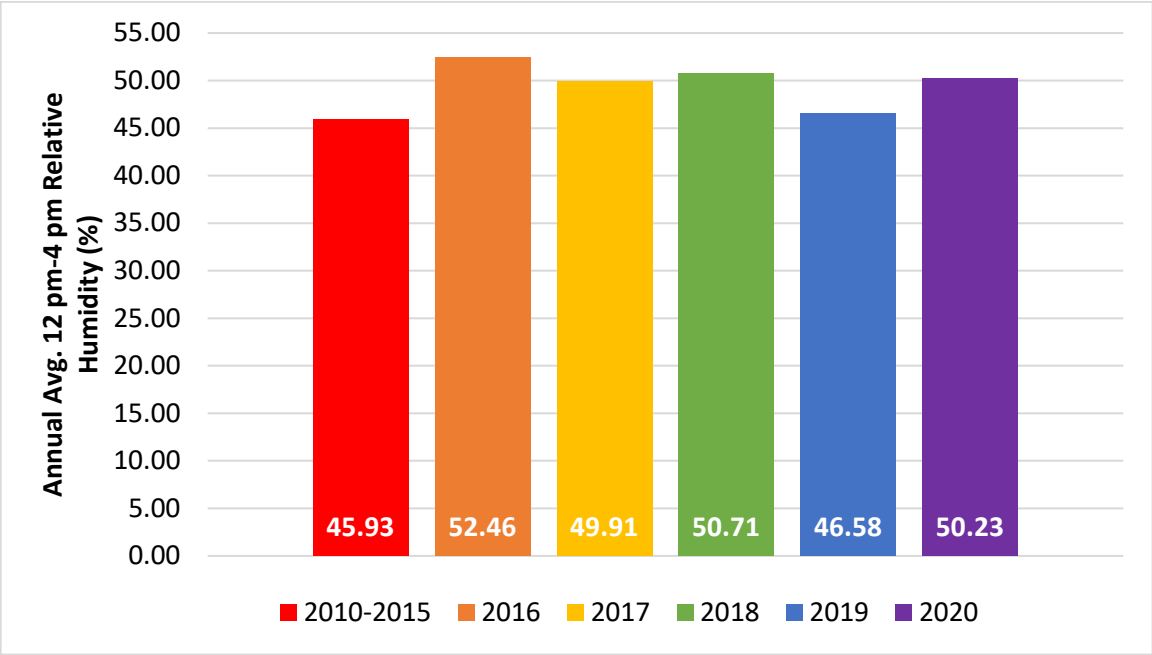
The figure below shows the distribution of relative humidity into ten bins and compares observed data in 2020 to previous studied timeframes. Overall, this data suggests that 2020 had few days with relative humidity above 70% which would suggest that there were more chances for the formation of high levels of O_3. However, 2020 had more days with 50%-70% relative humidity than in 2019. Therefore, these moderate relative humidity levels in 2020 may have affected O_3 formation.

Figure 4-34. Histogram of 12 pm – 4 pm Relative Humidity at Camp Mabry, 2010-2019, and Austin Bergstrom, 2020



CAPCOG also analyzed whether there was a significant difference in the annual average of relative humidity from 12 pm-4 pm for 2020 compared to previous years. In 2020, there was a higher 12-4pm relative humidity average than in 2019 which may be one of the factors that caused fewer high MDA8 O_3.

Figure 4-35. Annual Average 12 pm-4 pm Relative Humidity at Camp Mabry, 2010-2019, and Austin Bergstrom, 2020



4.5 Solar Radiation

CAPCOG's most recent O_3 conceptual model showed that average solar radiation at CAMS 38 between 12 pm-4 pm had a positive correlation with MDA8 O_3 at the same station. The regression analyses CAPCOG conducted on the relationship between O_3, meteorological factors, day of week, and year at CAMS 38, showed a +2.28 ppb/langleys per minute at CAMS 38.

Given this relationship, CAPCOG conducted a variety of statistical analyses to evaluate whether the 12 pm- 4 pm solar radiation measurements in 2020 were statistically different from the measurements in 2010-2019 or if the relationship between O_3 and solar radiation was different than the relationship observed 2010-2019.

4.5.1 Comparison of Relationship between Solar Radiation and MDA8 O_3 in 2020 to 2010-2019

The figures below show scatter plots with MDA8 O_3 values at CAMS 38 and 12 pm-4 pm solar radiation at CAMS 38 for 2010-2019. As the figures show, the 2020 data was consistent in showing a positive correlation between solar radiation and MDA8 O_3.

Figure 4-36. Scatter Plot of 12 pm – 4 pm Solar Radiation at CAMS 38 v. MDA8 O_3 at CAMS 38, 2010-2015

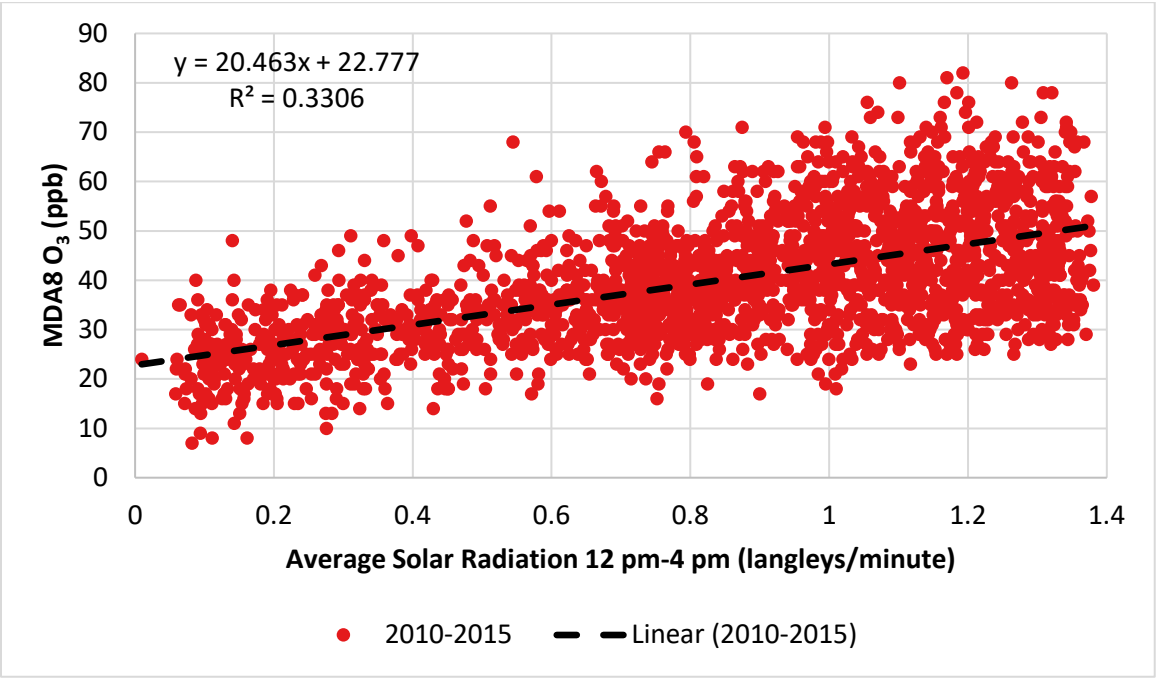


Figure 4-37. Scatter Plot of 12 pm – 4 pm Solar Radiation at CAMS 38 v. MDA8 O_3 at CAMS 38, 2016

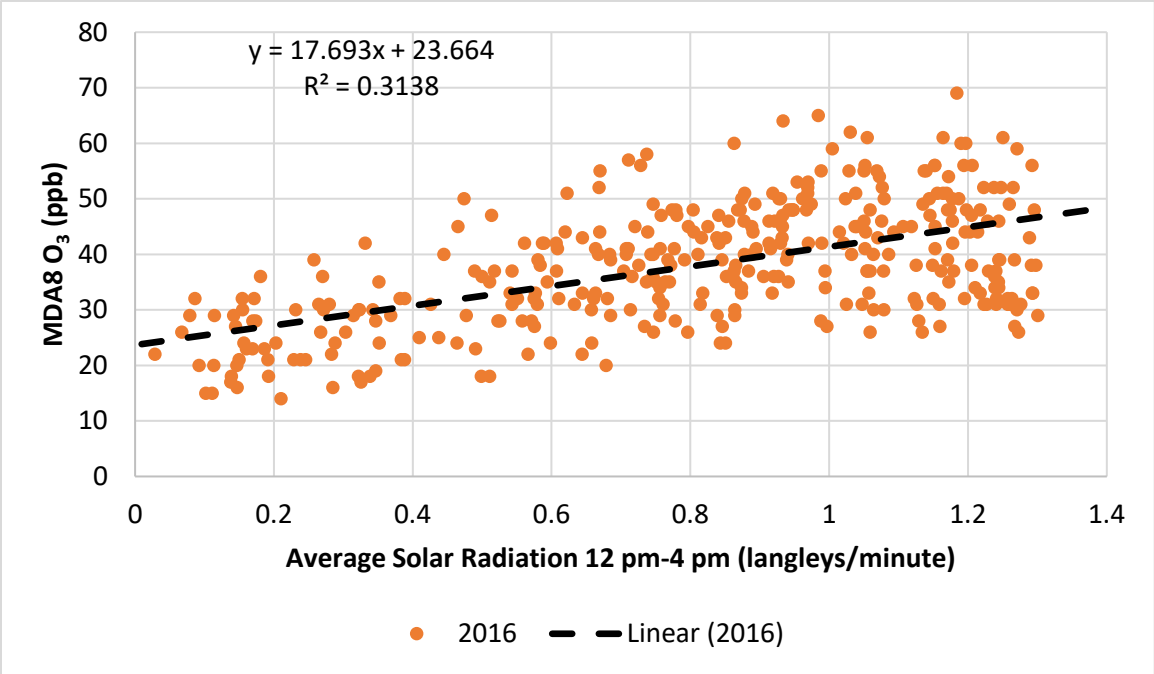


Figure 4-38. Scatter Plot of 12 pm – 4 pm Solar Radiation at CAMS 38 v. MDA8 O_3 at CAMS 38, 2017

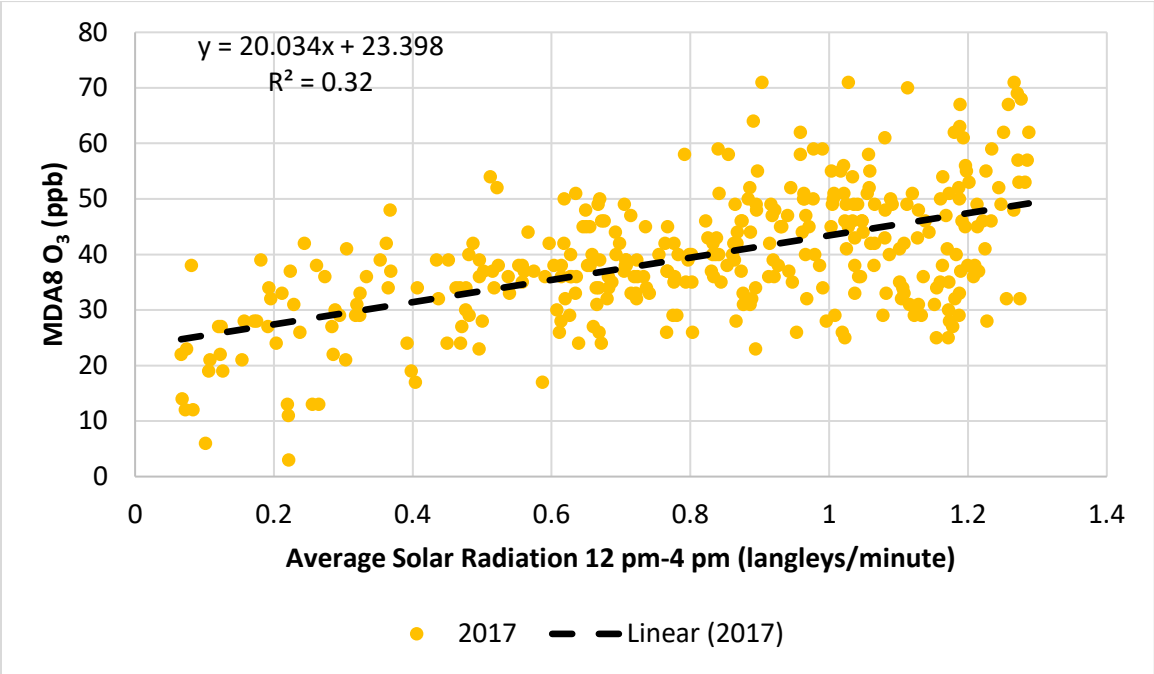


Figure 4-39. Scatter Plot of 12 pm – 4 pm Solar Radiation at CAMS 38 v. MDA8 O_3 at CAMS 38, 2018

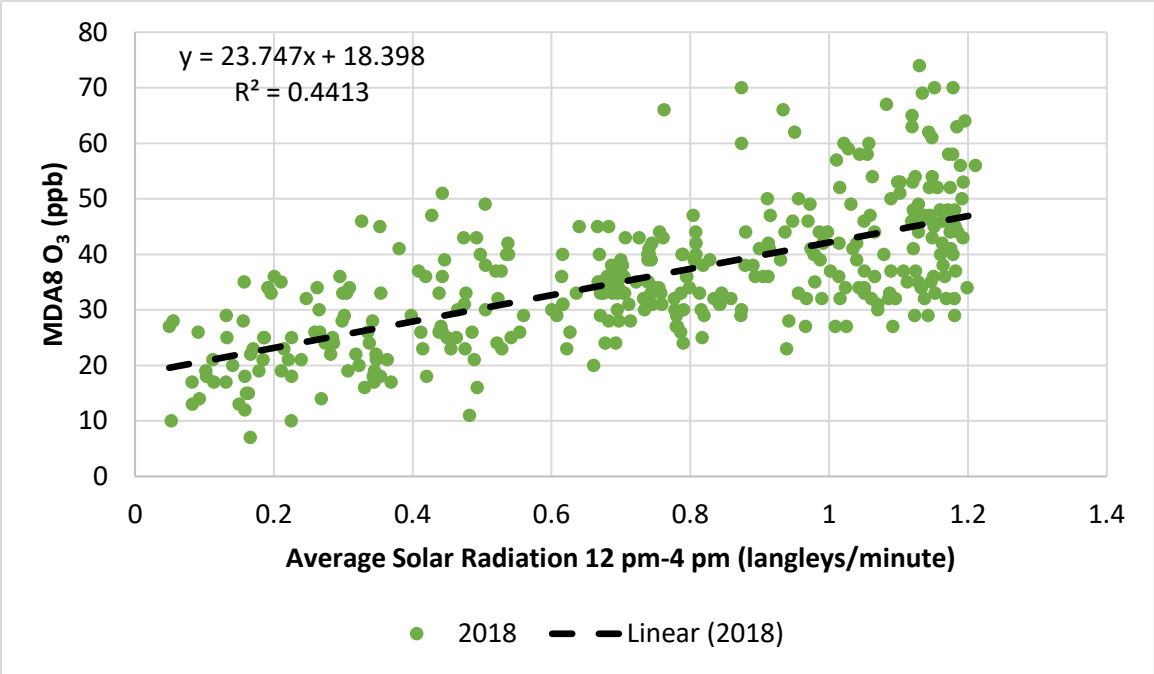


Figure 4-40. Scatter Plot of 12 pm – 4 pm Solar Radiation at CAMS 38 v. MDA8 O_3 at CAMS 38, 2019

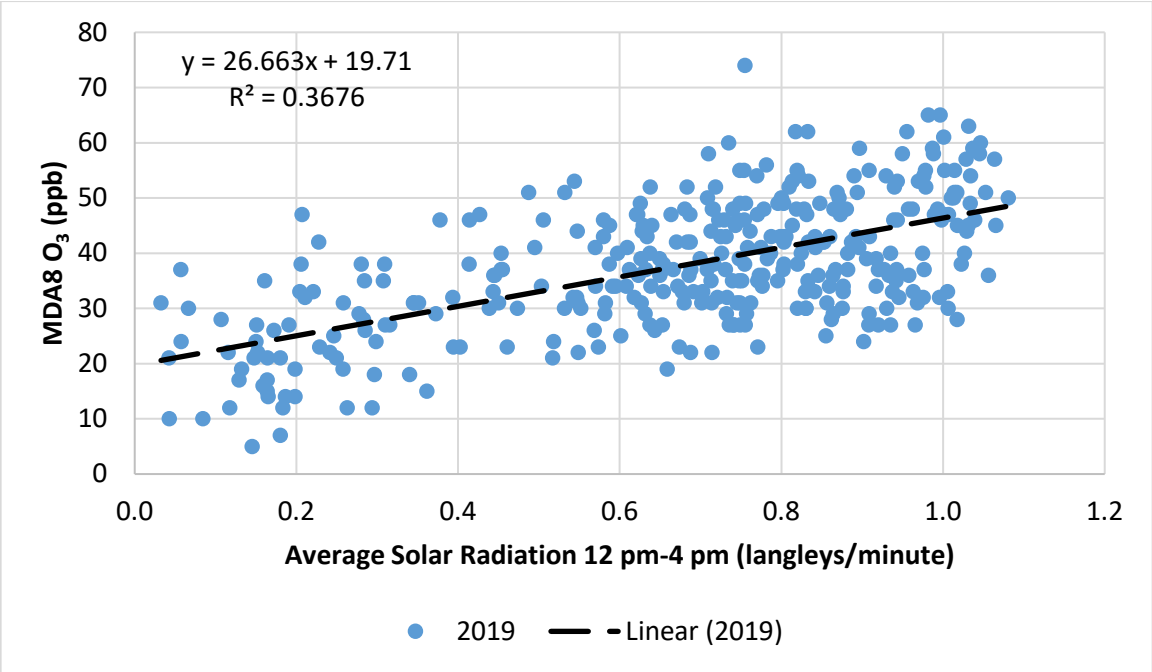
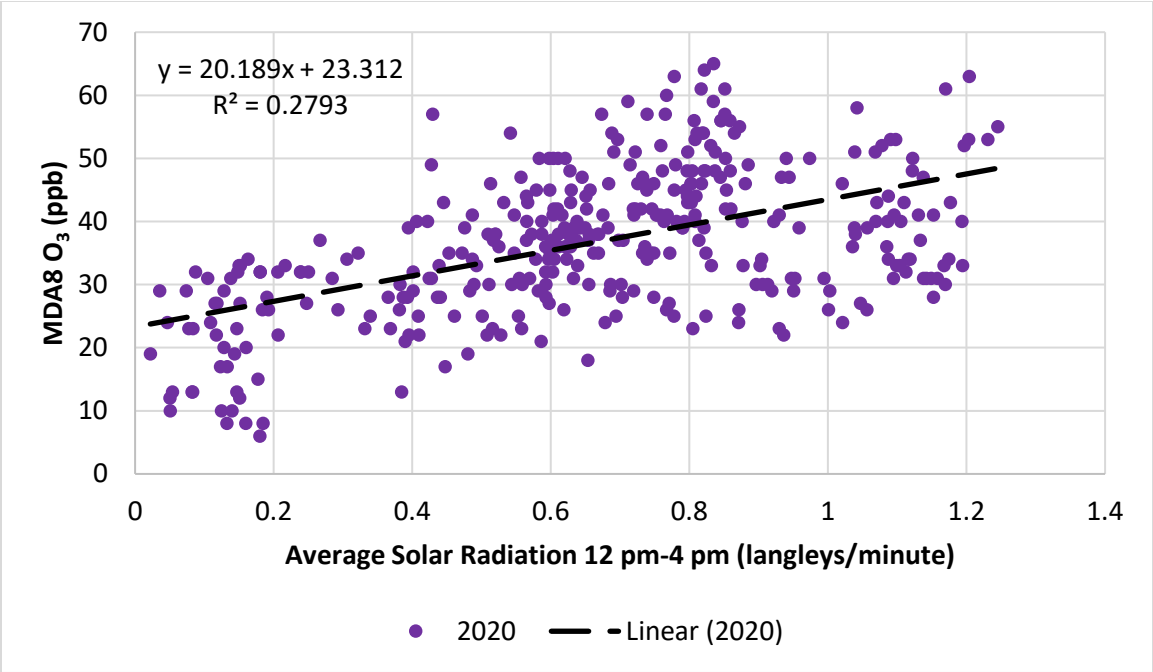
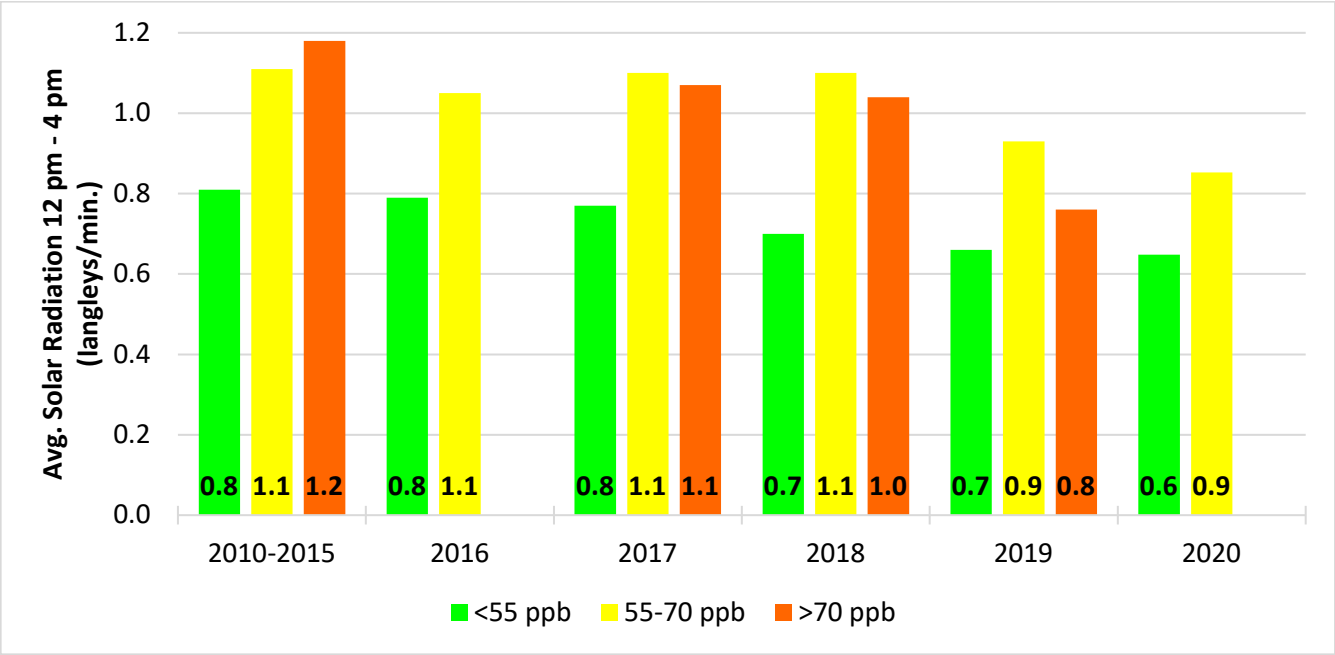


Figure 4-41. Scatter Plot of 12 pm – 4 pm Solar Radiation at CAMS 38 v. MDA8 O_3 at CAMS 38, 2020



The figure below shows a comparison of the typical solar radiation at CAMS 38 from 12 pm-4 pm on days when MDA8 O_3 at CAMS 38 was <55 ppb, 55-70 ppb, and >70 ppb in 2020 relative to 2010-2019. At CAMS 38, there was only one day in 2019 where O_3 measured >70 ppb, and there were zero days in 2020 where O_3 measured >70 ppb. As the graph below indicates, solar radiation for O_3 levels >55 ppb in 2020 were similar to levels in 2019 and solar radiation for 2020 is unlike levels seen before 2019. Therefore, lower solar radiation levels in 2020 may indicate one of the reasons that 2020 only had two days of regional MDA8 O_3 greater than 70 ppb, which is the same that was observed in 2019.

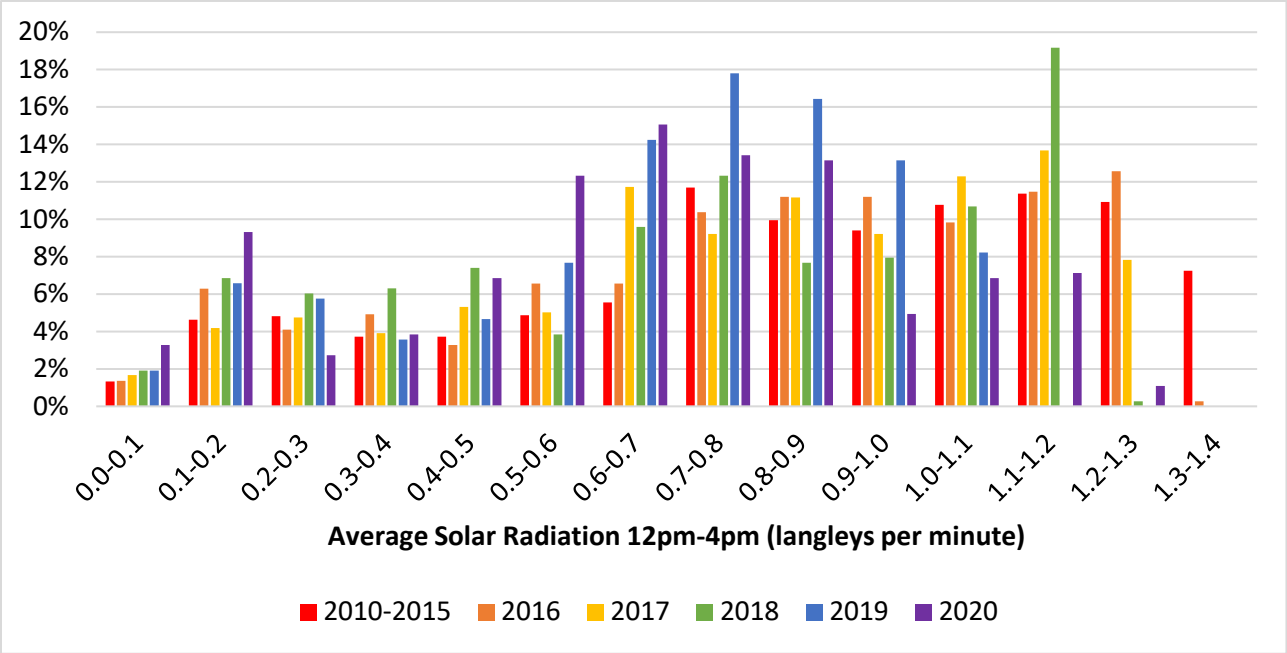
Figure 4-42. Typical Solar Radiation 12 pm – 4pm at CAMS 38 on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 38, 2010-2020



4.5.2 Comparison of 2020 Solar Radiation to 2010-2019 Radiation

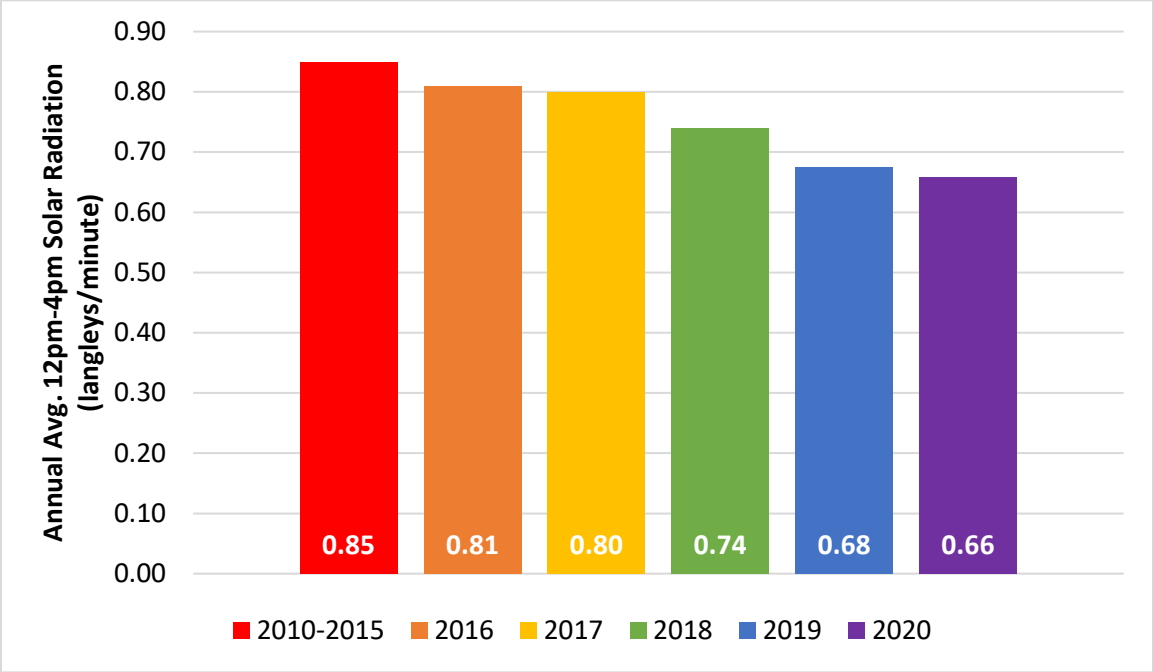
Based on a review of the meteorological data, CAPCOG was able to determine that there were statistical differences in the 12 pm-4 pm solar radiation at CAMS 38 in 2020 compared to 2010-2019. The distribution of days into 0.1 langleys/minute bins in the histogram below shows that 2019 had substantially more days with solar radiation less than 1.0 langleys/minute than 2010-2018. Therefore, lower solar radiation in 2020 compared to 2010-2018 and a similar level of solar radiation compared to 2019 may have contributed to less days with high MDA8 O_3.

Figure 4-39. Histogram of 12 pm – 4 pm Solar Radiation at CAMS 38, 2010-2020



CAPCOG also analyzed whether there was a significant difference in the annual average of solar radiation from 12 pm-4 pm for 2020 compared to previous years. In 2020, there was an annual average lower solar radiation from 12-4pm than in the past years which may be one of the factors that caused fewer high MDA8 O_3.

Figure 4-40. Annual Average 12 pm-4 pm Solar Radiation at CAMS 38, 2010-2020



A possible explanation for the yearly decrease in solar radiation is the Sun's solar cycle. Every 11 years, the Sun cycles from a solar maximum state – intense solar activity with increased sunspots and explosions of light and

solar material – to a solar minimum state – fewer sunspots and decreased explosions of light and solar material. The Sun entered a solar minimum in December 2019[3]. This solar minimum state would result in less solar radiation on Earth. However, solar radiation is expected to increase in the future as the Sun is starting a new solar cycle after the solar minimum.[4]

4.6 Wind Direction

CAPCOG's wind direction analyses included calculating the back trajectories of monitors with MDA8 O_3 levels measured >70 ppb in 2020. In CAPCOG's 2010-2015 Conceptual Model, CAPCOG developed HYSPLIT[5] 24-hour back-trajectories for the peak 1-hour O_3 hour on days when MDA8 O_3 >70 ppb at each monitoring station. CAPCOG used the same model and approach for the 2020 data as was used for the 2010-2015 data:

- NAM (North American Mesoscale) 12 km model
- Starting the back trajectories at the peak 1-hour O_3 concentration (the earliest one if there were two hours with the same peak 1-hour O_3 concentration)
- Elevations at 100 m, 500 m, and 1,000 m
- 24-hour back trajectories

The table below shows all of the instances when MDA8 O_3 exceeded 70 ppb at a monitor in the CAPCOG region, along with the start hour for the peak 1-hour O_3 concentration within the MDA8. There were two total days in 2020 when a regional monitor recorded ground level O_3 >70 ppb.

Table 4-1. MDA8 O_3 >70 ppb, 2020

Date	MDA8 O_3 Level (ppb)	Location	Start Hour for Peak 1-hr. Avg.
5/18/2020	72	CAMS 614	11:00 AM
8/18/2020	73	CAMS 1619	10:00 AM
	78	CAMS 1675	11:00 AM

4.6.1 County Back-Trajectory Analysis for Days when MDA8 O_3 >70 ppb

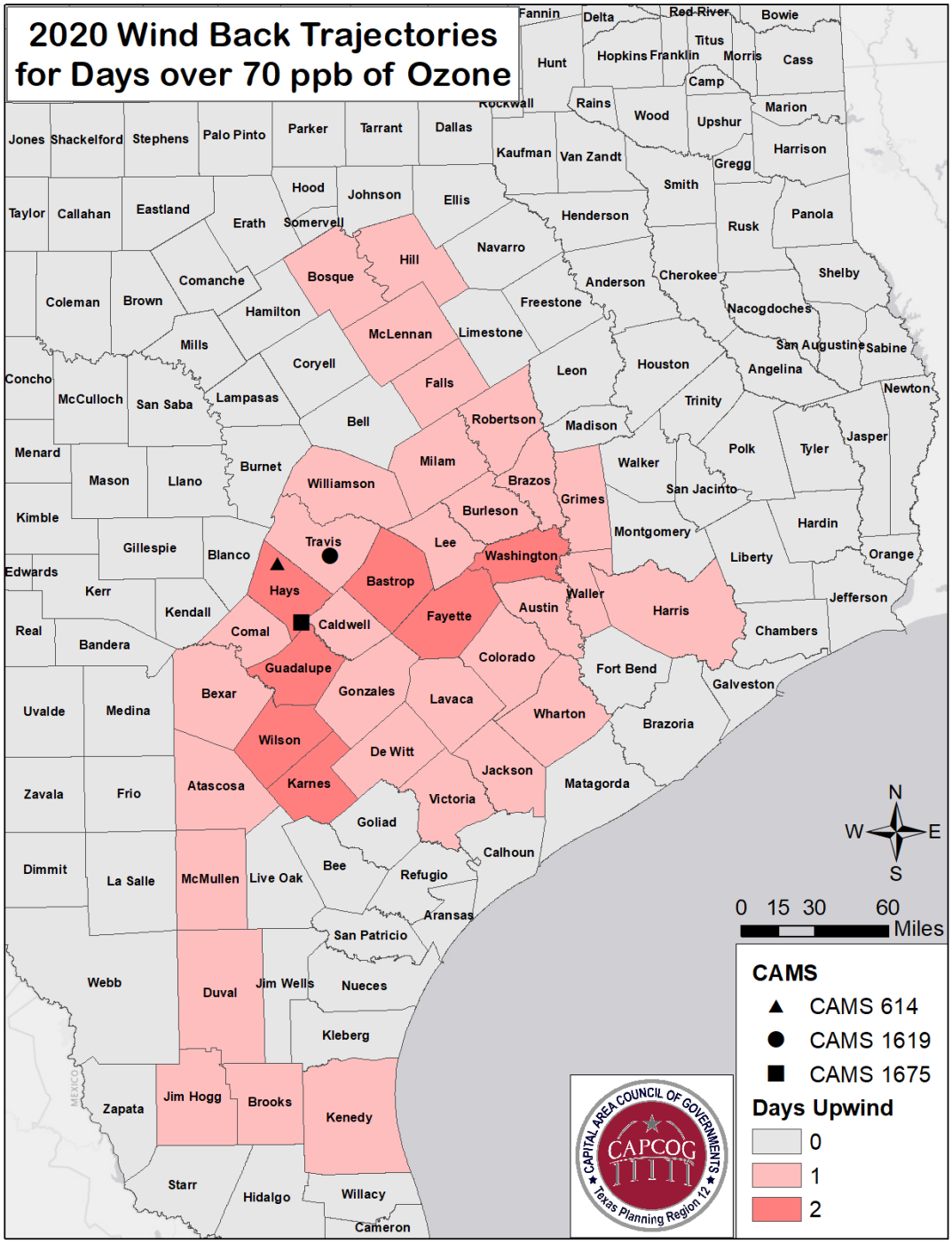
Figure 4-41 below displays the number of days that each county was upwind of a monitor in the MSA when the monitor recorded an MDA8 O_3 >70 ppb. These maps reflect 24-hour back trajectories starting at peak 1-hour concentrations at three altitudes – 100 m, 500 m, and 1,000 m. In 2020, upwind counties were most often to the east-southeast and the south-southwest of the region. This is consistent with the wind direction for high O_3 days in previous years.

[3] https://www.nasa.gov/msfcsolar

[4] https://www.nasa.gov/press-release/solar-cycle-25-is-here-nasa-noaa-scientists-explain-what-that-means

[5] Hybrid Single-Particle Lagrangian Integrated Trajectory

Figure 4-41. Number of Days Upwind in 2020 per County on Days with MDA8 O_3 >70 ppb at a CAPCOG Region Monitor at Altitudes of 100 m, 500 m, and 1,000 m

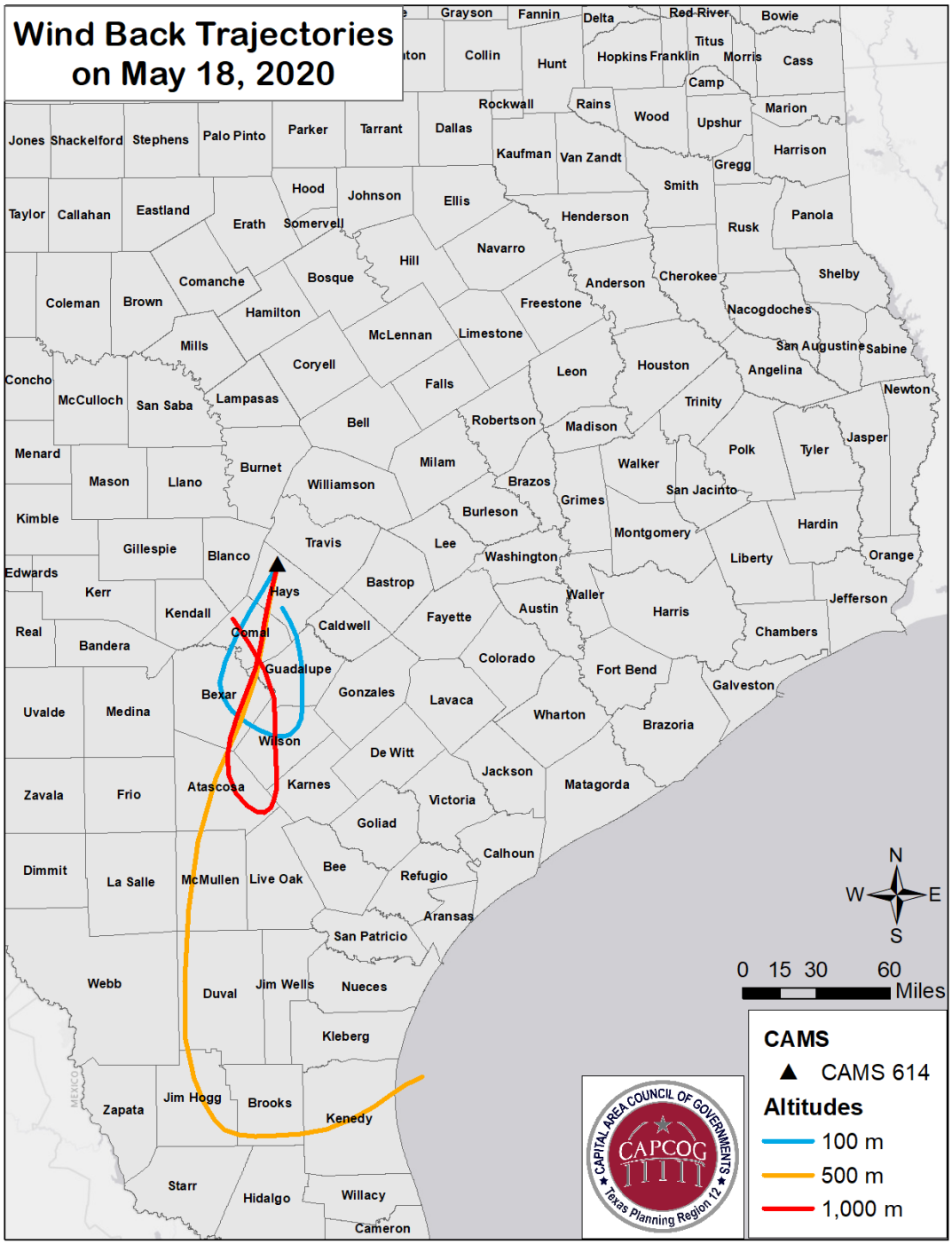


4.6.2 Wind Direction on Days with MDA8 O_3 >70 ppb at Each Monitor

In 2020, the region experienced two days with MDA8 O_3 at 70 ppb or above, May 18th and August 18th. On May 18, 2020, CAPCOG's CAMS 614 in Dripping Springs, Hays County, recorded MDA8 O_3 at 70 ppb or above. The

wind back trajectories indicate that wind blew predominantly from the south-southwest, including the 2015 O_3 non-attainment area of Bexar County and the Eagle Ford Shale production area.

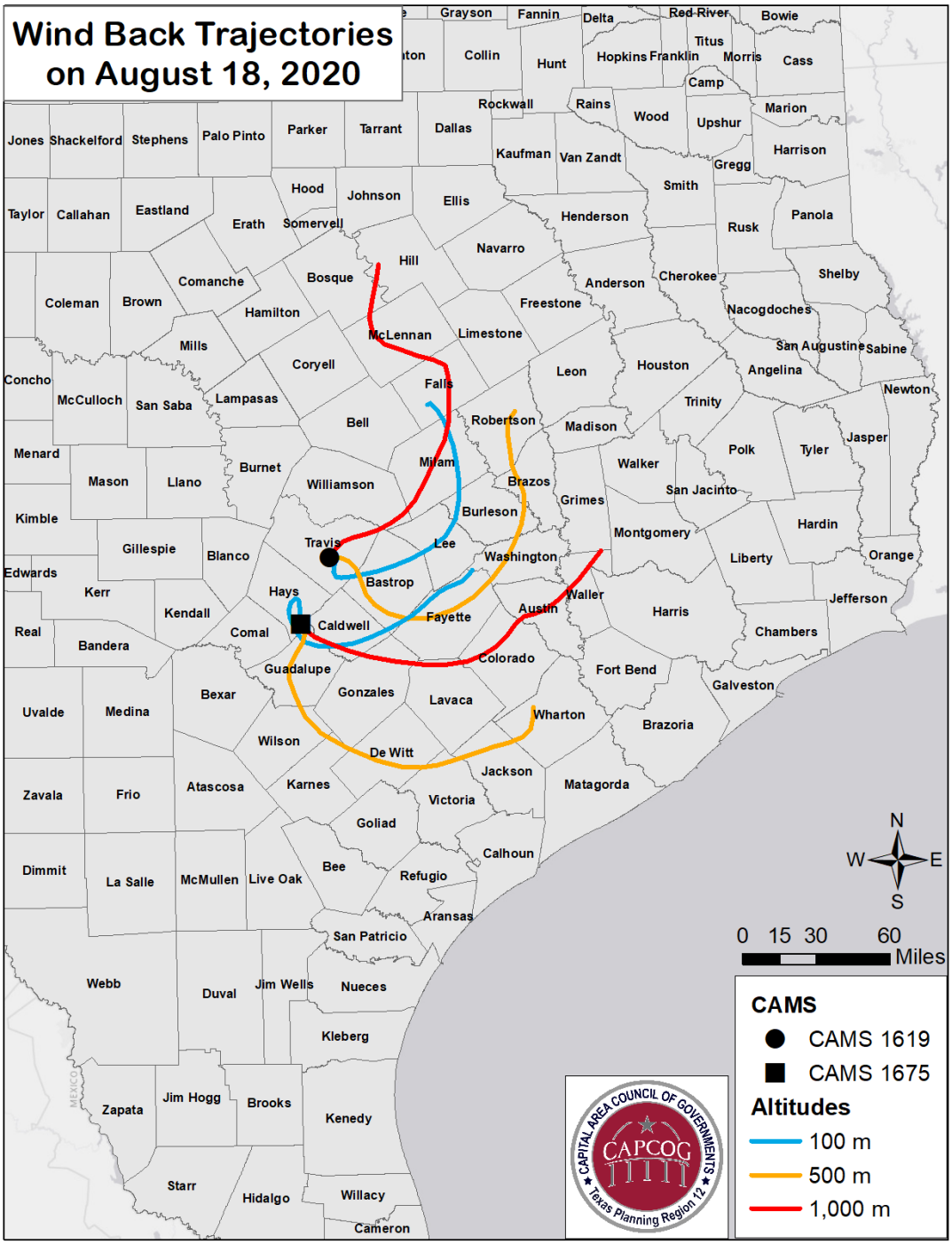
Figure 4-42. Wind Back-Trajectories on May 18, 2020, for Monitors over 70 ppb.



On August 18th, two CAPCOG monitors recorded MDA8 O_3 at 70 ppb or above, CAMS 1619 in East Austin, Travis County, and CAMS 1675 in San Marcos, Hays County. The back trajectories for both CAMS on August 18th indicate that the wind came from east-southeast for CAMS 1675 and east-northeast of the region for CAMS

1619, which includes the 2015 O_3 non-attainment area of Houston-Galveston-Brazoria for CAMS 1675 and the 2015 O_3 non-attainment area of Dallas-Fort Worth for CAMS 1619.

Figure 4-433. Wind Back-Trajectories on August 18, 2020, for Monitors over 70 ppb.



On both days that MDA8 O_3 was recorded as 70 ppb or higher in the region, the region was downwind from O_3 non-attainment areas in the state. This wind direction could have transported O_3 which may have contributed to

those high O_3 days in 2020. These wind directions are consistent with previous years in which regional monitors recorded high O_3.

5 Correlation between MDA8 O_3 and Other Criteria Pollutants

CAPCOG's 2010-2015 Conceptual Model indicated that there were statistical positive correlations between MDA8 O_3 values and other pollutants. Therefore, this section includes an analysis of the 2020 data compared to 2010-2019. For this analysis, CAPCOG analyzed the data for CAMS 3 for 2010-2019 and CAMS 38 and CAMS 1068 for 2020. Since CAMS 3 was inactive for the majority of 2020, CAPCOG has to use data from CAMS 38 for O_3 and CAMS 1068 for $PM_{2.5}$ and NO_2. This year's report cannot analyze SO_2, as has been done in the past, since the only SO_2 monitor is located at CAMS 3, which was not collecting data for the majority of 2020.

5.1 $PM_{2.5}$

CAPCOG calculated the average 24-hour $PM_{2.5}$ concentrations at CAMS 3 for 2010-2019 and CAMS 38 and CAMS 1068 for 2020 when the MDA8 O_3 values were >70 ppb, 55-70 ppb, and <55 ppb. The following figures show a comparison of these data. Since CAMS 3 was not active in 2020, $PM_{2.5}$ data from CAMS 1068 was used as it is the closest $PM_{2.5}$ monitor to CAMS 38 instead of CAMS 3. However, since CAMS 1068 typically records higher $PM_{2.5}$ concentrations, the CAMS 1068 data from 2020 is displayed in a separate figure as to not give the impression that $PM_{2.5}$ worsened significantly in 2020. Therefore, figure 5-1 displays the average 24-hour $PM_{2.5}$ concentrations at CAMS 3 for 2010-2019 when the MDA8 O_3 values were >70 ppb, 55-70 ppb, and <55 ppb. Figure 5-2 displays similar data for CAMS 38 for MDA8 O_3 and CAMS 1068 for $PM_{2.5}$. Although figure 5-2 shows higher $PM_{2.5}$, it follows the trend from previous years that 24-hour $PM_{2.5}$ and MDA8 O_3 have a positive correlation.

Figure 5-1. Typical 24-Hour $PM_{2.5}$ Concentrations at CAMS 3 for 2010-2019 on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb

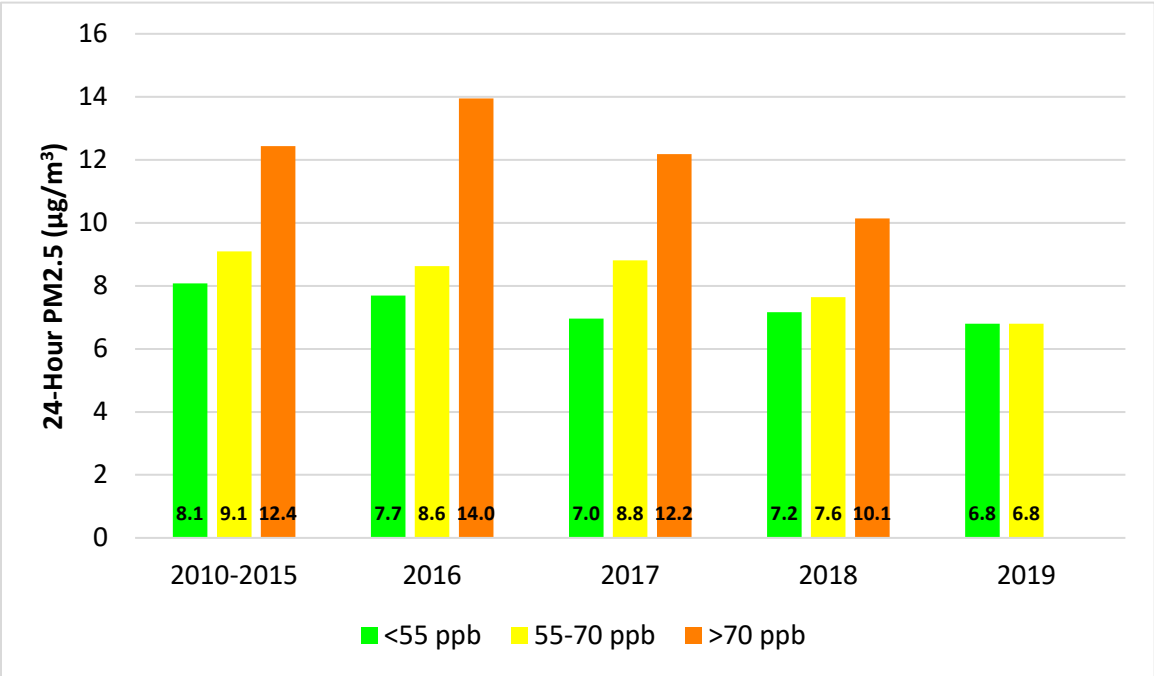
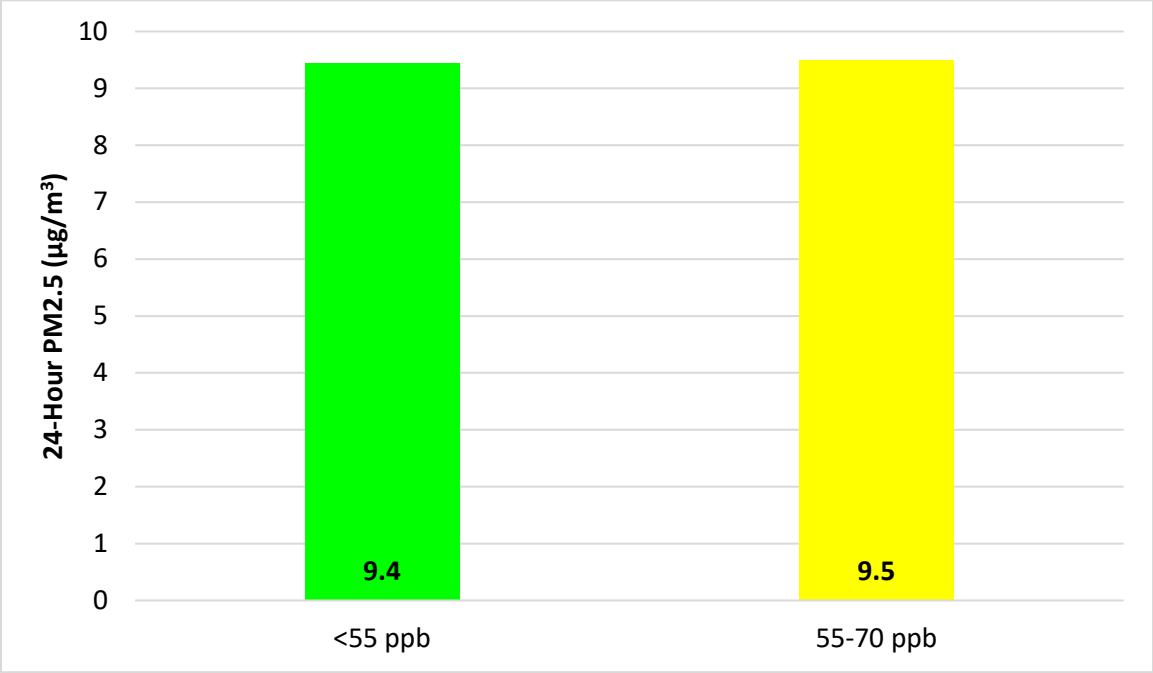


Figure 5-2. Typical 24-Hour PM2.5 Concentrations at CAMS 1068 for 2020 on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 38



5.2 NO_2

CAPCOG calculated the average maximum daily 1-hour (MDA1) NO_2 concentrations at CAMS 3 for 2010-2019 and CAMS 38 and CAMS 1068 for 2020 when the MDA8 O_3 values were >70 ppb, 55-70 ppb, and <55 ppb. The following figures show a comparison of these data. Since CAMS 3 was not active in 2020, NO_2 data from CAMS 1068 was used as it is the closest NO_2 monitor to CAMS 38 instead of CAMS 3. However, since CAMS 1068 typically records higher NO_2 concentrations, the CAMS 1068 data from 2020 is displayed in a separate figure as to not give the impression that NO_2 worsened significantly in 2020. Therefore, figure 5-3 displays the average MDA1 NO_2 concentrations at CAMS 3 for 2010-2019 when the MDA8 O_3 values were >70 ppb, 55-70 ppb, and <55 ppb. Figure 5-4 displays similar data for CAMS 38 for MDA8 O_3 and CAMS 1068 for NO_2. Although figure 5-4 shows higher NO_2, it follows the trend from previous years that MDA1 NO_2 and MDA8 O_3 have a positive correlation.

Figure 5-3. Typical MDA1 NO_2 Concentrations at CAMS 3 on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 3, 2010-2019

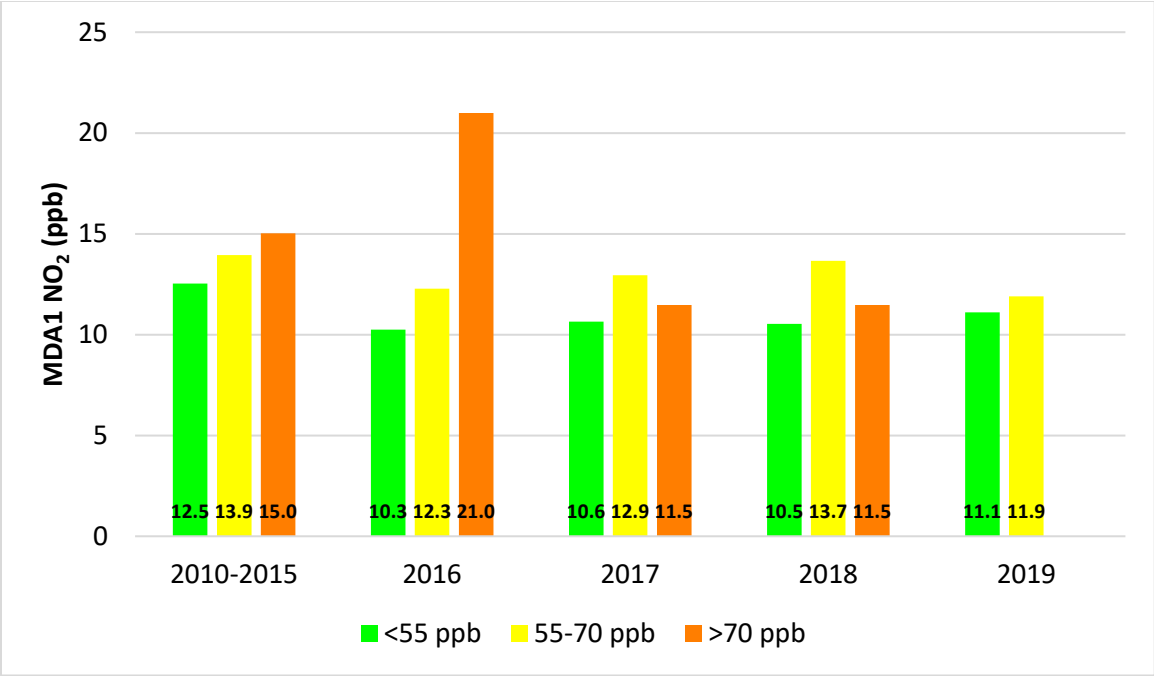
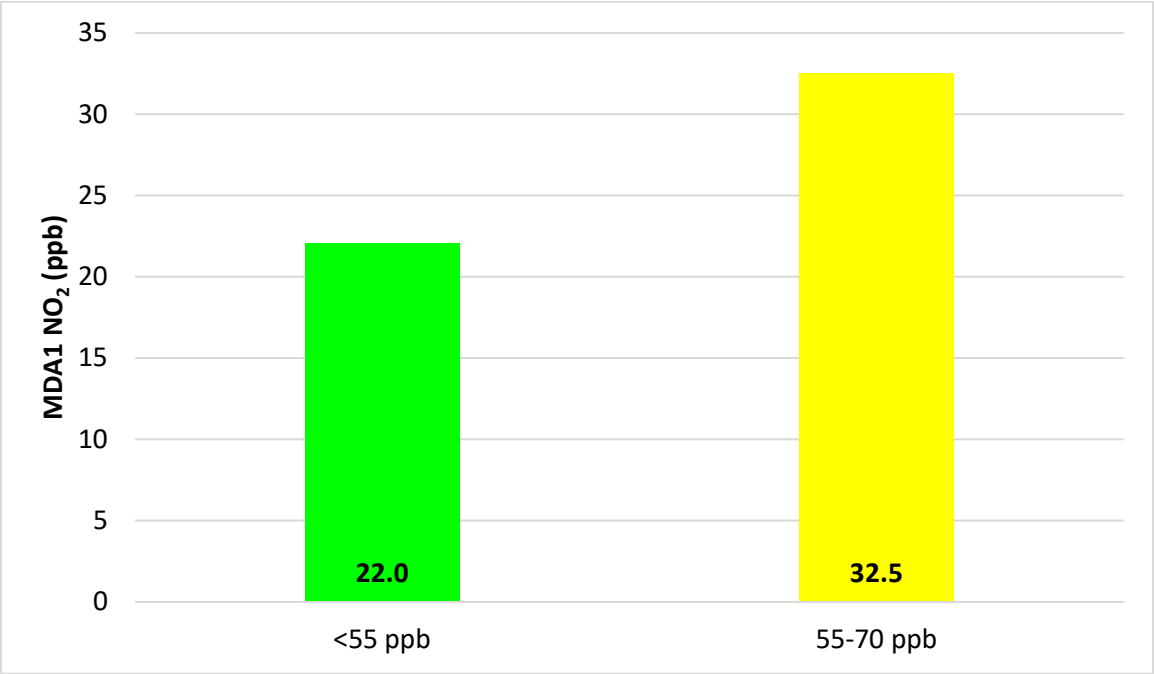


Figure 5-4. Typical MDA1 NO_2 Concentrations at CAMS 1068 on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 38, 2020

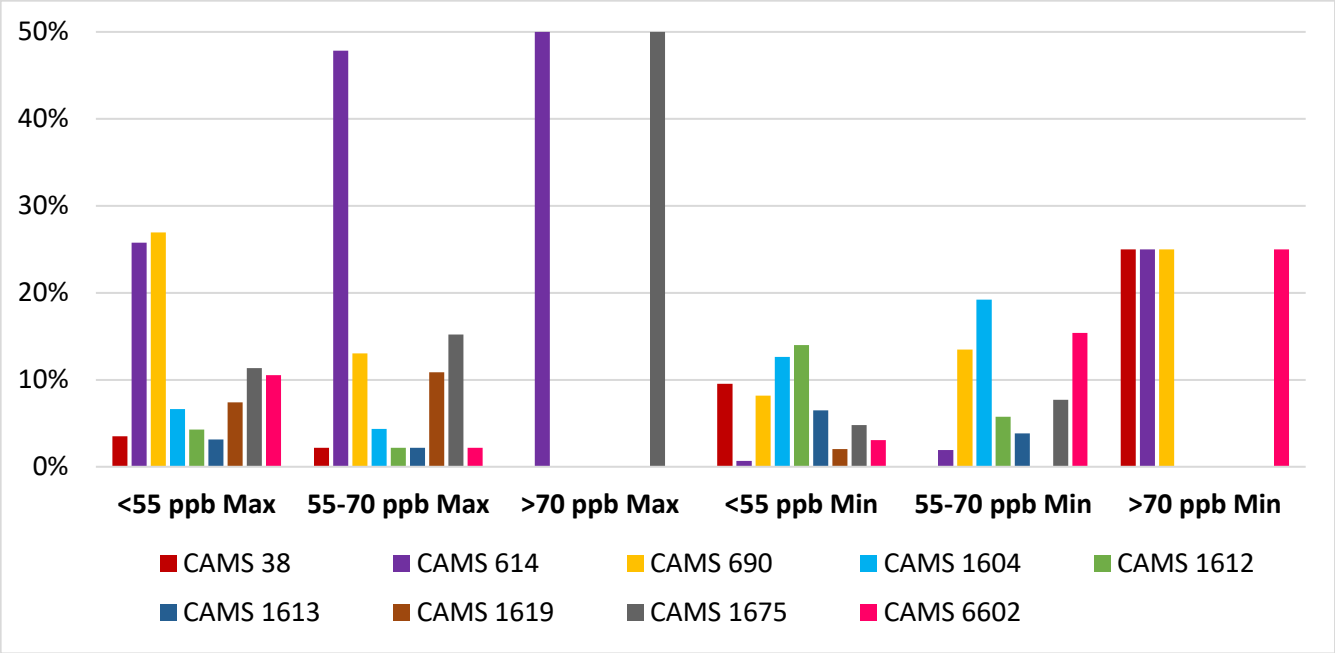


6 O_3 Transport Analysis

CAPCOG's 2010-2015 Conceptual Model included an O_3 transport analysis that used the maximum and minimum MDA8 O_3 values in the region in order to estimate the "background" MDA8 O_3 levels and the local contribution to MDA8 O_3 levels when the peak MDA8 O_3 in the region was <55 ppb, 55-70 ppb, and >70 ppb. CAPCOG limited the analysis to only on days when at least three monitors recorded data. CAPCOG performed this same analysis on the data collected in the region in 2020.

The following figures show the percent of times that each monitoring station in the MSA recorded the highest or lowest MDA8 O_3 in the region for each AQI range from March 1, 2020 – November 15, 2020. This was the timeframe in which CAPCOG's non-regulatory monitors were operating.

Figure 6-1. Highest or Lowest MDA8 O_3 Percentage by Monitor for 2020



A few significant notes about this figure:

- Since CAMS 3 was offline for the majority of 2020, it never recorded the regional maximum or minimum value for the timeframe analyzed. Therefore, it is not included in the figure.
- There were two days in which three CAMS recorded MDA8 O_3 >70 ppb; CAPCOG's CAMS 614 and CAMS 1675 recorded the 2 highest values.
- For days when MDA8 O_3 was 55-70 ppb and <55 ppb, CAPCOG's CAMS 614 most frequently recorded the region-wide maximum.
- For days when MDA8 O_3 was 55-70 ppb and <55 ppb, CAPCOG's CAMS 1604 most frequently recorded the region-wide minimum.

Observed data from CAMS 1605 was excluded because St. Edward's University researchers determined in 2016 that the O_3 data at CAMS 1605 was accurate and precise, but they believed that values were likely lower than expected due to some NO_X titration issues. The monitor is located less than 1 kilometer from IH-35, U.S.-71, and South Congress Avenue, causing a potentially high localized concentration of NO_X on campus.

The figures below show a comparison of the typical "background" MDA8 O_3 levels and the typical local contribution to peak MDA8 O_3 levels for 2010-2020.

Figure 6-2. Comparison of Background Contribution to MDA8 O_3 on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 3, 2010-2019, and CAMS 38, 2020

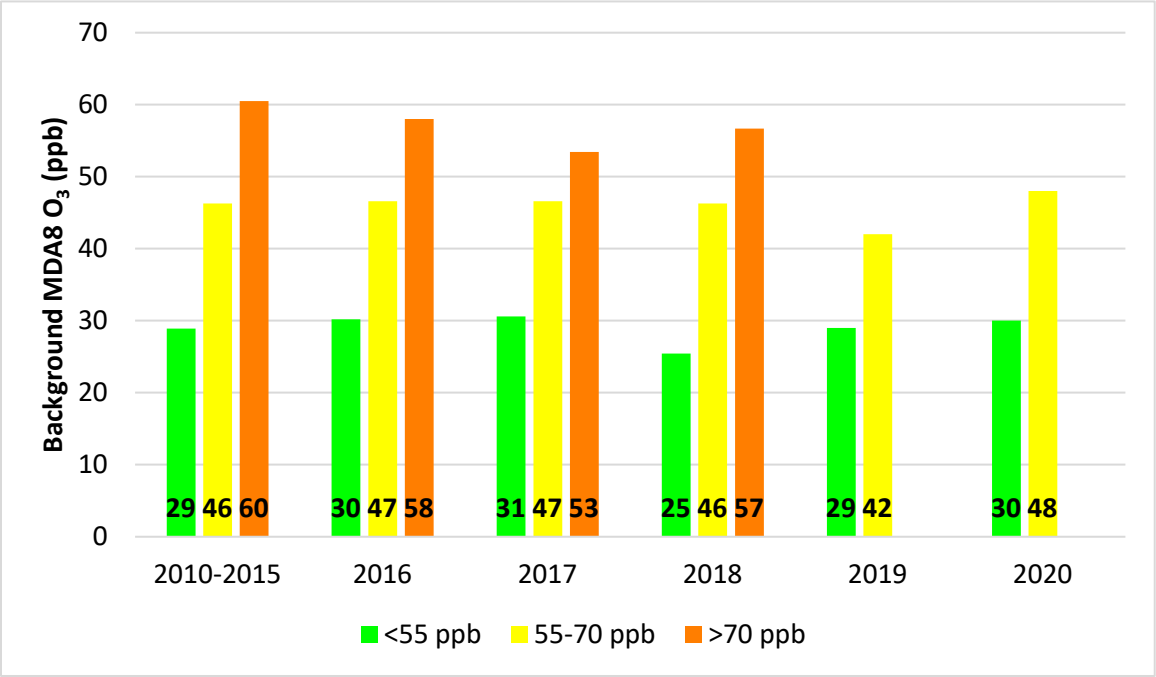
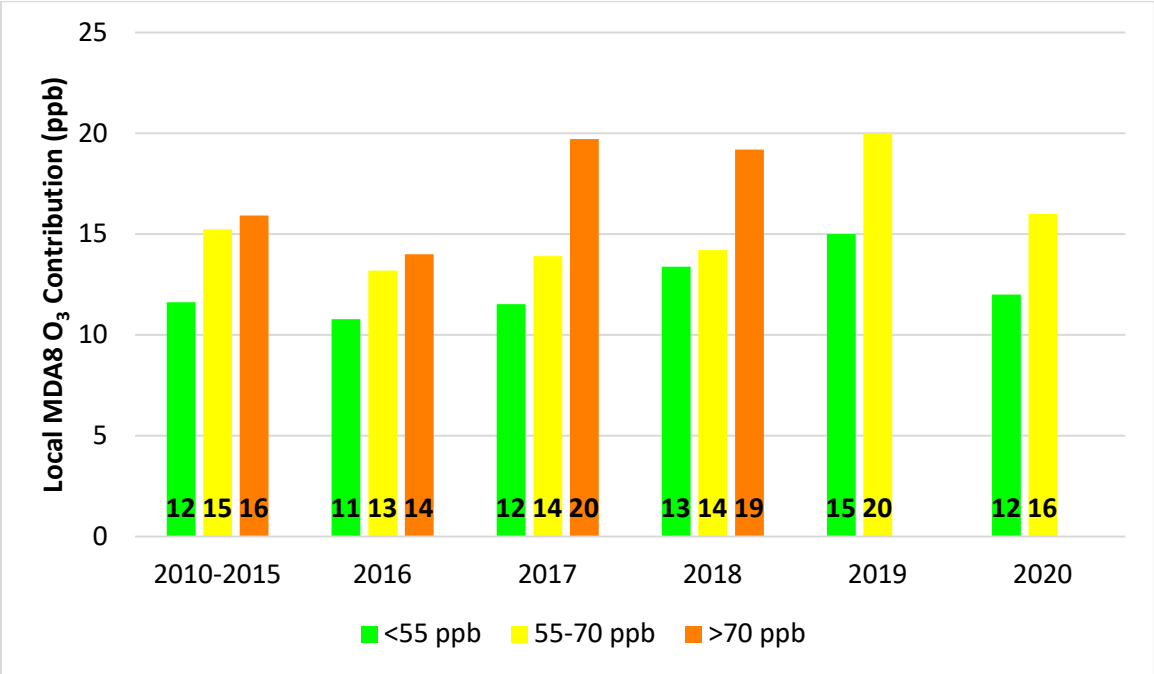


Figure 6-3. Comparison of Local Contribution to MDA8 O_3 on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 3, 2010-2019, and CAMS 38, 2020

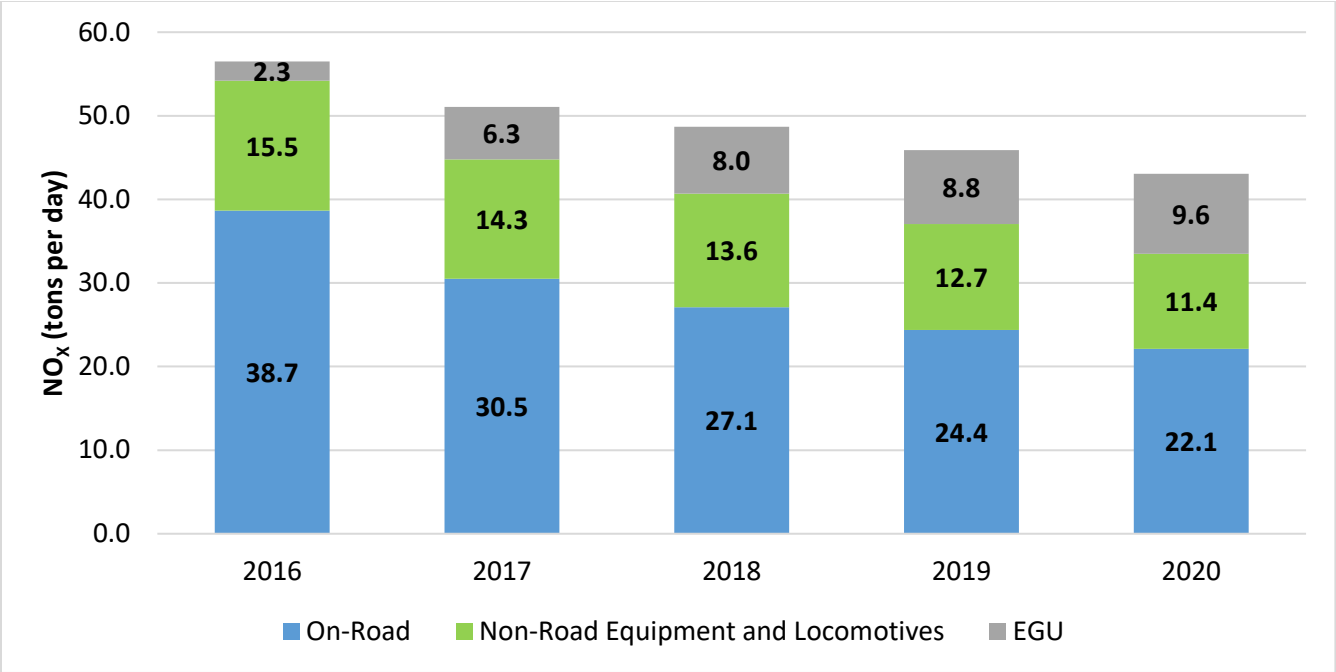


The graphs show that "background" levels in 2020 at CAMS 38 were similar to 2016 MDA8 O_3 levels at CAMS 3 on days with <55 ppb and 55-70 ppb. However, local contributions in 2020 were similar to 2010-2015 when MDA8 O_3 levels were in the <55 ppb and 55-70 ppb range.

7 NO_X Emissions Analysis

Apart from analyzing changes in meteorology year to year, analyzing changes in NO_X emissions year to year is also important to understanding O_3 formation within the region. Since 1999, NO_X emissions both within the region and across the country have decreased substantially. This has been true for both stationary sources and mobile sources. While emissions from mobile sources continue to decline year over year due to federal engine standards, emissions from point sources – particularly, power plants – can fluctuate substantially year to year. Between on-road vehicles, non-road equipment and locomotives, and power plants, overall NO_X emissions were lower in 2020 than they were in 2019. However, electric generating unit (EGU) NO_X emissions were higher in 2020 than in 2019. In 2020, NO_X from EGUs actually appears to have been enough to push overall regional NO_X emissions higher on high O_3 days. Note that on figure 7-1 below, only categories for which CAPCOG has OSD NO_X emissions estimates available for 2016-2020 are shown.

Figure 7-1. Summary of NO_X Emissions from On-Road, Non-Road, and EGU Point Source NO_X Emissions, 2016-2020



7.1 EGU Point Sources

2020 data for EGUs is available from EPA at the hourly level. The following figure shows the average daily NO_X emissions from EGUs in the MSA and adjacent counties and emissions on the top 4 days with high MDA8 O_3.[6]

[6] Excluding Decker Creek Power Plant gas turbines, which are not equipped with Continuous Emissions Monitoring Systems (CEMS) and therefore have emissions totals in EPA's database that reflect the worst-case scenario emissions rates.

Figure 7-2. Average Daily May – September NO_X Emissions from EGU Point Sources in Austin-Round Rock-Georgetown MSA and Surrounding Counties, 2010-2020

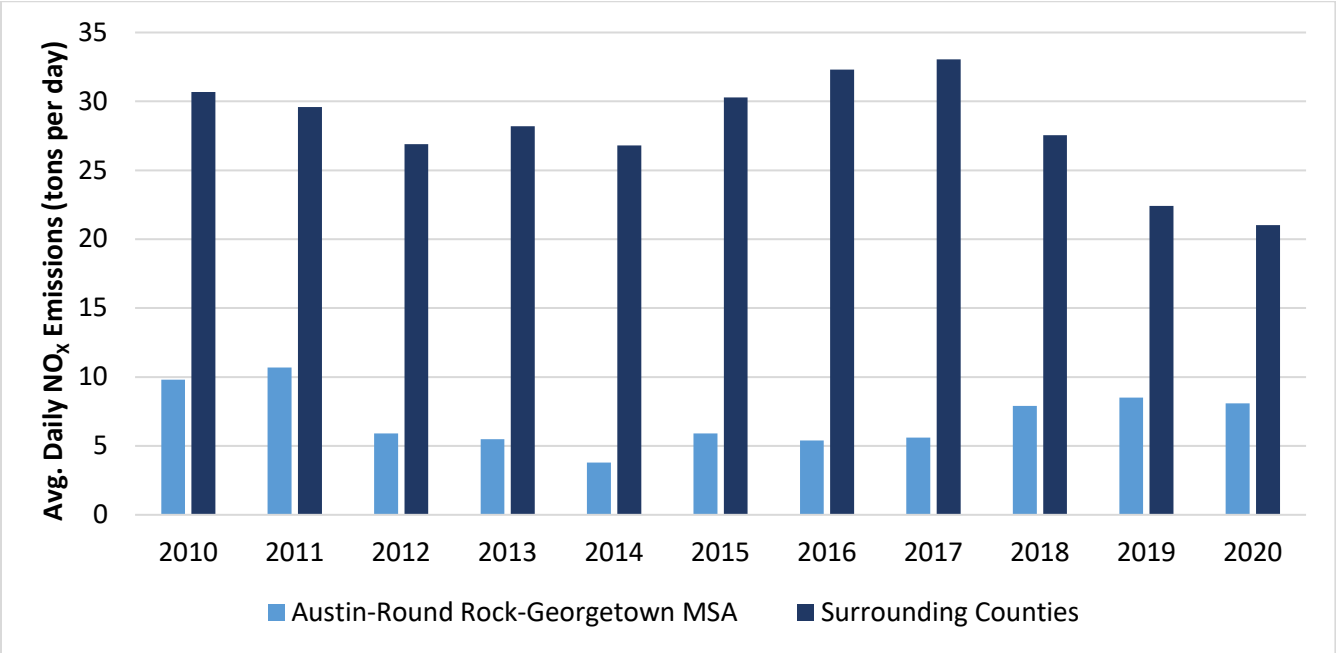
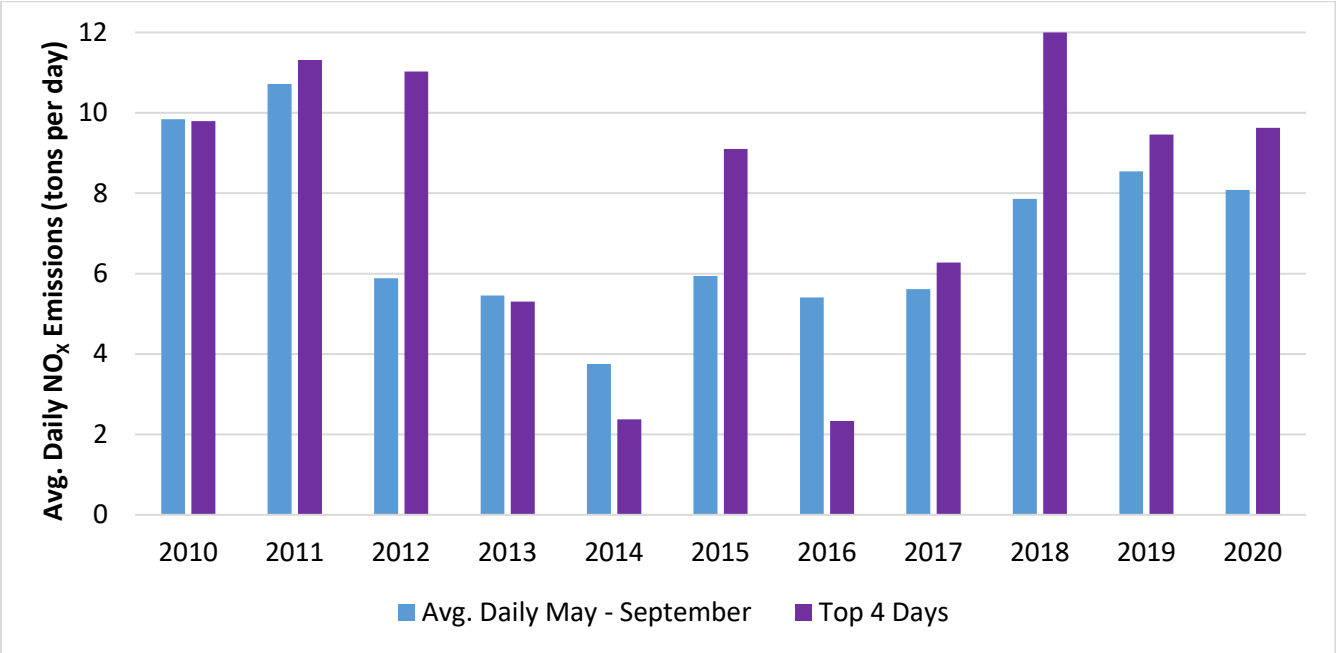


Figure 7-3 provides another perspective on the MSA's EGU emissions, comparing the standard "Ozone Season Day" emissions (considered to be May 1 – September 30) to the average emissions on the days when the top 4 MDA8 O_3 were recorded at CAMS 3 for 2010-2019[7] and CAMS 38 for 2020. As these figures show, the MSA's EGU NO_X emissions significantly were higher on the top 4 days than the average from May 1 to September 30.

[7] Note – in 2011, 2014, 2015, and 2016, due to data-handling conventions, there were either 2 or 3 days that qualified as the 4th-highest day since they all had the same MDA8 O_3 value. In these cases, CAPCOG included all days with MDA8 values classified as 4th-highest or higher).

Figure 7-3. Average O_3 Season Daily MSA EGU NO_X Emissions May – September and Top 4 Days at CAMS 3, 2010-2019, and CAMS 38, 2020



The difference between the average daily NO_x emissions and the top 4 days appears to be due to Decker Creek Power Plant and Sim Gideon Power Plant. Decker Creek and Sim Gideon are older power plants that are used to generate electricity during high demand periods. Additionally, two power plants in nearby counties have changed operations in the past two years; the Sandow Power Plant in Milam County closed in 2018[8]. The Gibbons Creek Power Plant in Grimes County was not used in 2019[9], and its closure was announced in late June 2019. With these two power plants no longer supplying electricity to the electric grid, it appears that local power plants, and especially Decker Creek and Sim Gideon, picked up some of the load on the top 4 days.

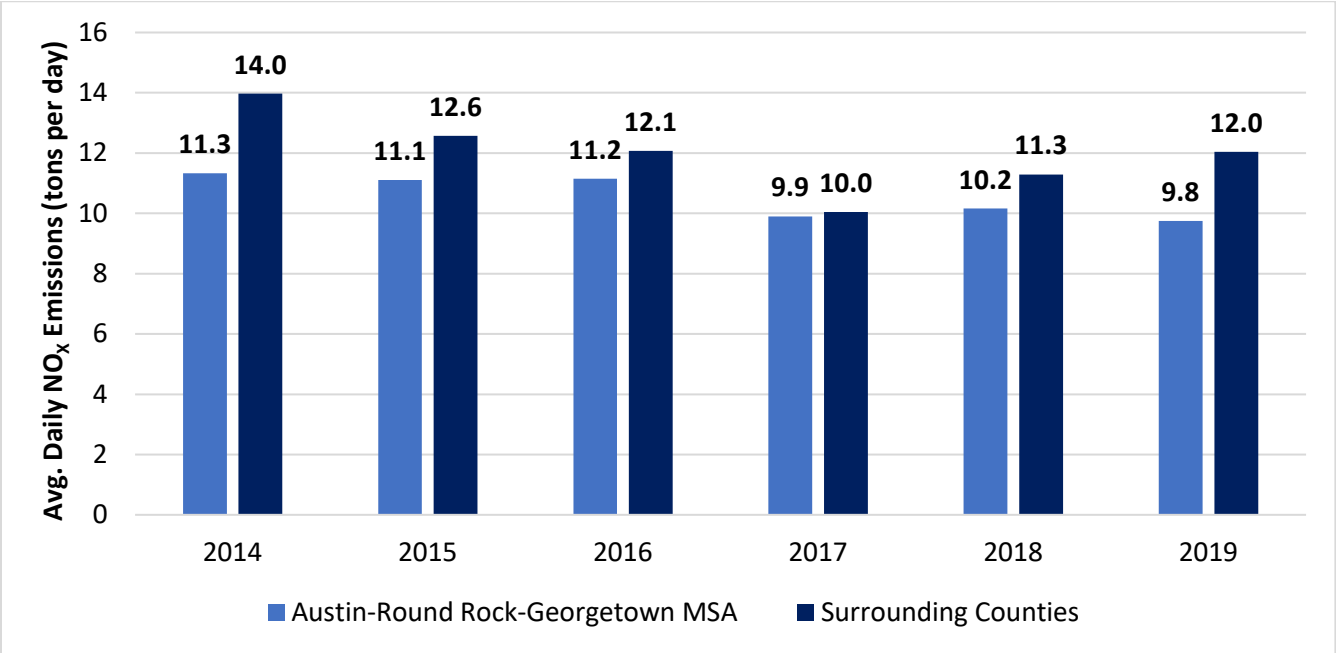
7.2 Non-EGU Point Sources

2020 non-EGU point source emissions data has not yet been posted online by TCEQ – that will likely happen in January 2022. However, non-EGU point source emissions have much less year-to-year variation than EGU point source emissions tend to have since non-EGU emissions. The following figure shows the average daily NO_X emissions for 2014 – 2019 from non-EGU point sources in the Austin-Round Rock-Georgetown MSA and surrounding counties. As the figure shows, the NO_X emissions from these sources were quite stable year-to-year during this time frame, suggesting that 2020 emissions are likely comparable. Variations in year-to-year in NO_X emissions from non-EGU point sources in adjacent counties within this time frame were more substantial, but this variation is unlikely that this increase would have a significant impact on local O_3 concentrations within the MSA compared to year-to-year variations within the MSA would.

[8] https://www.bizjournals.com/austin/news/2017/10/16/central-texas-energy-plant-to-shut-down-as-part-of.html

[9] https://www.kallanishenergy.com/2019/07/05/coal-fired-texas-power-plant-to-close-oct-23/

Figure 7-4. Average Daily NO_X Emissions from Non-EGU Point Sources in Austin-Round Rock-Georgetown MSA and Surrounding Counties, 2014-2019[10]

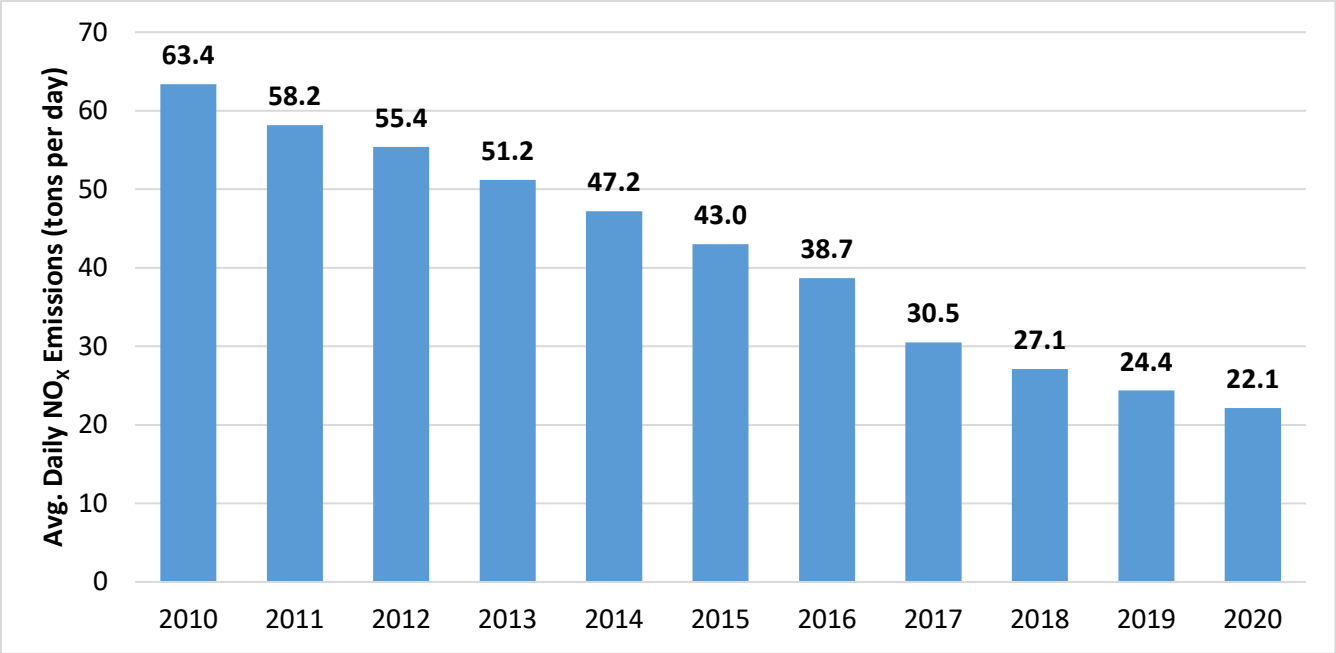


7.3 On-Road Mobile Sources

TCEQ's on-road "trends" emissions inventories include average summer weekday NO_X emissions by county for 1999-2050. The following figure shows the 2010 – 2020 NO_X trends inventory emissions estimates for the MSA and adjacent counties. As the figure shows, NO_X emissions decreased in the MSA by 2.3 tpd (9% from 2019 to 2020).

[10] Note – for unknown reasons, U.T.'s Hal Weaver Plant showed annual emissions but did not report any ozone season day emissions for 2017, although other records clearly show it was in use during the summer months. CAPCOG calculated the total for this facility using TCEQ data from other years in conjunction with Energy Information Administration electricity generation data for 2018 summer months in order to develop this estimate.

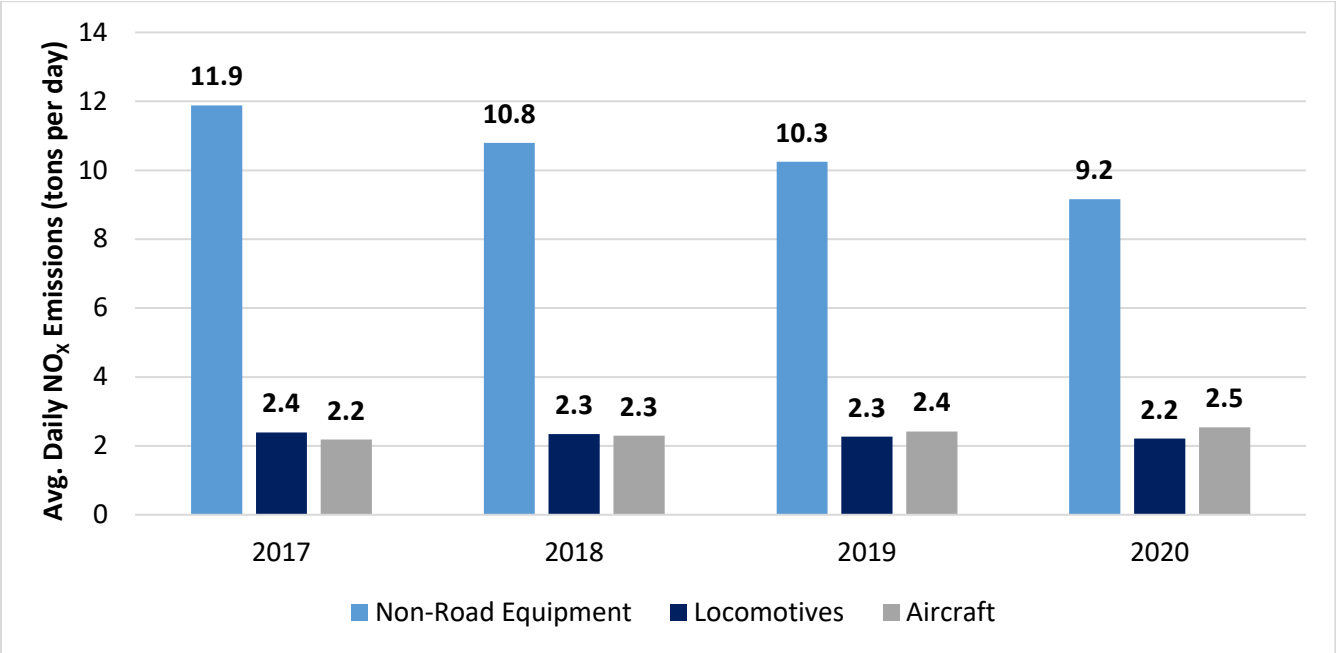
Figure 7-5. Average Summer Weekday NO_X Emissions from On-Road Sources in Austin-Round Rock-Georgetown MSA, 2010-2020



7.4 Non-Road Mobile Sources

Mobile sources emissions from non-road equipment and locomotives are lower in 2020 than in the previous years, while aircraft emissions are estimated to be slightly higher. Overall, non-road NO_X emissions in the MSA are estimated to be about 1.03 tpd lower in 2020 than they were in 2019.

Figure 7-6: Non-Road Average MSA OSD NO_X Emissions 2017-2020 (tpd)



8 CONCLUSION

This report provides an update to the "state of the knowledge" regarding the influence of emissions, meteorology, transport, and other processes on O_3 pollution within the region. Major findings include the following:

- No monitor in the region recorded a 4th-highest MDA8 O_3 level greater than 70 ppb.
- While the 2020 O_3 levels were substantially lower than in 2019 or 2018, they would not be considered "outliers" based on year-to-year variation across the 2017-2019 period.
- One local meteorological factor stands out as a potential explanation for the lower O_3 observed in the MSA in 2020 compared to previous years: more days with lower solar radiation, which was lower in 2020 than in all of the other time frames analyzed.
- There were several other meteorological factors that the region's Conceptual Model has previously shown were associated with high O_3 that were prevalent in 2020, including low wind speed and low relative humidity.
- The "transport" analysis suggests that the local contribution to O_3 was 16 ppb for days 55-70 ppb, which is similar to the average for 2010-2015 for days >70 ppb.
- Aside from counties within the Austin-Round Rock-Georgetown MSA, counties in the San Antonio metro area and the Houston metro area were the most common "upwind" counties of regional monitors when MDA8 O_3 levels were >70 ppb.
- $PM_{2.5}$ levels in 2020 exhibited a positive correlation with O_3.
- NO_X emissions from on-road, non-road, and EGU sources within the MSA likely decreased from 2019 to 2020, contributing to the reduced O_3 concentrations.
- Overall, 2020 meteorological data trends were consistent with the relationship between MDA8 O_3 and weather conditions observed in 2010-2019.
- Observed wind speeds, peak temperatures, and temperature changes from 12 pm – 4 pm were consistent with observations in 2010-2019.
- Relative humidity from 12 pm – 4 pm was higher than levels observed in 2019.

9 APPENDIX

Additional data collected for this analysis can be reviewed in this appendix including CAMS calibration data, CAMS air pollution measurements, and CAMS meteorological statistics. The appendix is an Excel workbook, which is available by clicking the paperclip icon below.