2019 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 2019 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 10 different O_3 monitoring stations and two National Weather Service (NWS) stations in the MSA, comparing the 2019 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, 2017, and 2018. Some of the most noteworthy findings of this report include the following:

- In 2019, there were only two days that measured O_3 greater than 70 part per billion (ppb), down from ten in 2018 and seven in 2017, and substantially lower 4th-highest maximum daily 8-hour averages (MDA8) O_3 than in 2018 and 2017; these lower O_3 concentrations are likely attributable primarily to lower solar radiation, but also can be partly explained by lower NO_X emissions.
- On the other hand, there were a larger number of days when O_3 levels exceeded 54 ppb in 2019 compared to 2018 and 2017; one non-meteorological explanation for this could be that while average emissions of nitrogen oxides (NO_X) from power plants were lower on the days with the highest MDA8 O_3 at the region's key regulatory monitor, they were higher on other days from May 1 – September 30.
- Despite the lower 4th-highest MDA8 O_3 averages at the region's two regulatory O_3 monitoring station in 2019 than in 2018, the region's 3-year O_3 design value for 2017-2019 actually increased to 69 ppb from 68 ppb for 2016-2018 due to the 4th-highest value at Continuous Air Monitoring Station (CAMS) 3 in 2019 being higher (65 ppb) than the value in 2016 (64 ppb).
- On the two days when MDA8 O_3 exceeded 70 ppb, the areas to the southeast of the MSA were the most common upwind areas, similar to the previous year's patterns. Within the region, Hays County and Caldwell County were upwind of the region's monitors that recorded 8-hour O_3 greater than 70 ppb on both days when this occurred, while Williamson County was not upwind of these monitors on either day.

This report includes:

- General summaries of O_3 data in the region from 2019 compared to 2010-2018 (Section 2);
- Analysis of the temporal profiles and features of O_3 in the region in from 2010-2019 (Section 3);
- Investigations of potential relationships between meteorology and O_3 pollution from 2010-2019 (Section 4);
- Analysis of correlations between O_3 pollution and ambient $PM_{2.5}$, NO_2, and SO_2 concentrations from 2010-2019 (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 2010-2019 (Section 6); and
- Analysis of the potential changes in NO_X emissions between 2010-2019 that could explain changes in the O_3 levels observed within the region in 2019 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
$PM_{2.5}$: 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

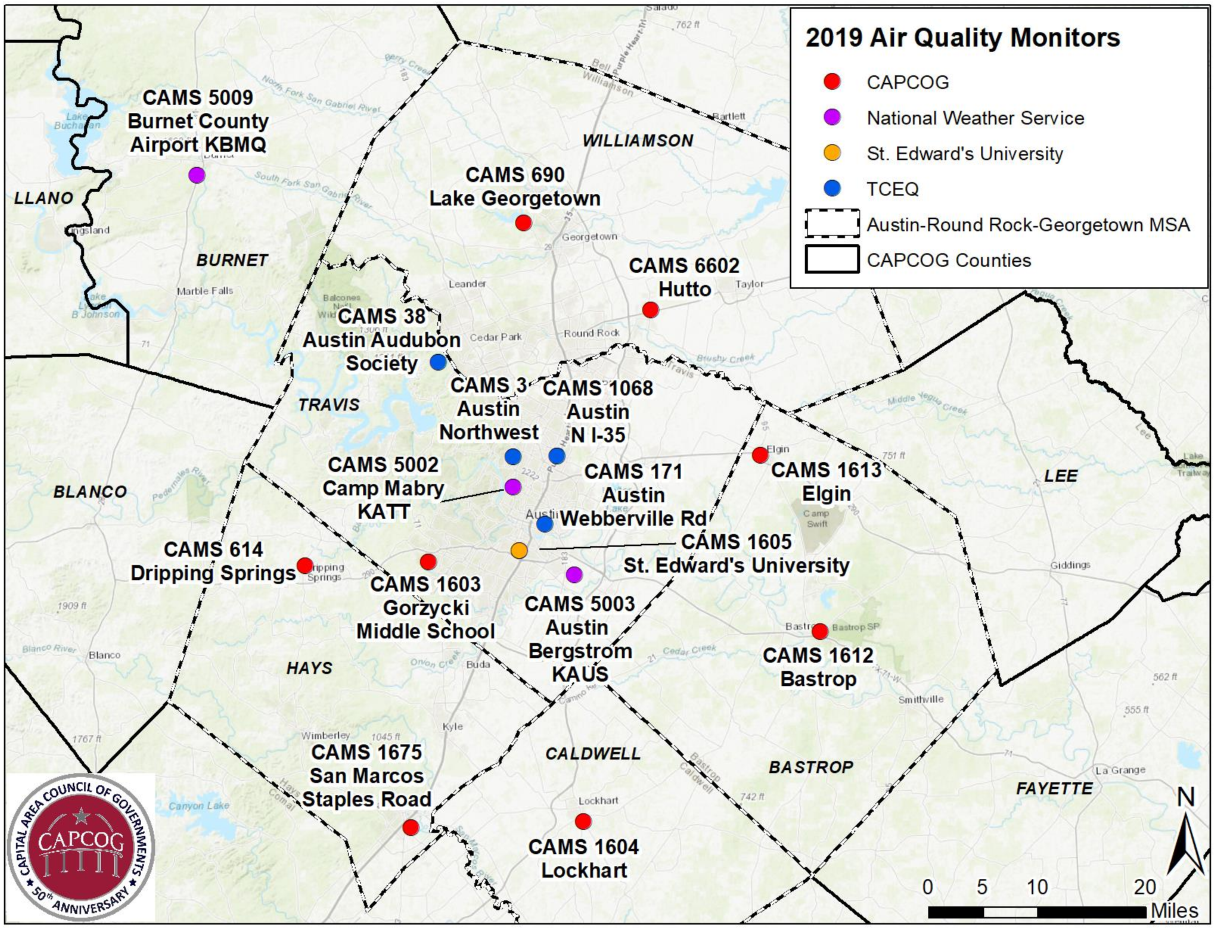
The purpose of this project is to analyze 2019 ambient air monitoring data collected in the Austin-Round Rock-Georgetown Metropolitan Statistical Area (MSA) that consists of Bastrop, Caldwell, Hays, Travis, and Williamson Counties, including comparing it with data from prior years dating back to 2010.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

- Blue circles are Texas Commission on Environmental Quality (TCEQ) stations that collected regulatory air pollution and meteorological data in 2019.
    - 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.
    - 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 1612 (Bastrop) and CAMS 1613 (Elgin) are new monitors in 2019 that replaced CAMS 614 (Fayette Co.) and CAMS 684 (McKinney Roughs).
- 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. 2019 Air Quality Monitors in the Austin-Round Rock-Georgetown MSA and CAPCOG Counties

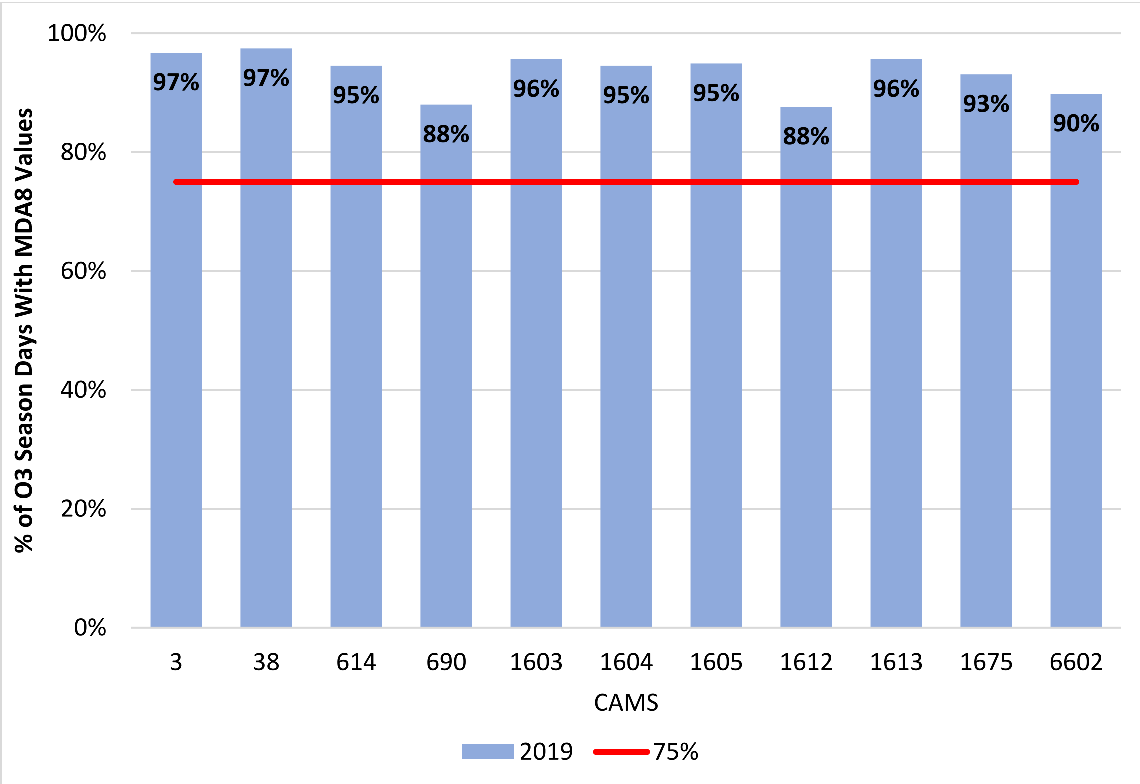


TCEQ's monitoring stations are "regulatory" because they equipped with Federal Reference Method (FRM) monitoring equipment in accordance with federal regulations, and are therefore used as the basis for assessing the region's compliance with the National Ambient Air Quality Standards (NAAQS). CAPCOG's 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

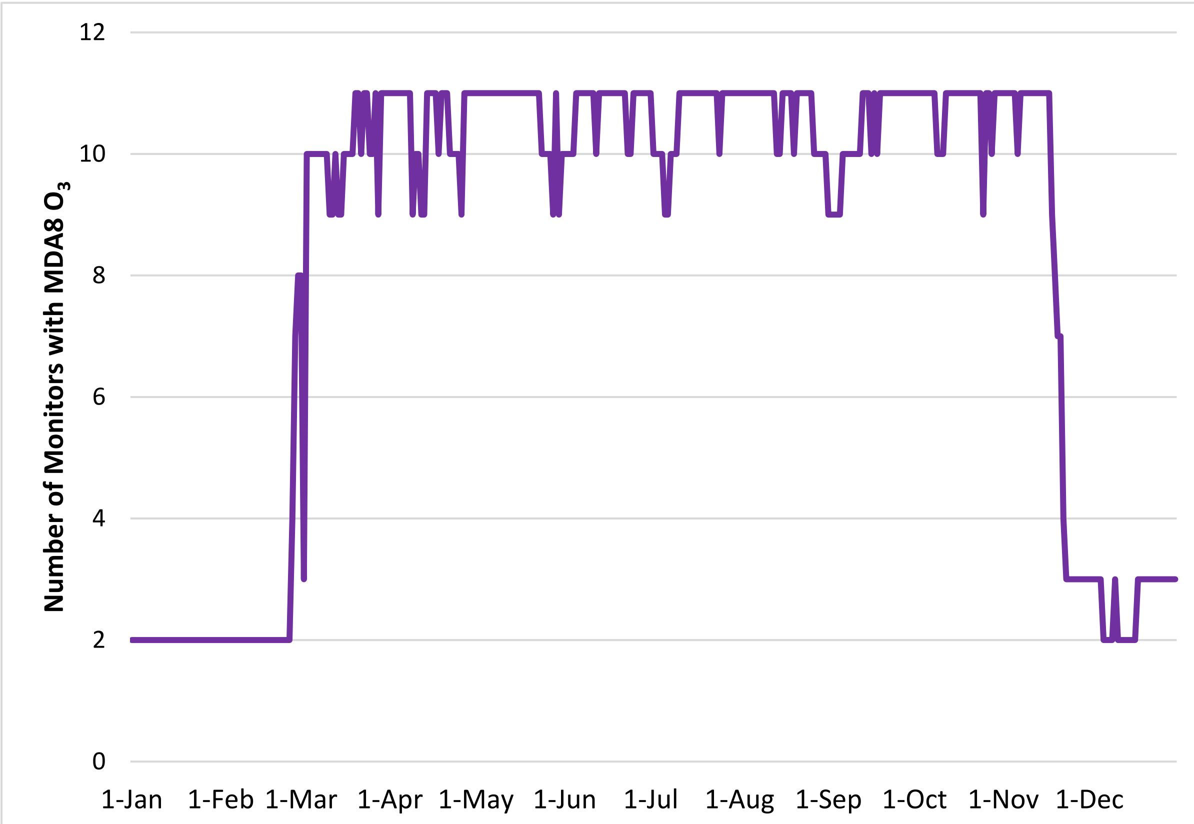
In order to provide perspective on the overall availability of maximum daily 8-hour average (MDA8) O_3 values for analysis, the following figure shows the percentage of O_3 season MDA8 values available for each monitoring station in 2019. TCEQ's two O_3 monitors collected data year-round, the eight CAPCOG CAMS collected data from mid-February to mid-November, and the St. Edwards University CAMS collected data from mid-February to the end of December. 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 each year during these 275 days.

Figure 1-2. CAMS MDA8 O_3 Value Data Completeness for the 2019 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 2019.

Figure 1-3. Number of Monitors with Recorded MDA8 O_3 Values by Date in 2019



1.3 O_3 NAAQS Attainment Status

Through the end of 2019, the region's O_3 levels continue to be attaining the 2015 O_3 NAAQS of 0.070 parts per million (ppm), although the region's 3-year O_3 "design value" climbed from 0.068 ppm from 2016-2018 to 0.069 ppm for 2017-2019[2]. The 2017-2019 design value at CAMS 3 and CAMS 38 were 0.069 ppm and 0.066 ppm, respectively. While the 4th-highest MDA8 O_3 levels at CAMS 3 and CAMS 38 were both lower in 2019 than they were in 2018, they were both also higher than they were in 2016, causing the region's three-year design values to increase from 2016-2018 to 2017-2019 due to an increase in the 3-year average at CAMS 3. CAMS 3's official 4th-highest MDA8 O_3 in 2019 was 65 ppb due to EPA's data-handling conventions that allows 6-hour and 7-hour averages to be used if a full 8-hour average is not available.[3] However, TCEQ's LEADS system appears to only include full 8-hour averages, and the 4th-highest full MDA8 O_3 at CAMS 3 was 63 ppb, which would have led to a 68 ppb design value as suggested on TCEQ's website. CAPCOG became aware of this discrepancy after EPA's 2019 design value reports were posted. Therefore, CAPCOG is displaying the official data for CAMS 3 in 2019 from EPA, but all of the data for the other monitors is from LEADS.

The research monitors that CAPCOG operates are not FRM stations; and therefore, they are not used to establish the region's compliance with the NAAQS. However, their data can indicate if there are O_3

[2] https://www.epa.gov/air-trends/air-quality-design-values

[3] See 40 CFR, Appendix U to Part 50

problems that are not getting picked up by TCEQ's FRM monitors. For example, one of the two high O_3 days only was recorded at a CAPCOG monitor.

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 2019 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 2010-2018 occur with any greater or less frequency in 2019?

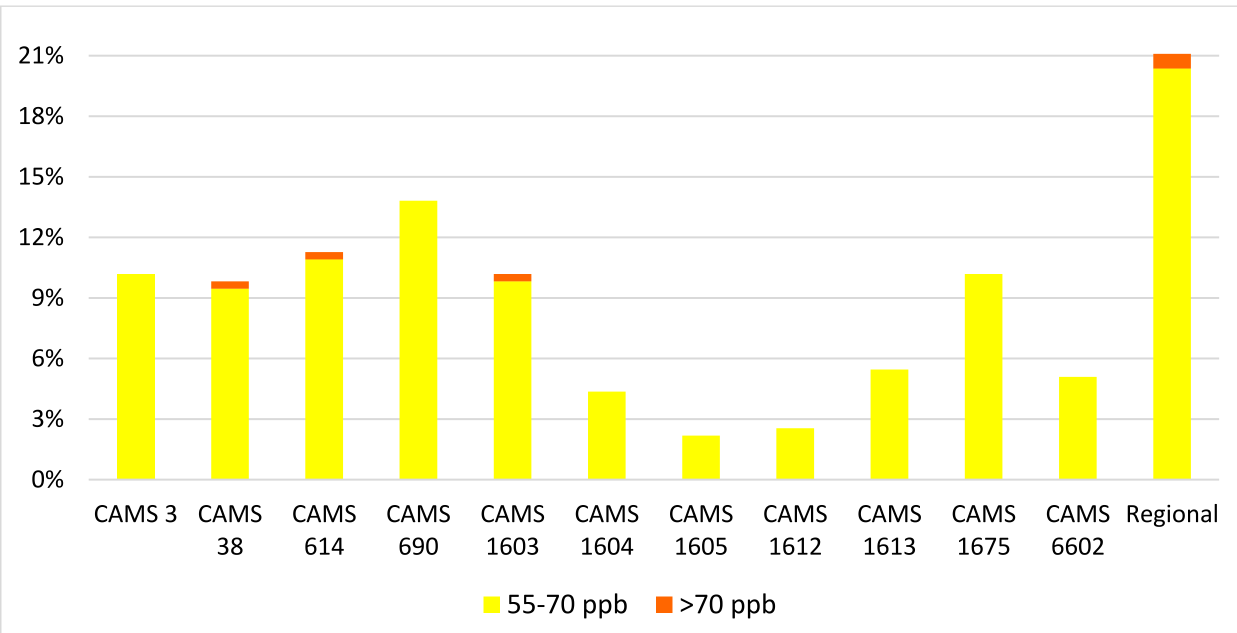
2 Analysis of Daily Maximum 8-Hour O_3 Data and Seasonal O_3 Exposure

This section provides general data on the MDA8 O_3 levels measured in the region in 2019. 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 2019 was 74 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.

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 2019 (March-November). There were 2 days in 2019 with MDA8 O_3 levels measured above 70 ppb. MDA8 O_3 was measured at 55 ppb or above on 21% of days in O_3 season.

Figure 2-1. Percentage of O_3 season days when monitored MDA8 O_3 was 55-70 ppb or >70 ppb, 2019



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 2-1. Days with MDA8 O_3 >70 ppb by monitoring station and year, 2010-2019

CAMS	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
3	8	13	6	1	0	8	1	3	6	0	46
38	3	6	6	3	0	7	0	1	1	1	28
614	4	9	6	0	0	5	0	1	3	1	29

CAMS	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
690	1	6	8	9	0	5	0	3	3	0	35
1603	n/a	n/a	n/a	n/a	0	6	0	0	7	1	14
1604	n/a	n/a	n/a	n/a	0	0	0	2	0	0	2
1605	n/a	n/a	n/a	n/a	n/a	n/a	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
1613	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	0	0
1675	n/a	2	6	3	0	3	0	0	6	0	20
6602	n/a	13	0	1	0	4	0	0	1	0	19
Regional	11	20	12	10	0	12	1	7	10	2	85

Table 2-2. Days with MDA8 O_3 55-70 ppb by monitoring station and year, 2010-2019

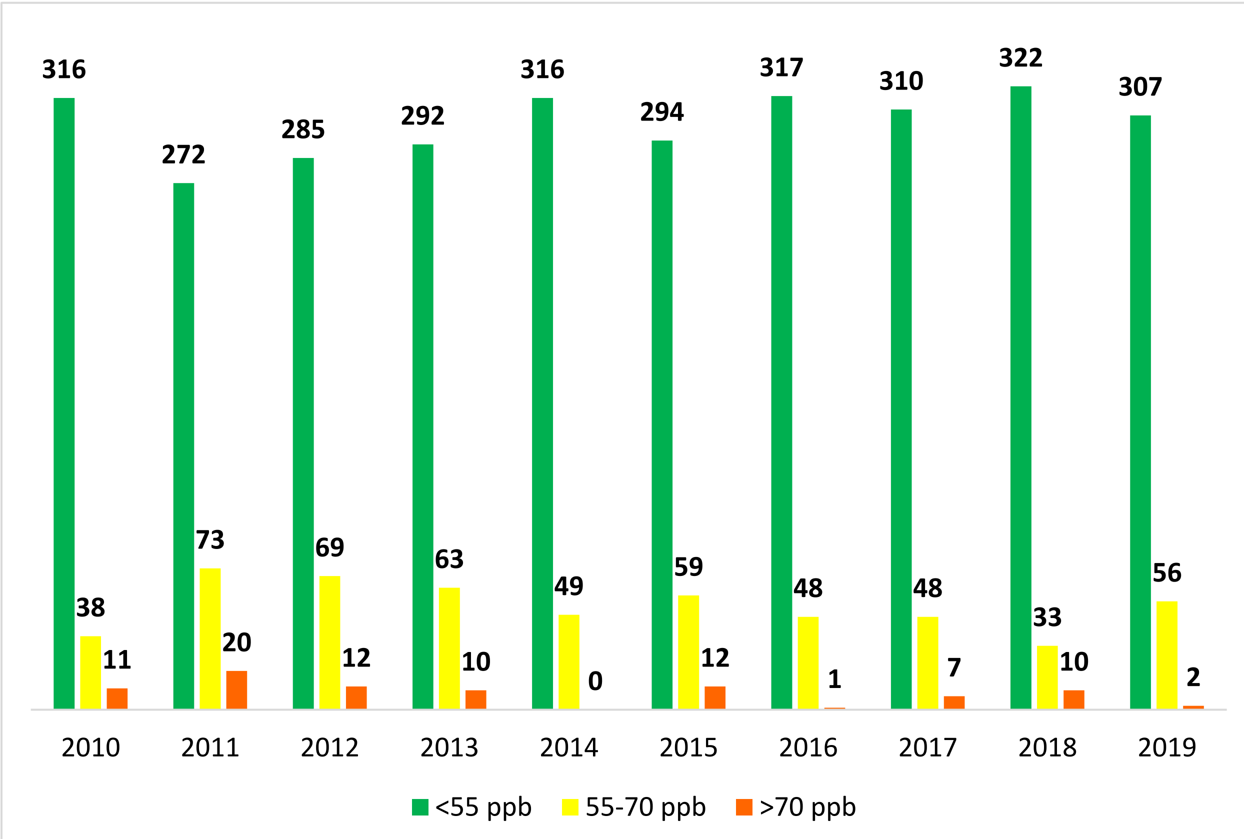
CAMS	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
3	32	57	45	49	28	49	34	31	26	28	379
38	30	65	54	44	36	47	28	32	25	26	387
614	26	69	38	19	24	45	22	25	31	30	329
690	17	64	43	45	29	40	20	41	31	38	368
1603	n/a	n/a	n/a	n/a	8	44	23	15	15	27	132
1604	n/a	n/a	n/a	n/a	21	31	23	34	16	12	137
1605	n/a	n/a	n/a	n/a	n/a	n/a	2	12	16	6	36
1612	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	7	7
1613	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	15	15
1675	n/a	16	41	28	17	41	16	23	24	28	234
6602	n/a	41	31	38	0	34	15	27	23	14	223
Regional	38	73	69	63	49	59	48	48	33	56	536

Table 2-3. Days with MDA8 O_3 <55 ppb by monitoring station and year

CAMS	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
3	316	267	298	310	329	302	329	323	327	323	3,124
38	326	286	297	300	315	296	334	323	331	325	3,133
614	152	138	164	178	170	188	243	233	245	231	1,942
690	179	136	145	158	177	198	250	219	241	207	1,910
1603	n/a	n/a	n/a	n/a	155	204	239	244	230	237	1,309
1604	n/a	n/a	n/a	n/a	163	217	240	219	257	248	1,344
1605	n/a	n/a	n/a	n/a	n/a	n/a	318	295	322	286	1,221
1612	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	236	236
1613	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	249	249
1675	n/a	26	168	184	176	205	250	227	247	228	1,711
6602	n/a	117	168	174	0	164	257	211	250	236	1,577
Regional	316	272	285	292	316	294	317	310	322	307	3,031

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 2019, while there were fewer "unhealthy for sensitive groups" days (days >70 ppb) than in 2017 or 2018, there were more days that were "moderate", at least 55 ppb, than in 2016, 2017, or 2018.

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 2019 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. Since CAMS 1612 and CAMS 1613 were established in 2019, these tables only contain 2019 data.

Table 2-4. CAMS 3 top 10 measured MDA8 O_3 values by year

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

[4] This is the 4th high that is used by EPA as discussed in Section 1.3,

Table 2-5. CAMS 38 top 10 measured MDA8 O_3 values by year

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

Table 2-6. CAMS 614 top 10 measured MDA8 O_3 values by year

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

Table 2-7. CAMS 690 top 10 measured MDA8 O_3 values by year

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

Table 2-8. CAMS 1603 top 10 measured MDA8 O_3 values by year

Rank	2014	2015	2016	2017	2018	2019	2019 in C.I. for 2014-2016	2019 in C.I. for 2015-2017	2019 in C.I. for 2016-2018
1	63	76	64	62	82	72	Yes	Yes	Yes
2	59	72	64	60	80	65	Yes	Yes	Yes
3	58	72	63	60	74	65	Yes	Yes	Yes
4	57	72	63	59	73	64	Yes	Yes	Yes
5	57	72	63	59	72	63	Yes	Yes	Yes
6	56	72	62	58	72	61	Yes	Yes	Yes
7	56	69	62	58	71	60	Yes	Yes	Yes
8	55	69	61	58	66	60	Yes	Yes	Yes
9	54	68	61	58	66	60	Yes	Yes	Yes
10	53	67	61	57	63	60	Yes	Yes	Yes
Avg. Top 4	59	73	64	60	77	66	Yes	Yes	Yes
Avg. Top 10	57	71	62	59	72	63	Yes	Yes	Yes

Table 2-9. CAMS 1604 top 10 measured MDA8 O_3 values by year

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

Table 2-10. CAMS 1605 top 10 measured MDA8 O_3 values by year

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

Table 2-11. CAMS 1612 top 10 measured MDA8 O_3 values by year

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

Table 2-12. CAMS 1613 top 10 measured MDA8 O_3 values by year

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

Table 2-13. CAMS 675/1675 top 10 measured MDA8 O_3 values by year

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

Table 2-14. CAMS 6602 top 10 measured MDA8 O_3 values by year

Rank	2011	2012	2013	2014	2015	2016	2017	2018	2019	2019 in C.I. for 2010-2012	2019 in C.I. for 2013-2015	2019 in C.I. for 2014-2016	2019 in C.I. for 2015-2017	2019 in C.I. for 2016-2018
1	80	70	77	n/a	77	62	68	71	62	Low	Yes	Yes	Yes	Yes
2	80	70	70	n/a	75	59	67	70	62	Low	Yes	Yes	Yes	Yes
3	79	69	70	n/a	72	58	66	68	60	Low	Yes	Yes	Yes	Yes
4	75	69	69	n/a	71	58	65	68	60	Low	Yes	Yes	Yes	Yes
5	74	69	65	n/a	70	58	63	66	60	Low	Yes	Yes	Yes	Yes
6	72	67	64	n/a	69	57	63	65	60	Low	Yes	Yes	Yes	Yes
7	72	66	63	n/a	68	57	62	65	59	Low	Yes	Yes	Yes	Yes
8	72	64	63	n/a	65	57	62	63	58	Low	Yes	Yes	Yes	Low
9	71	64	63	n/a	64	56	61	62	58	Low	Yes	Yes	Yes	Yes
10	71	63	63	n/a	62	56	60	61	58	Low	Yes	Yes	Yes	Yes
Avg. Top 4	79	70	72	n/a	74	59	67	69	61	Low	Yes	Yes	Yes	Yes
Avg. Top 10	75	67	67	n/a	69	58	64	66	59	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 2013-2019. Consistent with the data-handling conventions for the 2015 O_3 NAAQS, values beyond the units' digit are truncated.

Table 2-15. 4th-highest MDA8 O_3 values at Regional O_3 Monitors, 2013-2019 (ppb)

CAMS	2013	2014	2015	2016	2017	2018	2019	2013-2015 Avg.	2014-2016 Avg.	2015-2017 Avg.	2016-2018 Avg.	2017-2019 Avg.
3	69	62	73	64	70	72	65[5]	68	66	69	68	69
38	70	63	73	62	67	70	63	68	66	67	66	66
614	67	63	71	65	67	60	64	67	66	68	64	63
690	75	66	75	61	70	69	67	72	67	69	68	68
1603	n/a	57	72	63	59	73	64	n/a	64	65	62	65
1604	n/a	64	67	60	67	66	61	n/a	63	65	64	64
1605	n/a	n/a	n/a	52	61	66	58	n/a	n/a	n/a	59	61
1612	n/a	n/a	n/a	n/a	n/a	n/a	59	n/a	n/a	n/a	n/a	n/a
1613	n/a	n/a	n/a	n/a	n/a	n/a	60	n/a	n/a	n/a	n/a	n/a
1675	70	61	70	62	63	74	63	67	64	65	66	66
6602	69	n/a	71	58	65	68	60	n/a	n/a	65	63	64

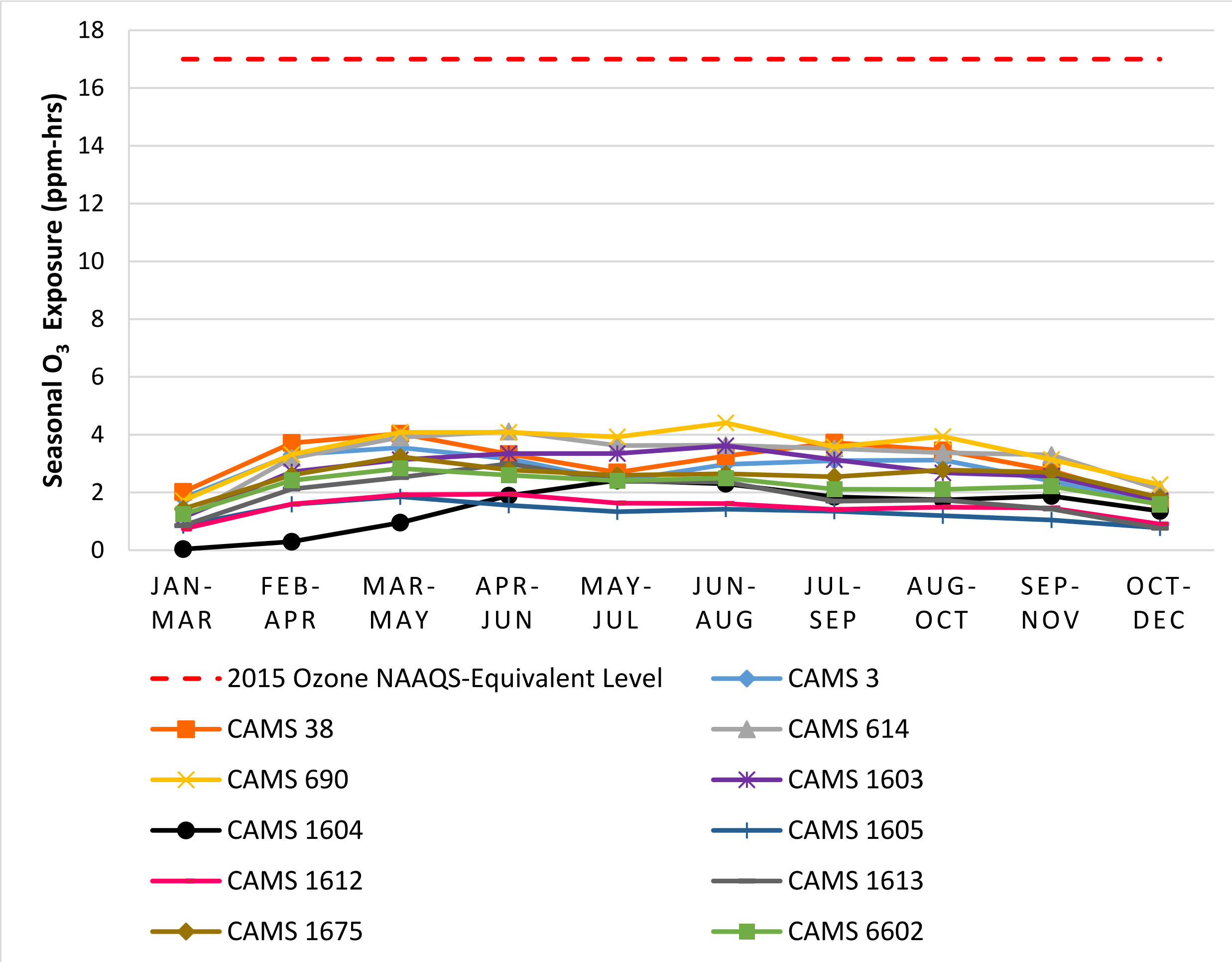
As the table shows, CAMS 3 again had the highest three-year average from 2017-2019 at 69 ppb. Most O_3 monitors in the region averaged a higher three-year average from 2017-2019 than 2016-2018. This is due to the low O_3 levels recorded in 2016 falling out of the three-year average, although O_3 levels in 2019 were actually lower than in 2018 or 2017.

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.

[5] See explanation on pg. 10 for the calculation of the 4th-high value at CAMS 3 for 2019.

Table 2-16. Weighted Seasonal O_3 Exposure by Monitoring Station and 3-month period, 2019 (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 2016-2019 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 2019 data to the 2010-2018 data in order to evaluate whether there was evidence of a difference in the temporal patterns of 2019's regional, MDA8 O_3 values.

3.1 Earliest and Latest Dates for High O_3 in 2019

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 2010-2019.

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
Regional Peak ≥55 ppb	2/10 – 11/8	2/11 – 10/27	2/22 – 10/26	3/13 – 8/23	3/17 – 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
CAMS 3 Top 4	4/13 – 10/24	2/12 – 10/3	5/6 – 9/1	5/7 – 8/2	3/22 – 9/6
CAMS 3 Top 10	3/13 – 10/25	2/12 – 10/3	4/7 – 9/13	4/28 – 8/3	3/21 – 10/5
CAMS 38 Top 4	5/2 – 10/24	2/12 – 10/2	5/6 – 9/13	4/28 – 8/3	4/9 – 9/6
CAMS 38 Top 10	3/13 – 10/26	2/12 – 10/2	4/7 – 9/13	4/24 – 8/3	3/22 – 10/6

The 2019 data continued to show that “moderate” O_3 levels can occur as early as February or March and as late as October or November within the region’s official O_3 monitoring season. Notably, the region recorded its latest-yet MDA8 O_3 concentration ≥55 ppb within the timeframe analyzed. CAPCOG’s monitoring program typically runs through 11/15, so, this data point may prompt a re-evaluation of the timeframe for CAPCOG to conduct monitoring in the future. CAPCOG intends to decide on whether to extend monitoring beyond 11/15/2020 during the 2020 O_3 season based on forecasts and resources closer to that date.

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 2010-2019.

Figure 3-1. Percentage of days with MDA8 O_3 values 55-70 ppb by month

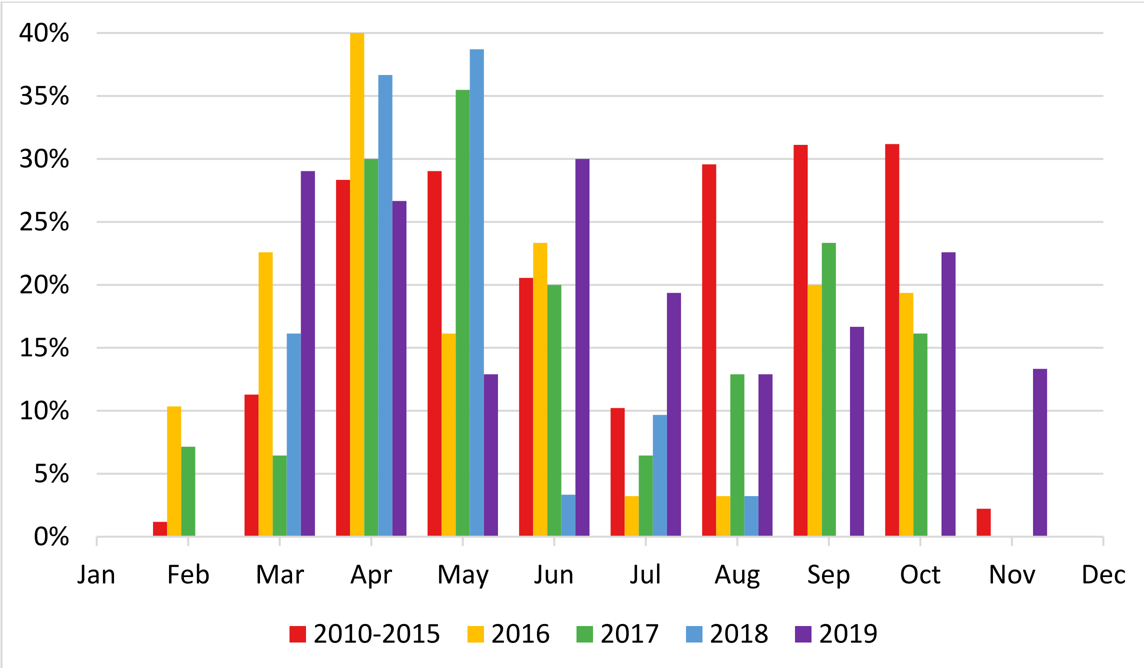
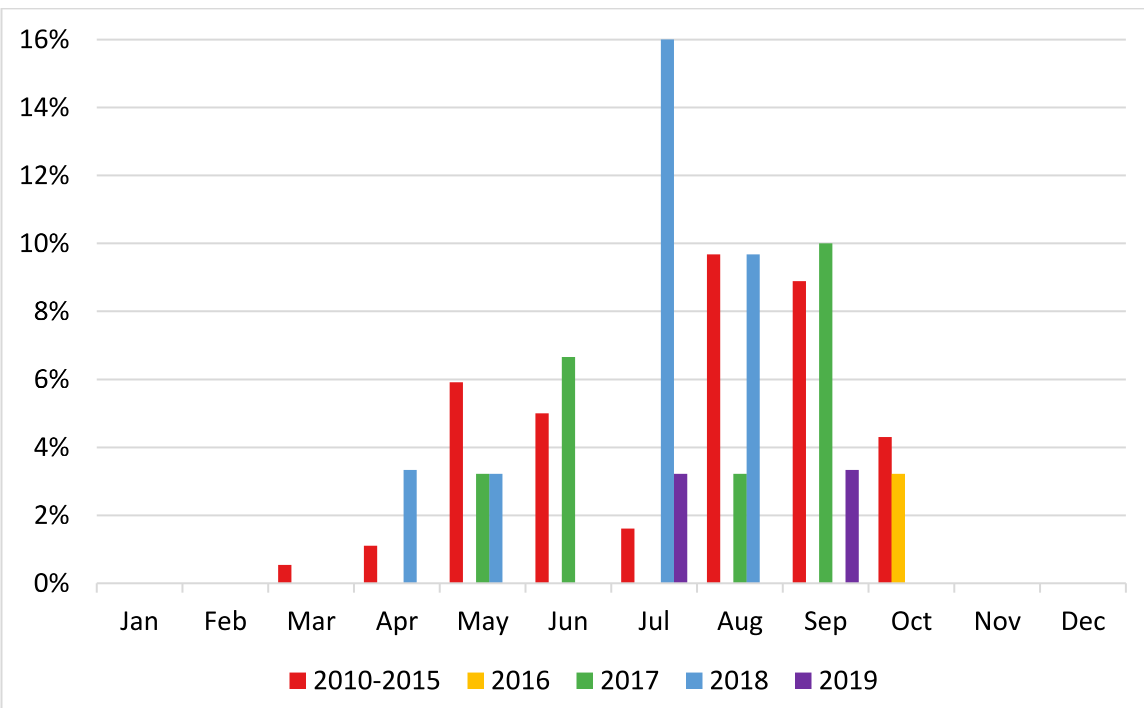


Figure 3-2. Percentage of days with MDA8 O_3 values >70 ppb by month



As mentioned in the previous section, the lack of high O_3 data in 2019 was notable, especially compared to multiple high days in 2018. MDA8 O_3 levels exceeded 70 ppb twice in 2019, which is more in line with data from 2014 and 2016.

In 2016 and 2017, MDA8 O_3 values reached 55 ppb or higher in February; whereas, 2019 followed suit with 2018 in that MDA8 O_3 values did not reach 55 ppb in February. However, it is notable that there were more days that measured 55-70 ppb towards the end of the 2019 O_3 season, October and November, than in 2016-2018.

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

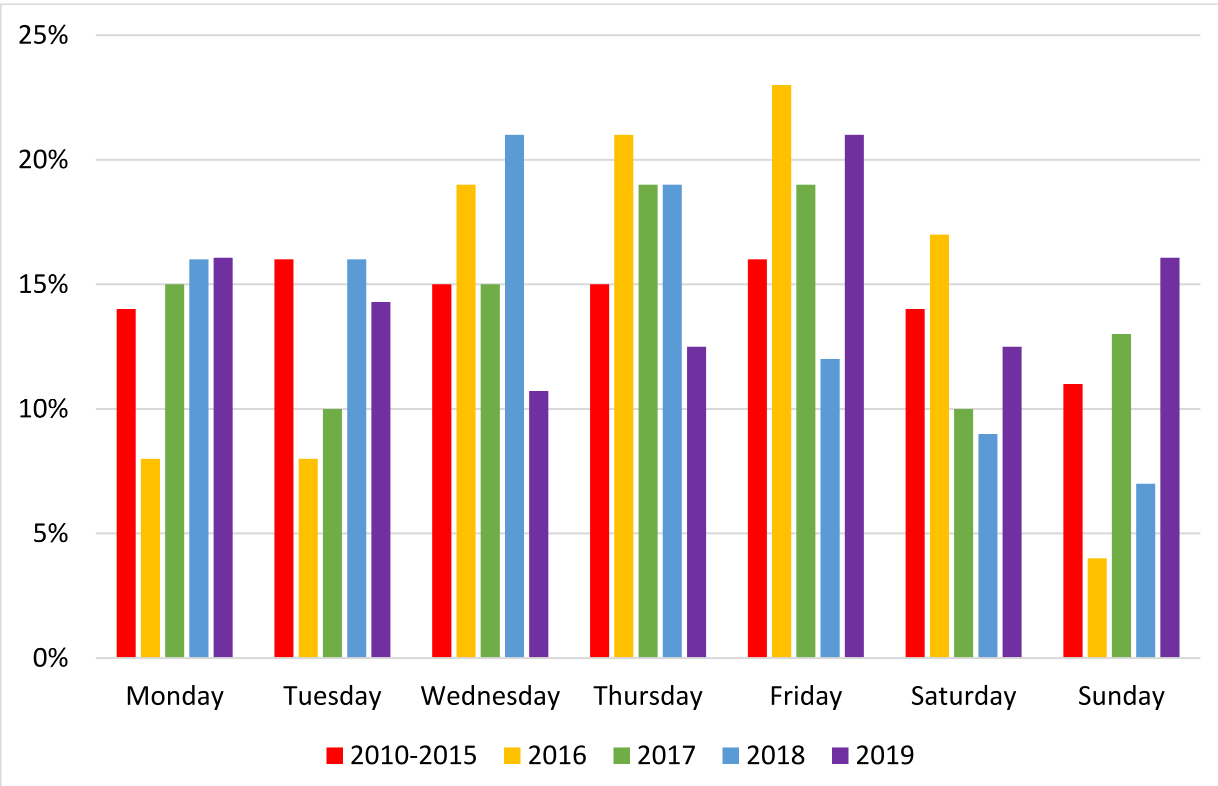
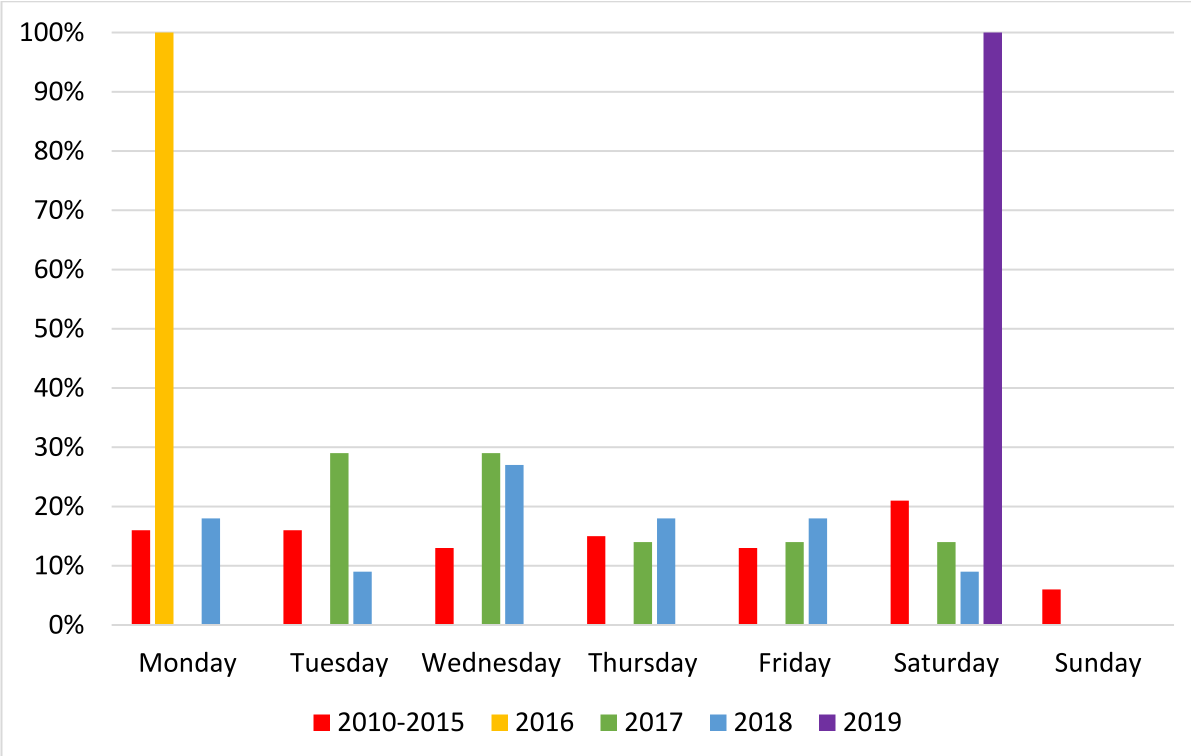


Figure 3-4. Distribution of MDA8 O_3 above 70 by day of the week

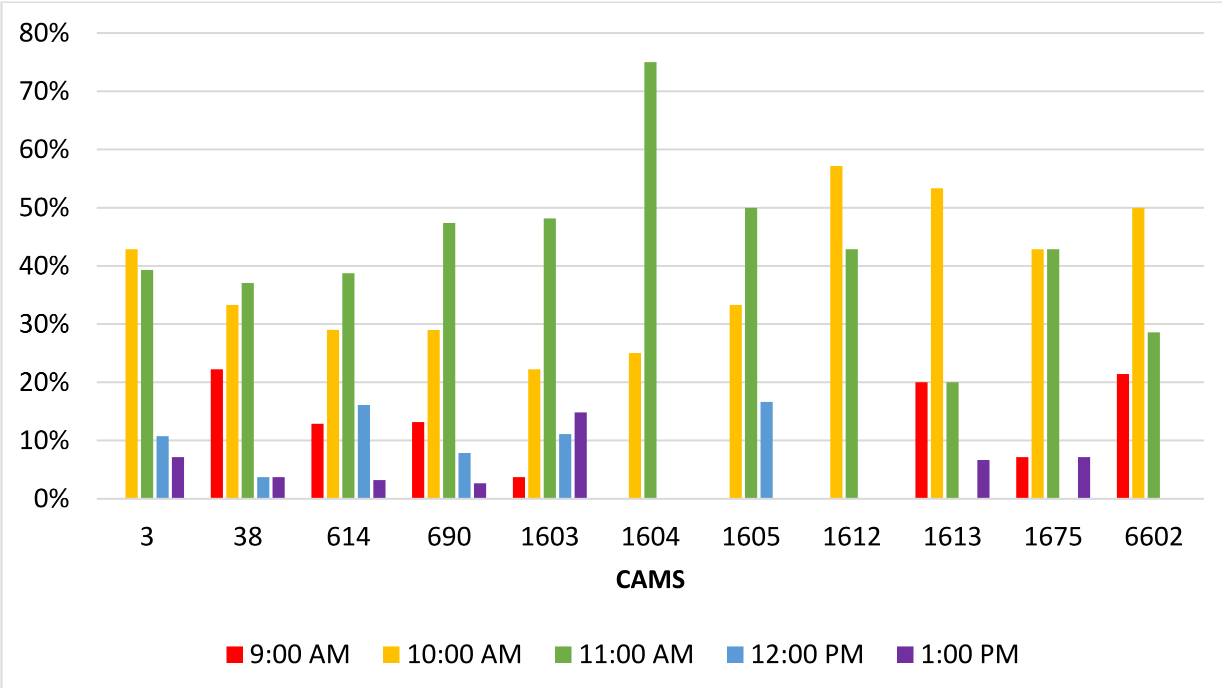


The daily distribution for O_3, that was ≥55 ppb, indicates that moderate levels of O_3 occurred on all days of the week, with Friday having a slightly larger percentage. There were only 2 days in 2019 that experienced O_3 greater than 70 ppb, and both of those days happened to be on a Saturday. As evident in Figure 3-4, high O_3 days are likely to 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 2019. As the figure shows, 10 am and 11 am were the most common start hours for MDA8 O_3 values ≥55 ppb at all monitoring stations.

Figure 3-5. Distribution of start hour for MDA8 O_3 ≥55 ppb by monitoring station, 2019



In the figures below, CAPCOG compared the distribution of start hours in 2019 to what was observed in 2010-2018 for MDA8 O_3 ≥55 ppb at each monitor. The individual monitor trends follow the pattern of the start hour at 10 am or 11 am.

Figure 3-6. Start hour for MDA8 O_3 ≥55 ppb at CAMS 3, 2010-2019

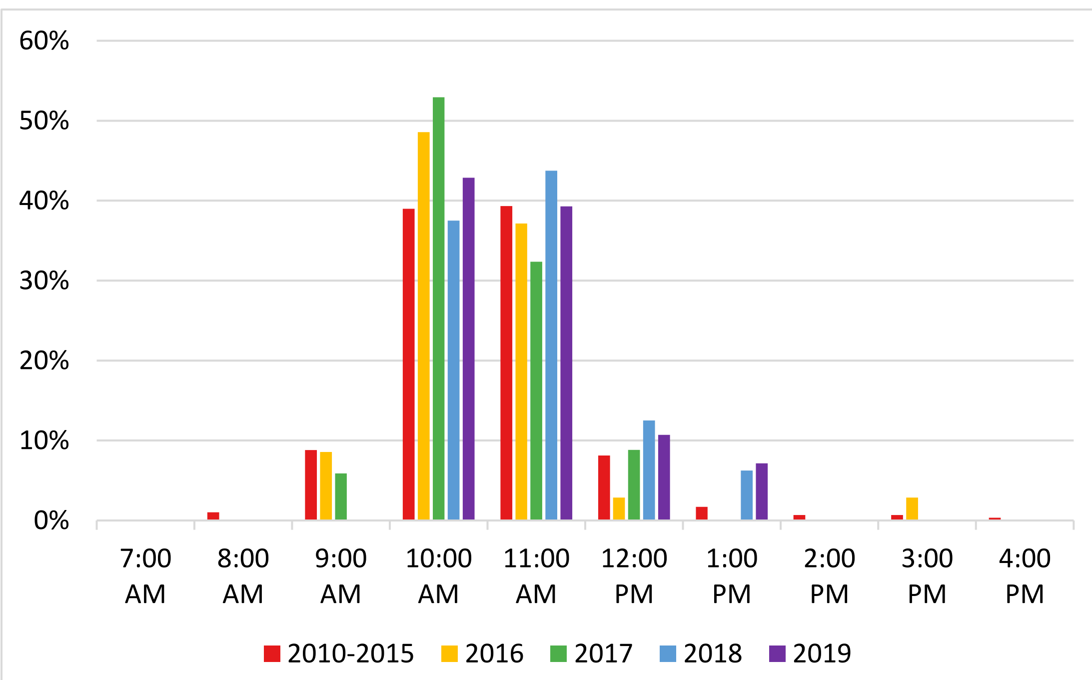


Figure 3-7. Start hour for MDA8 O_3 ≥55 ppb at CAMS 38, 2010-2019

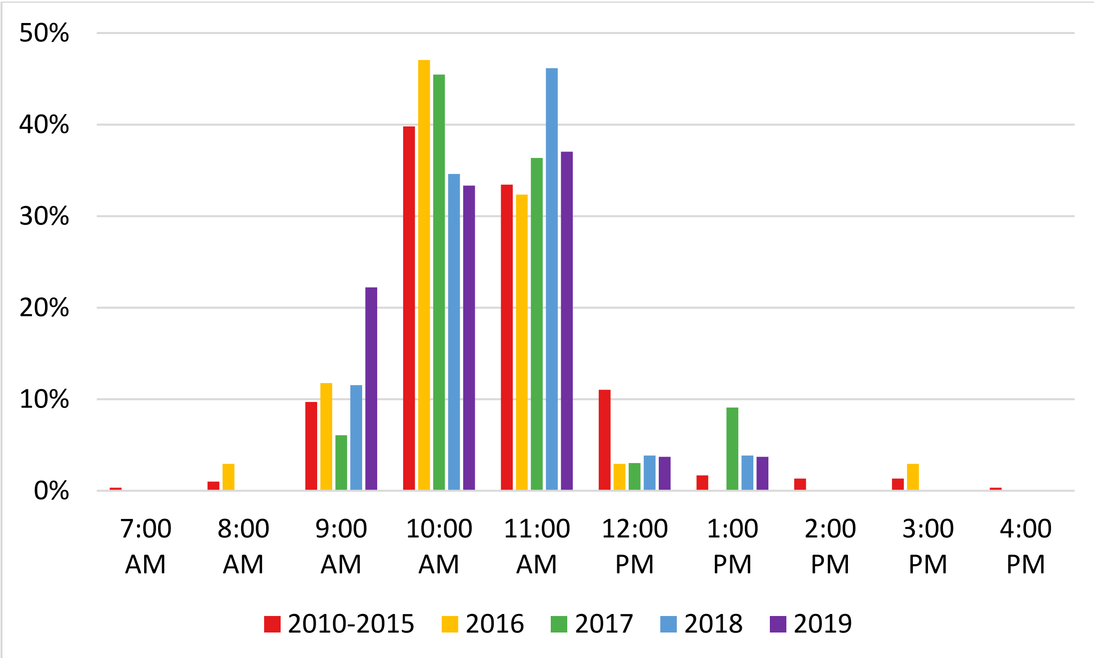


Figure 3-8. Start hour for MDA8 O_3 ≥55 ppb at CAMS 614, 2010-2019

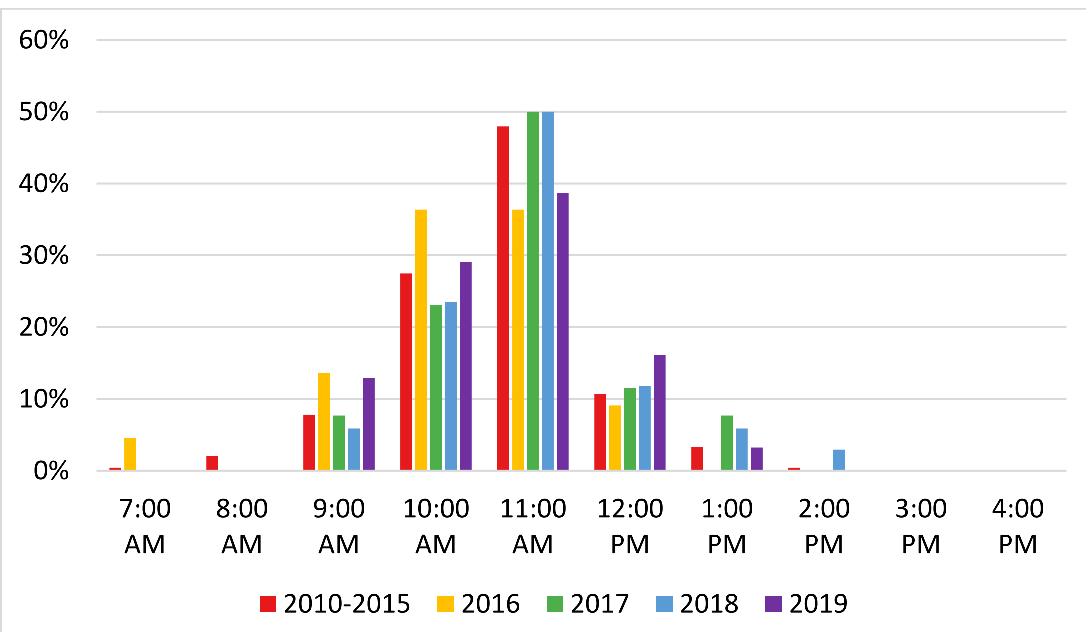


Figure 3-9. Start hour for MDA8 O_3 ≥55 ppb at CAMS 690, 2010-2019

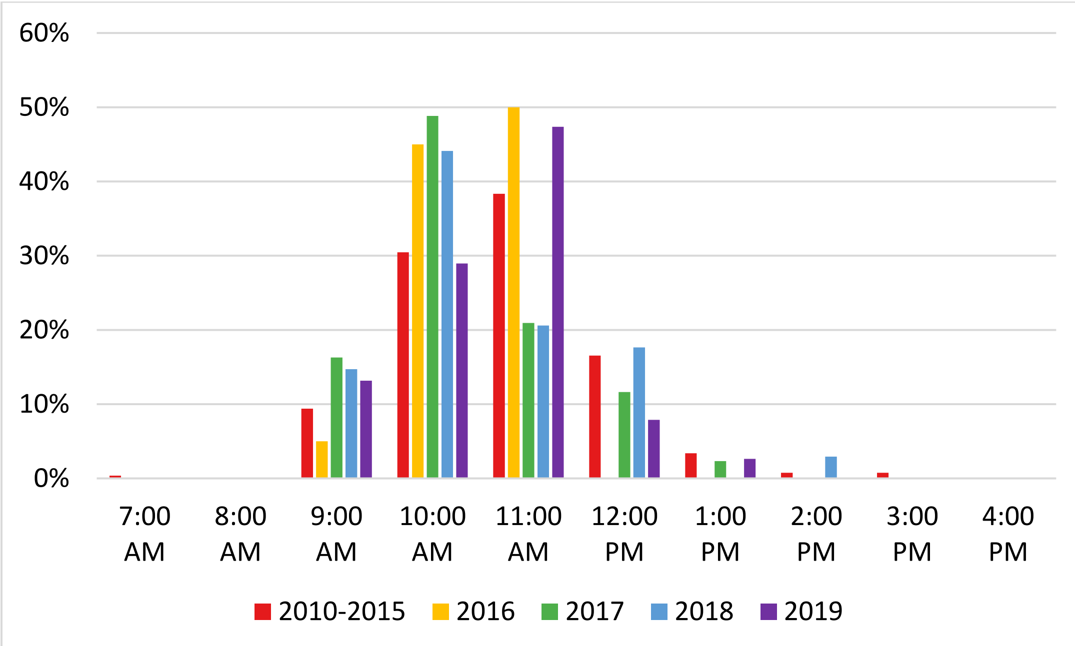


Figure 3-10. Start hour for MDA8 O_3 ≥55 ppb at CAMS 1603, 2010-2019

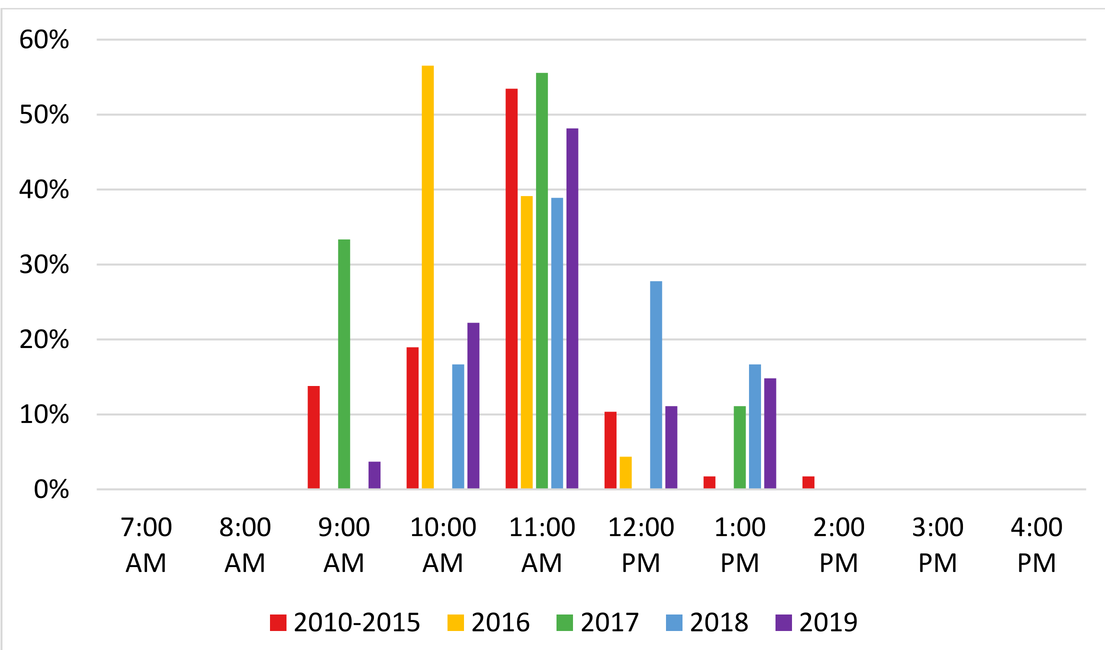


Figure 3-11. Start hour for MDA8 O_3 ≥55 ppb at CAMS 1604, 2010-2019

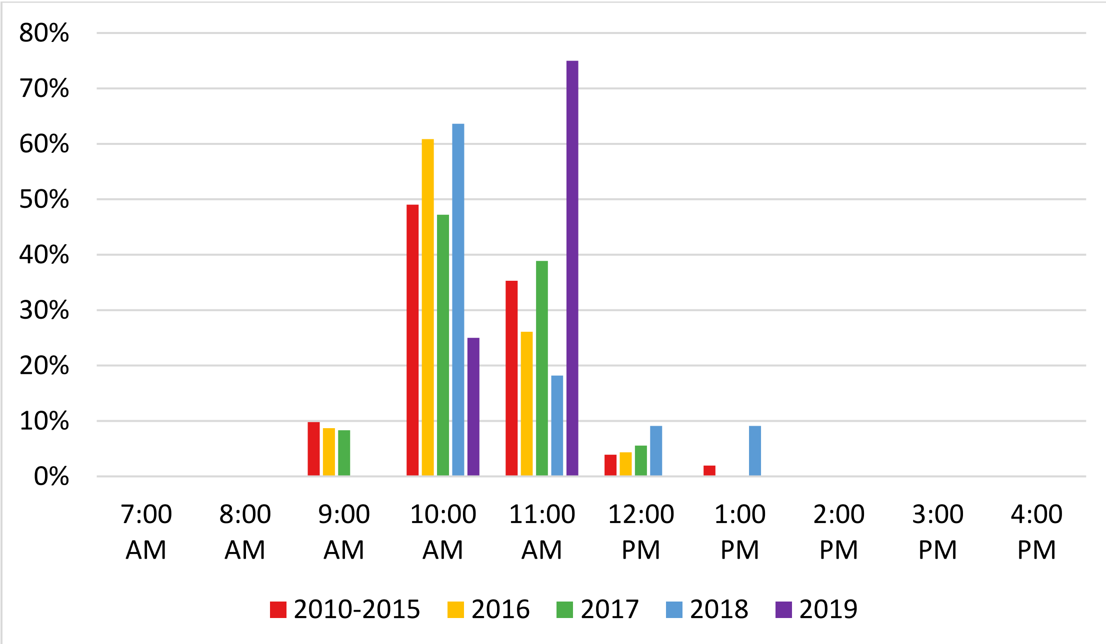


Figure 3-12. Start hour for MDA8 O_3 ≥55 ppb at CAMS 1612, 2019

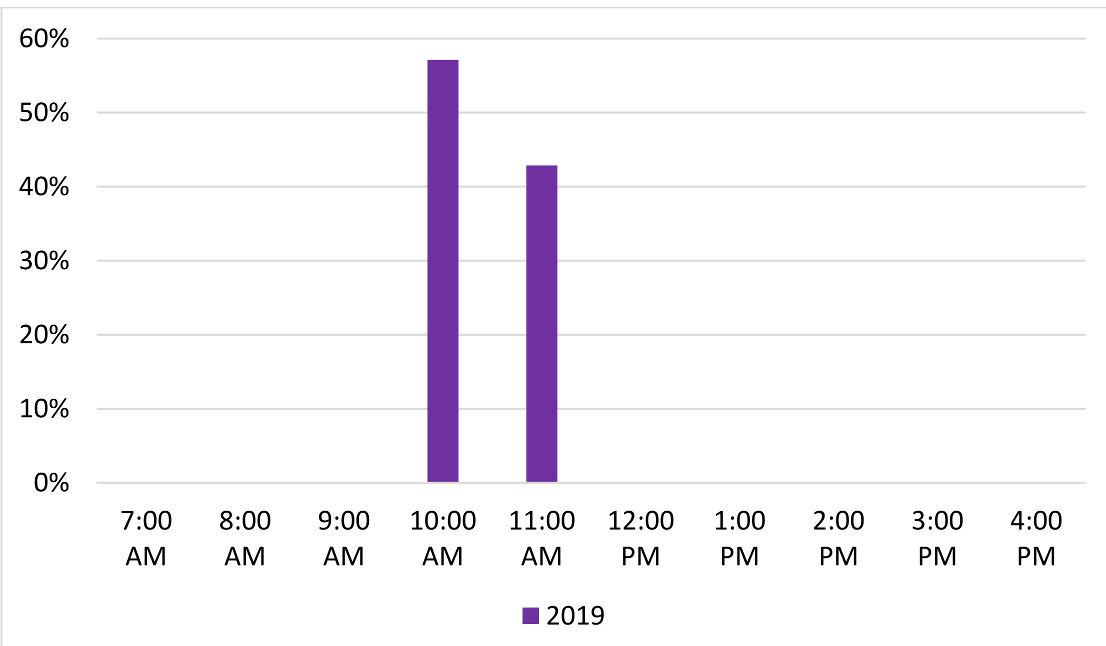


Figure 3-13. Start hour for MDA8 O_3 ≥55 ppb at CAMS 1613, 2019

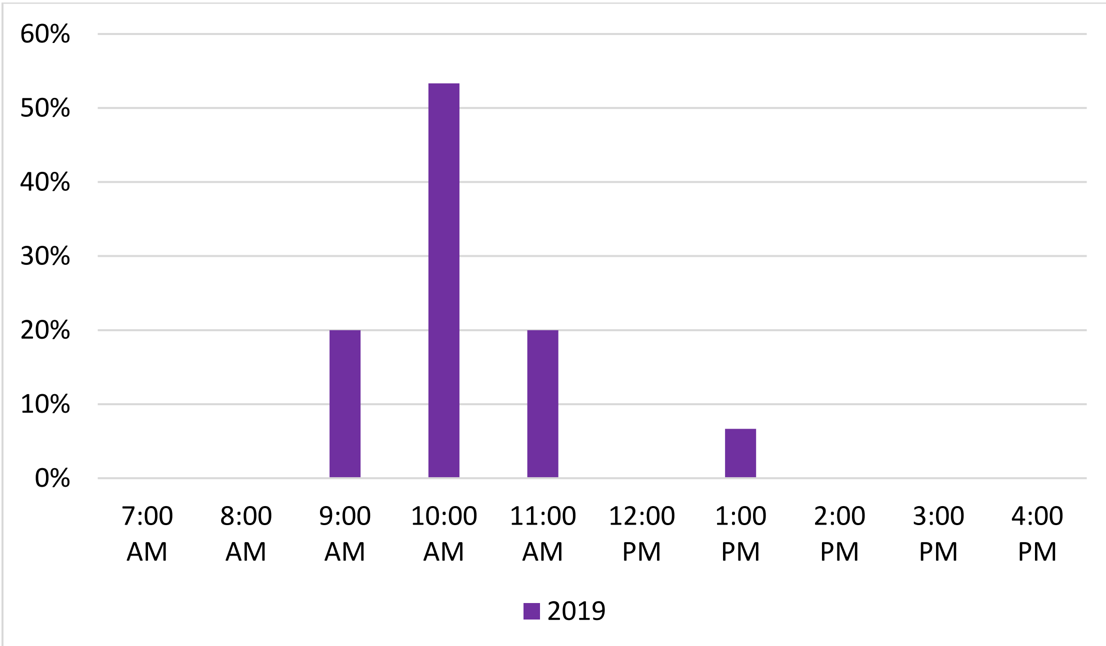


Figure 3-14. Start hour for MDA8 O_3 ≥55 ppb at CAMS 1675, 2010-2019

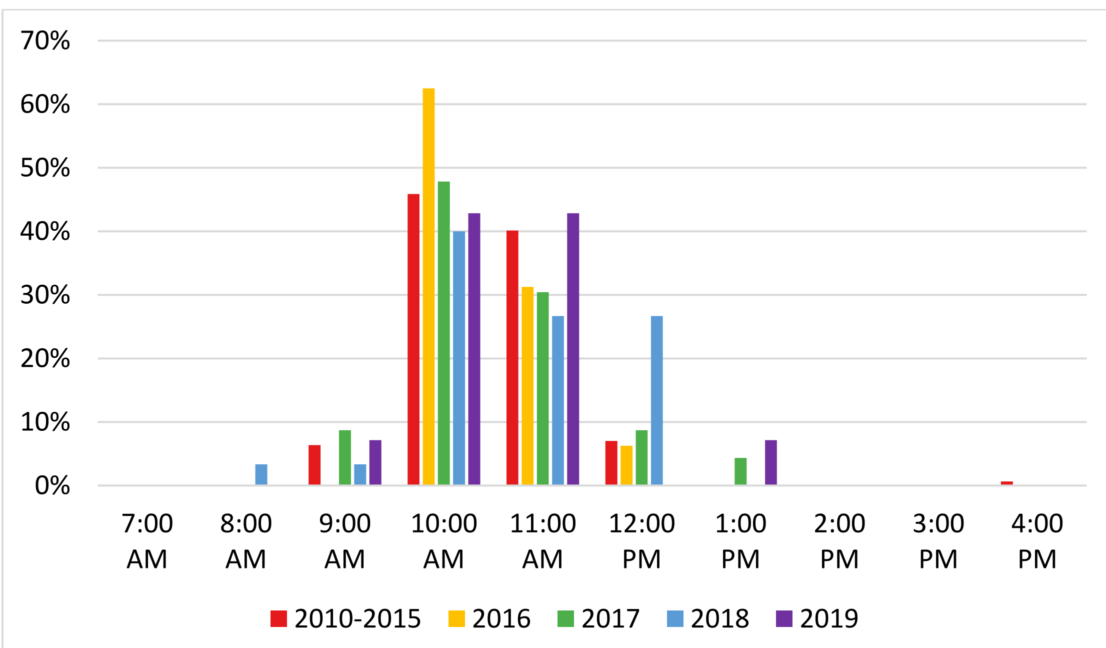
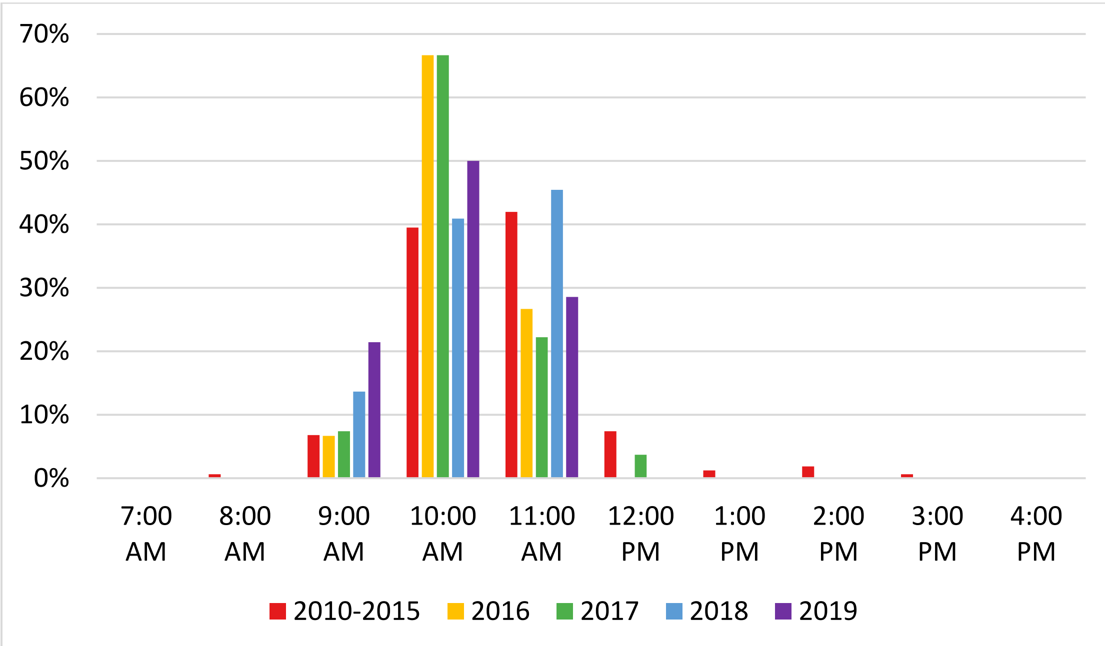


Figure 3-15. Start hour for MDA8 O_3 ≥55 ppb at CAMS 6602, 2010-2019



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

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 2019 wind speeds were statistically different from wind speeds observed 2010-2018 and the relationship between O_3 and wind speed observed between 2010-2018.

4.1.1 Comparison of Relationship between Wind Speed and MDA8 O_3 in 2019 to 2010-2018

The figures below show the relationship between observed wind speeds and observed MDA8 O_3 values at CAMS 3. All trend lines have a small slope which show that there is not a strong negative or positive relationship. While 2016-2018 shows a slight positive relationship, 2019, like 2010-2015, had a slight negative relationship.

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

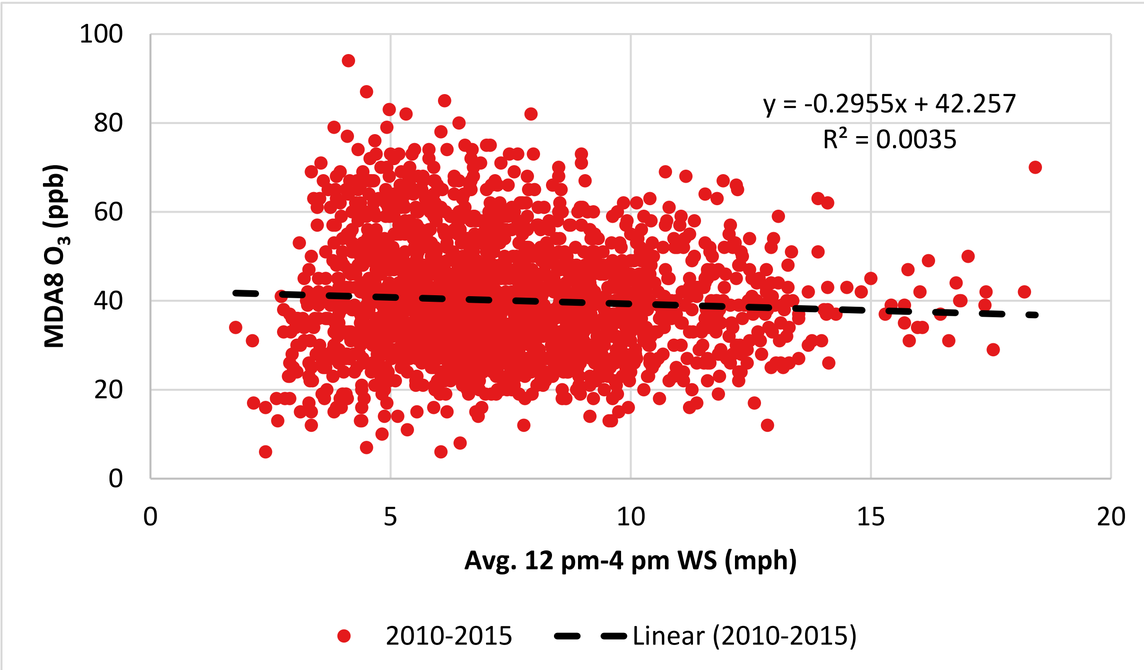


Figure 4-2. Scatter Plot of 12 pm – 4 pm Wind Speed at CAMS 3 v. MDA8 O_3 at CAMS 3, 2016

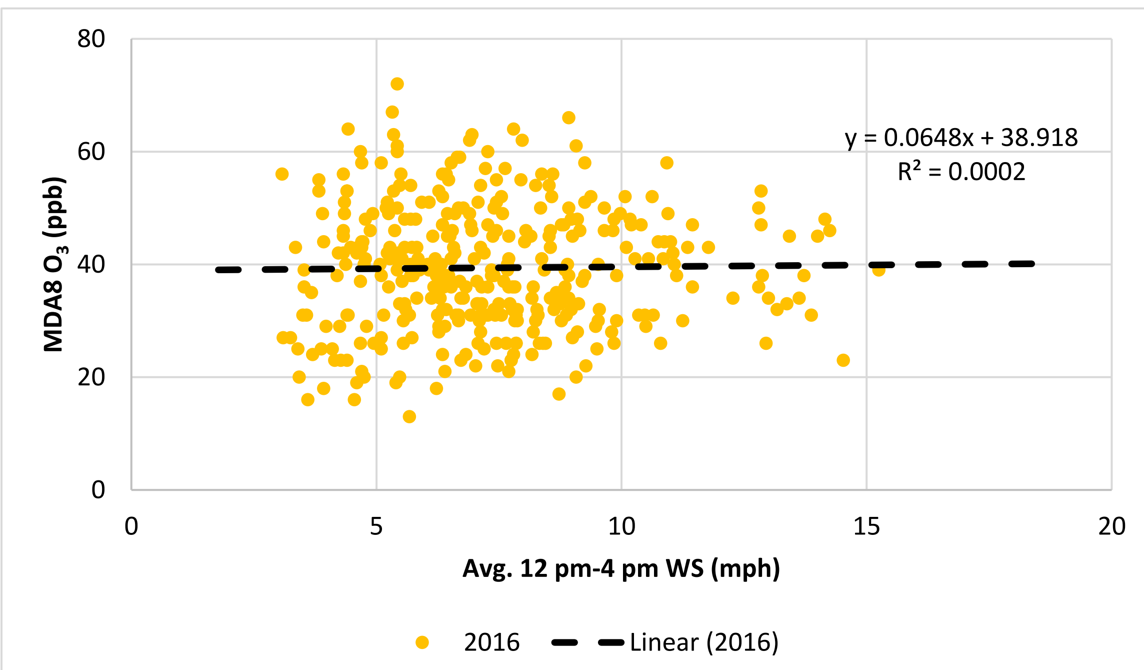


Figure 4-3. Scatter Plot of 12 pm – 4 pm Wind Speed at CAMS 3 v. MDA8 O_3 at CAMS 3, 2017

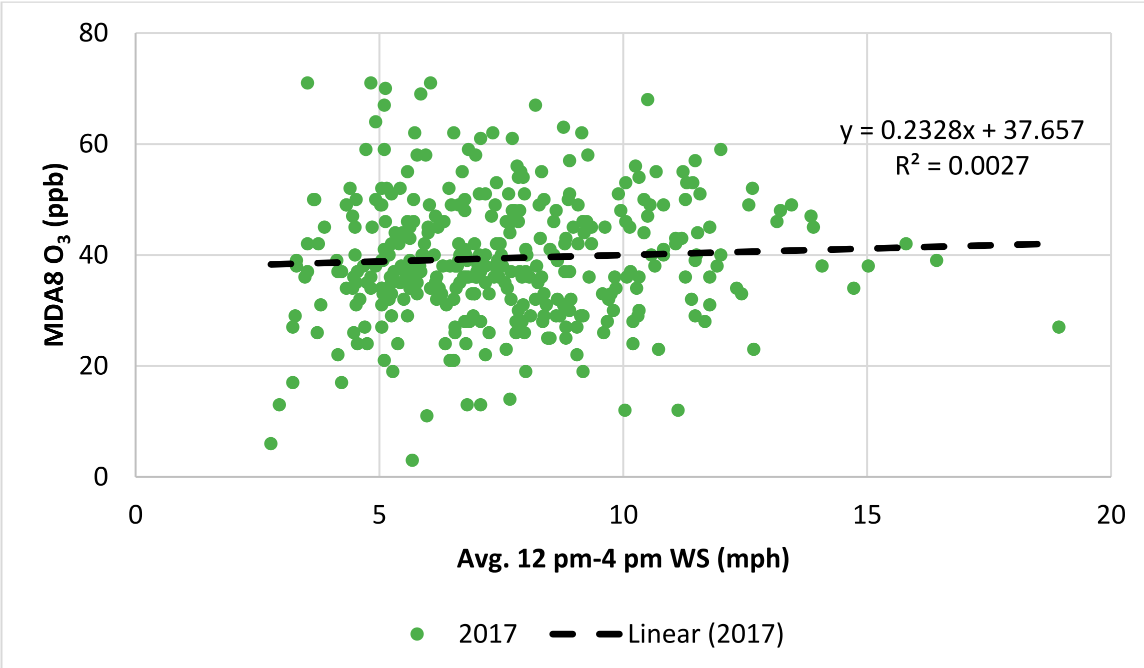


Figure 4-4 Scatter Plot of 12 pm – 4 pm Wind Speed at CAMS 3 v. MDA8 O_3 at CAMS 3, 2018

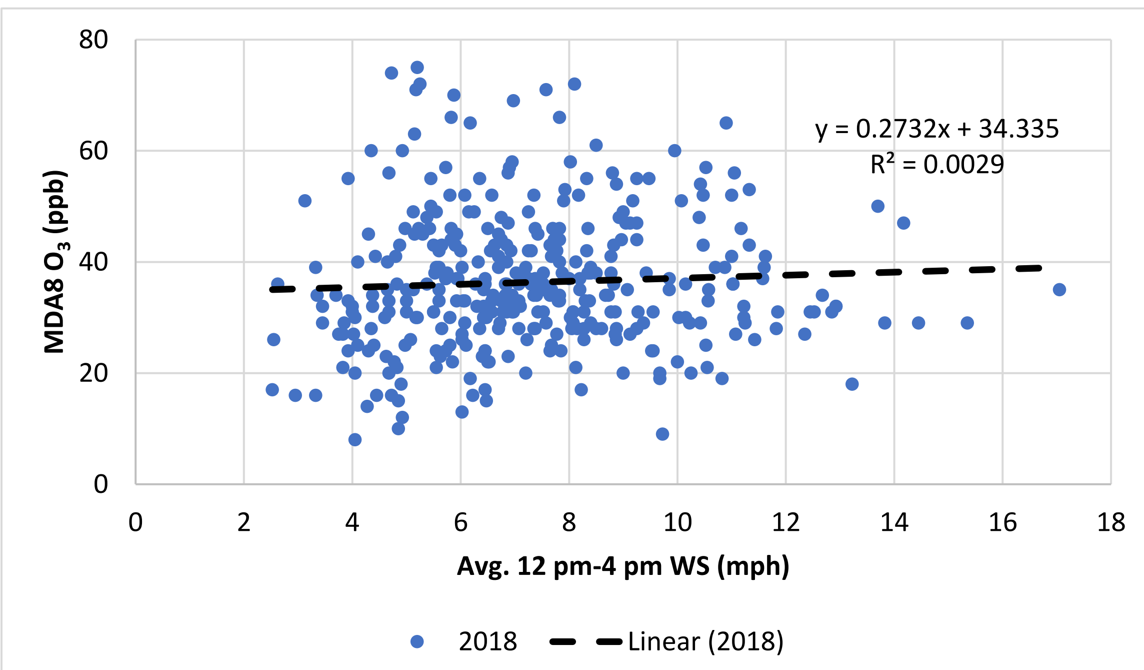
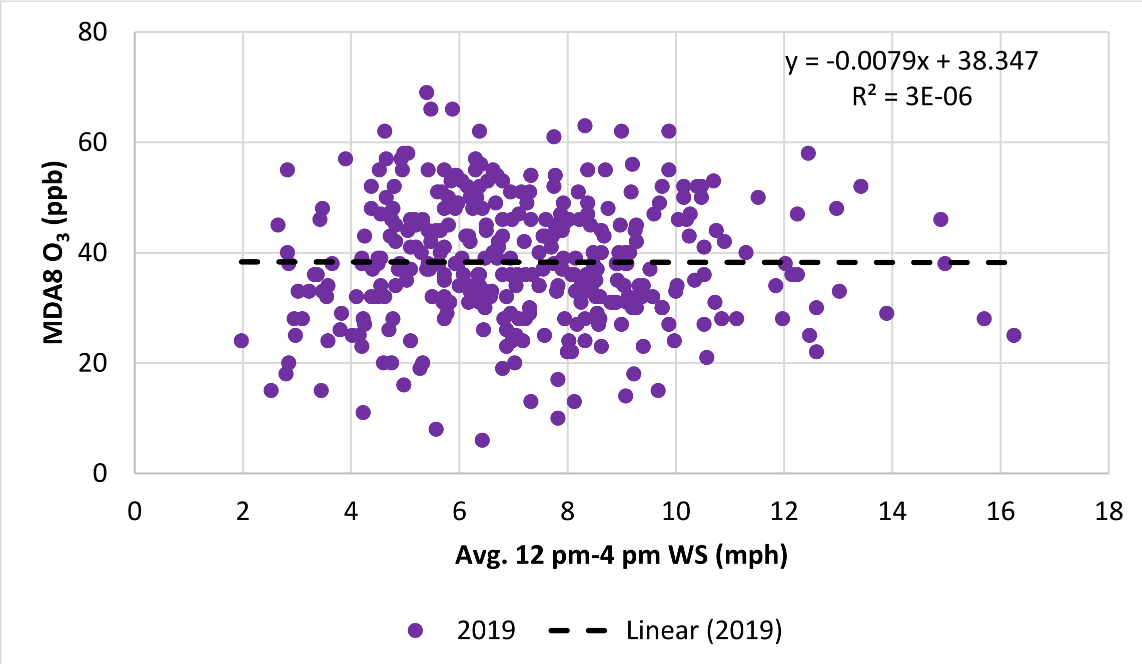
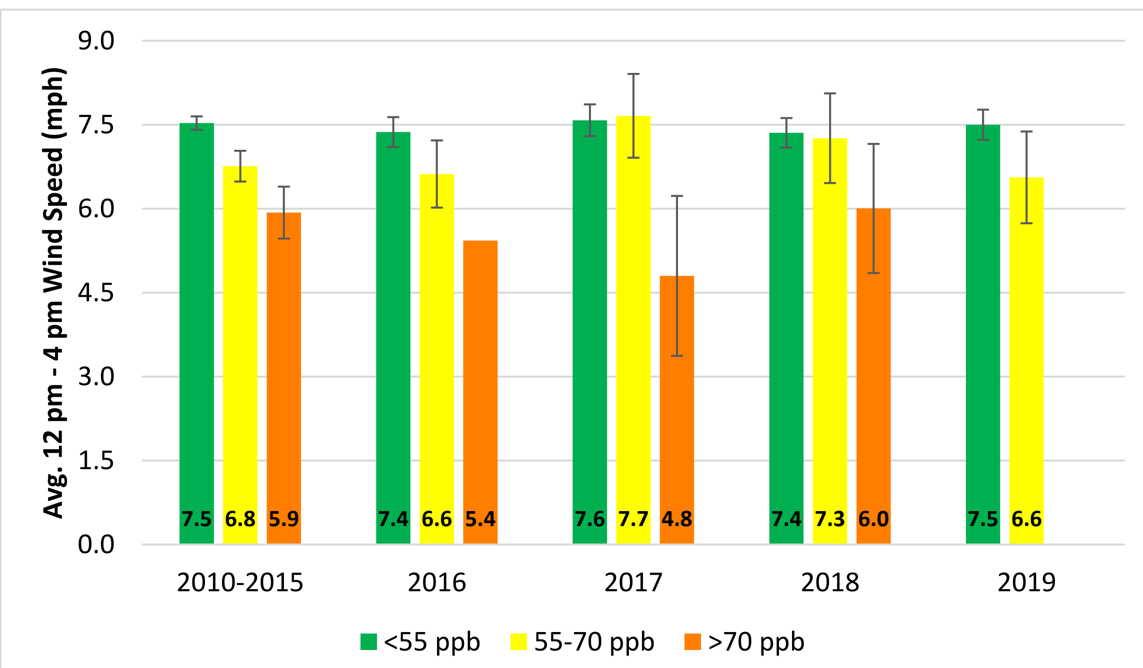


Figure 4-5. Scatter Plot of 12 pm – 4 pm Wind Speed at CAMS 3 v. MDA8 O_3 at CAMS 3, 2019



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 3 in 2019 compared to previous timeframes. Since there were no days with MDA8 O_3 >70 ppb at CAMS 3 in 2019, the figure below does not contain the average wind speed for that interval.

Figure 4-6. Typical Wind Speed 12 pm – 4 pm at CAMS 3 on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 3, 2010-2019

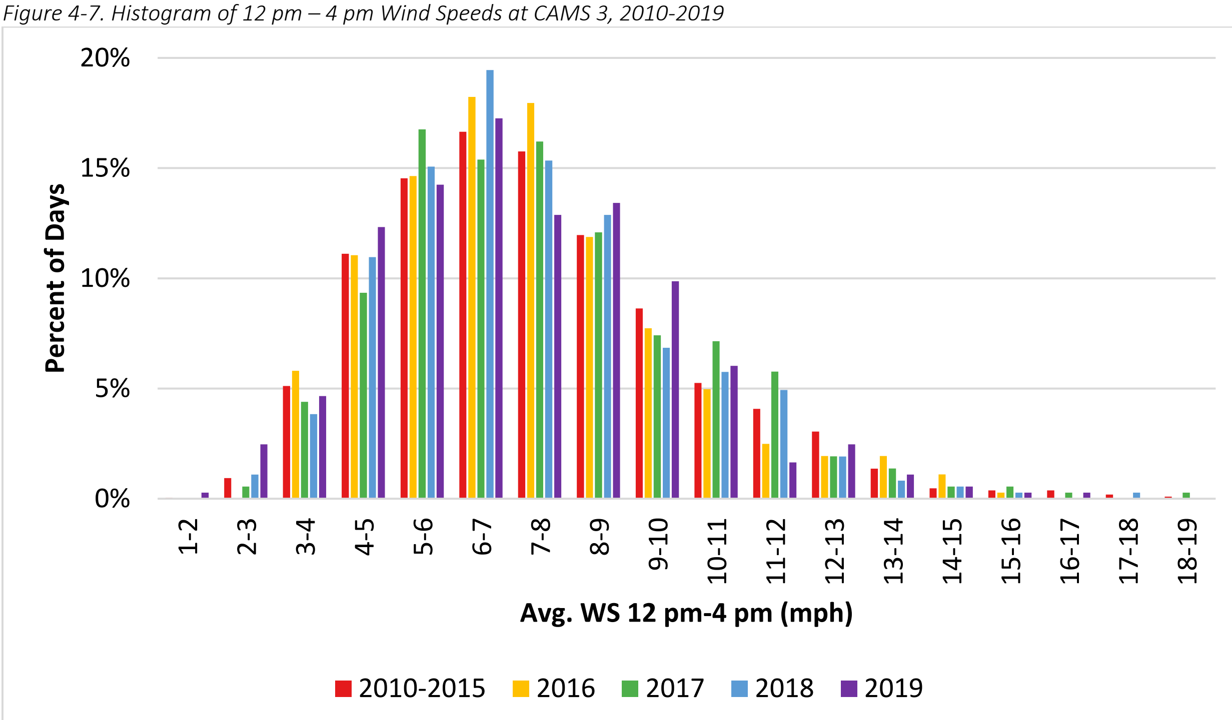


The average wind speed and O_3 concentration relationship for 2019 follows the relationship from the previous years. This relationship indicates that lower wind speeds can allow for higher O_3 formation.

4.1.2 Comparison of 2019 Wind Speeds to 2010-2015 Wind Speeds

The figure below shows the distribution of daily average wind speeds between 12 pm-4 pm at CAMS 3.

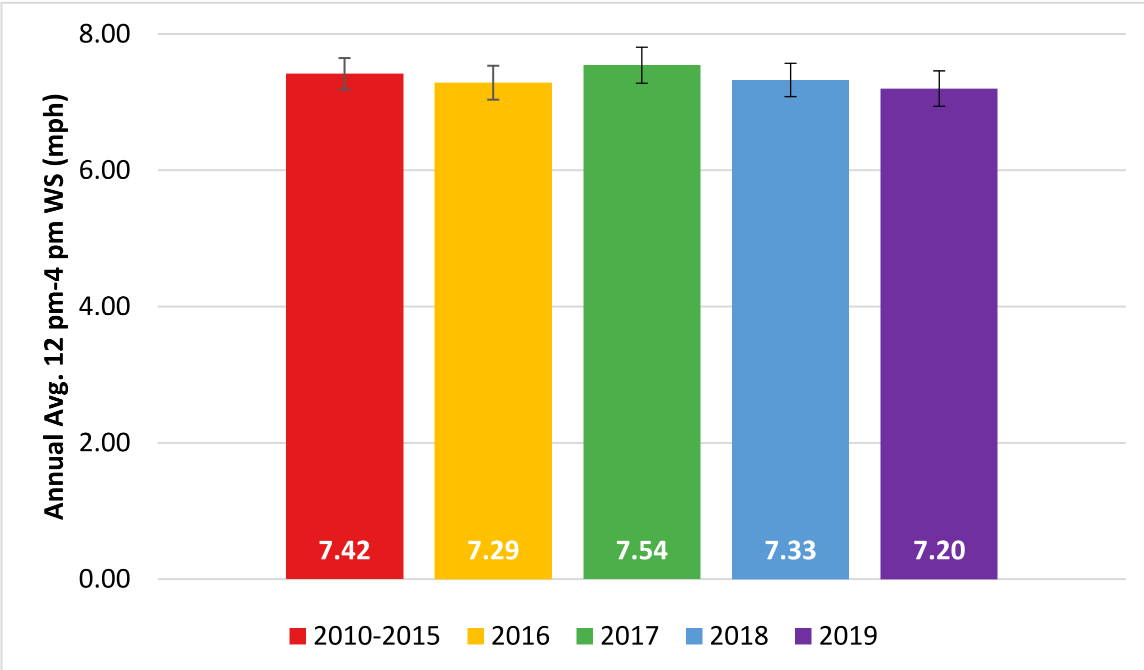
Figure 4-7. Histogram of 12 pm – 4 pm Wind Speeds at CAMS 3, 2010-2019



CAPCOG performed a chi-squared test of independence on the data, in the figure above, to determine if the distributions were statistically different. CAPCOG found that there was not a significant difference in the distribution using this test at a 0.05 or 0.10 significance level in 2019 comparted to any previous timeframe.

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 2010-2019, along with the 95% confidence intervals. There is no significant difference in the annual average wind speed.

Figure 4-8. Annual Avg. 12 pm-4 pm Wind Speed at CAMS 3, 2010-2019



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 2019 temperatures were statistically different from temperatures observed 2010-2018 or if the relationship between O_3 and temperature was statistically different than the relationship observed 2010-2018.

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 4-9. Scatter Plot of 12 pm – 4 pm Temperature at CAMS 3 v. MDA8 O_3 at CAMS 3, 2010-2015

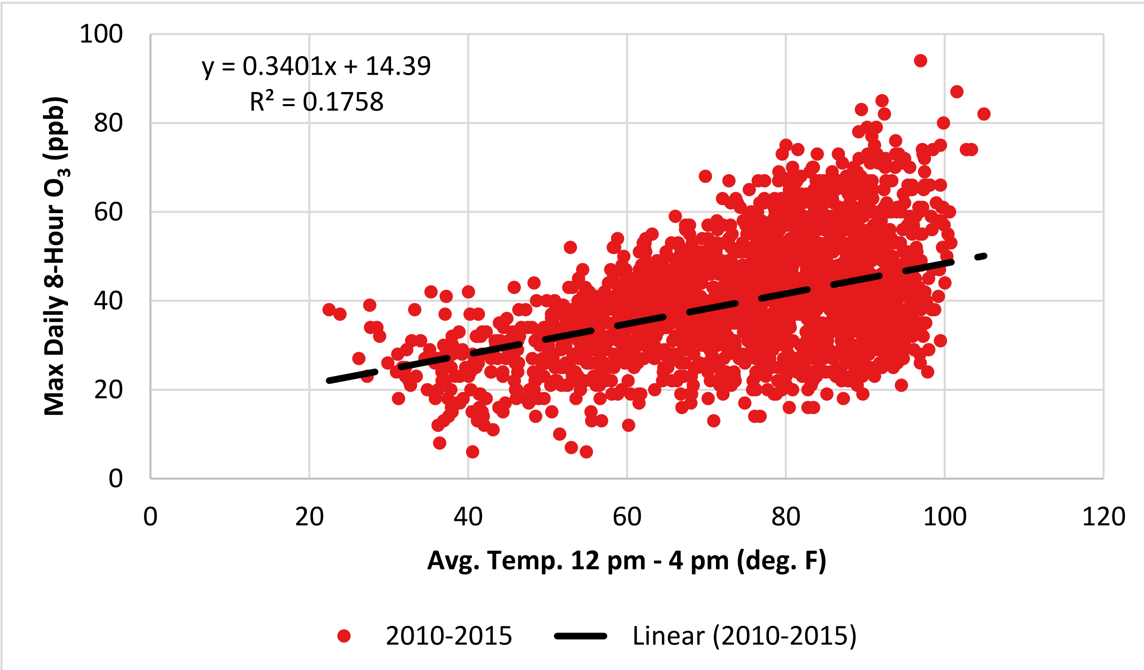


Figure 4-10. Scatter Plot of 12 pm – 4 pm Temperature at CAMS 3 v. MDA8 O_3 at CAMS 3, 2016

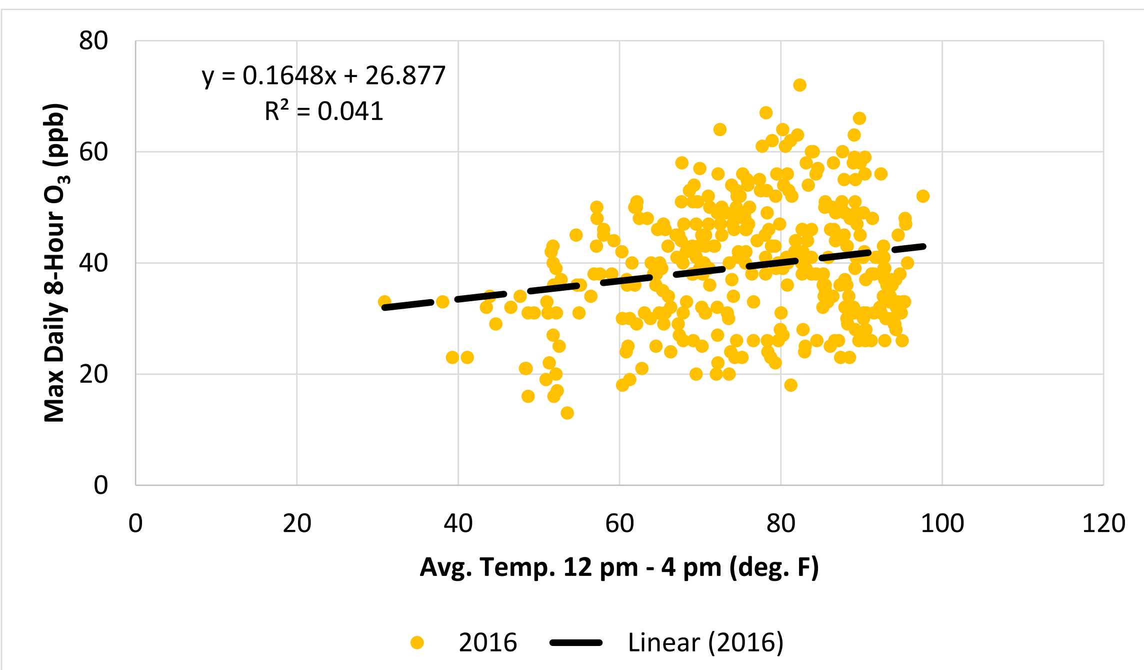


Figure 4-11. Scatter Plot of 12 pm – 4 pm Temperature at CAMS 3 v. MDA8 O_3 at CAMS 3, 2017

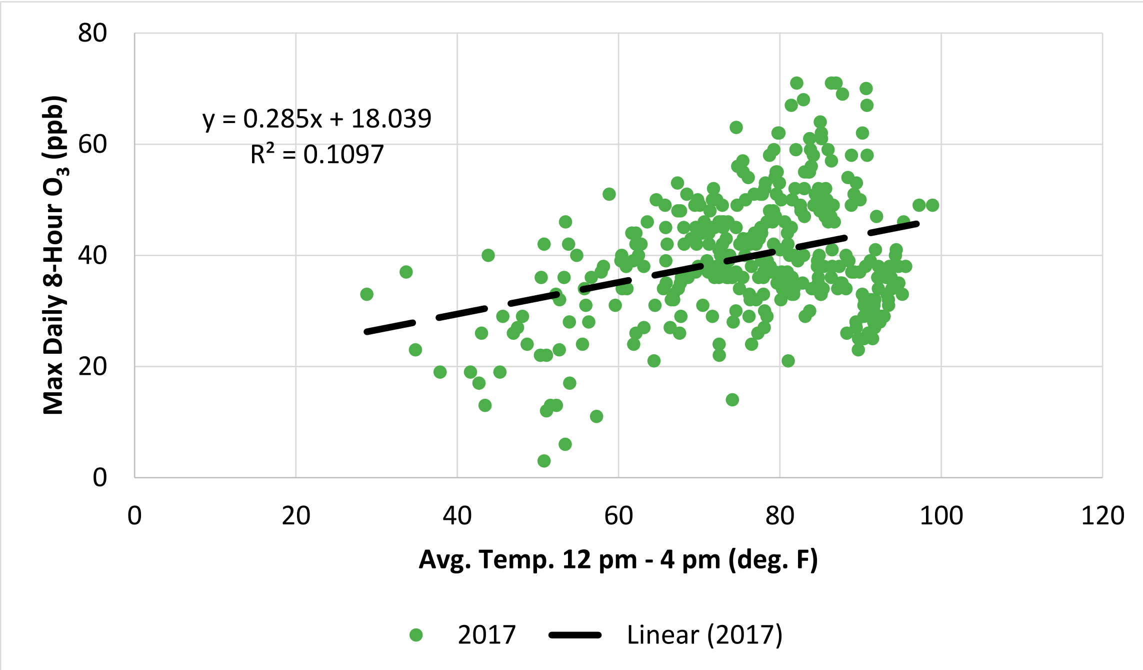


Figure 4-12. Scatter Plot of 12 pm – 4 pm Temperature at CAMS 3 v. MDA8 O_3 at CAMS 3, 2018

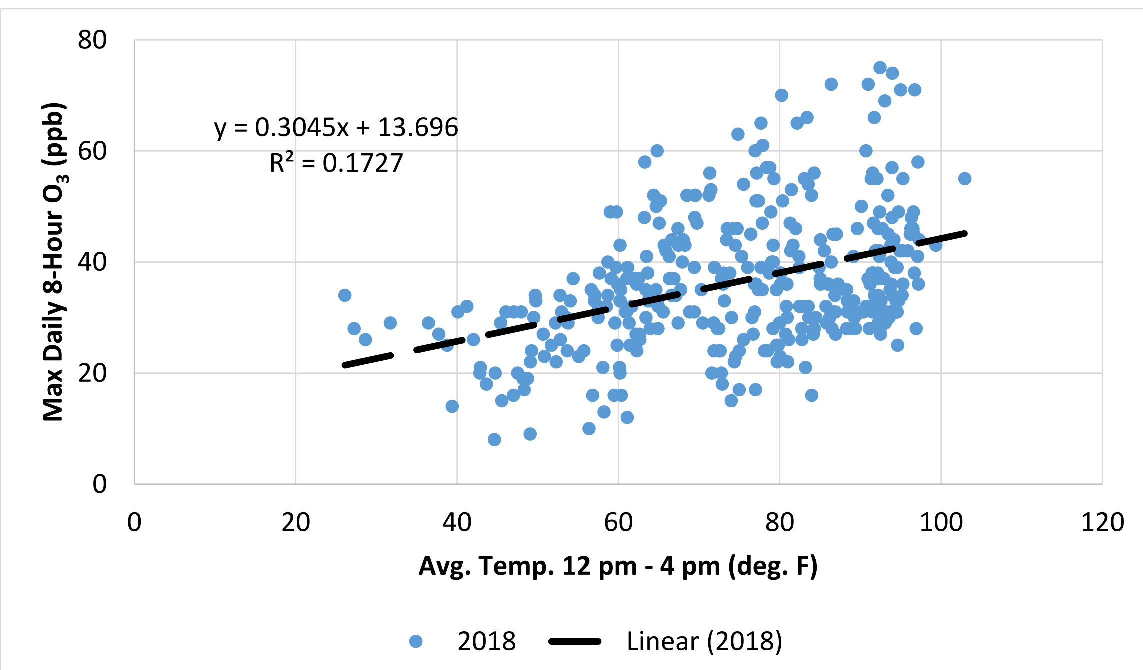
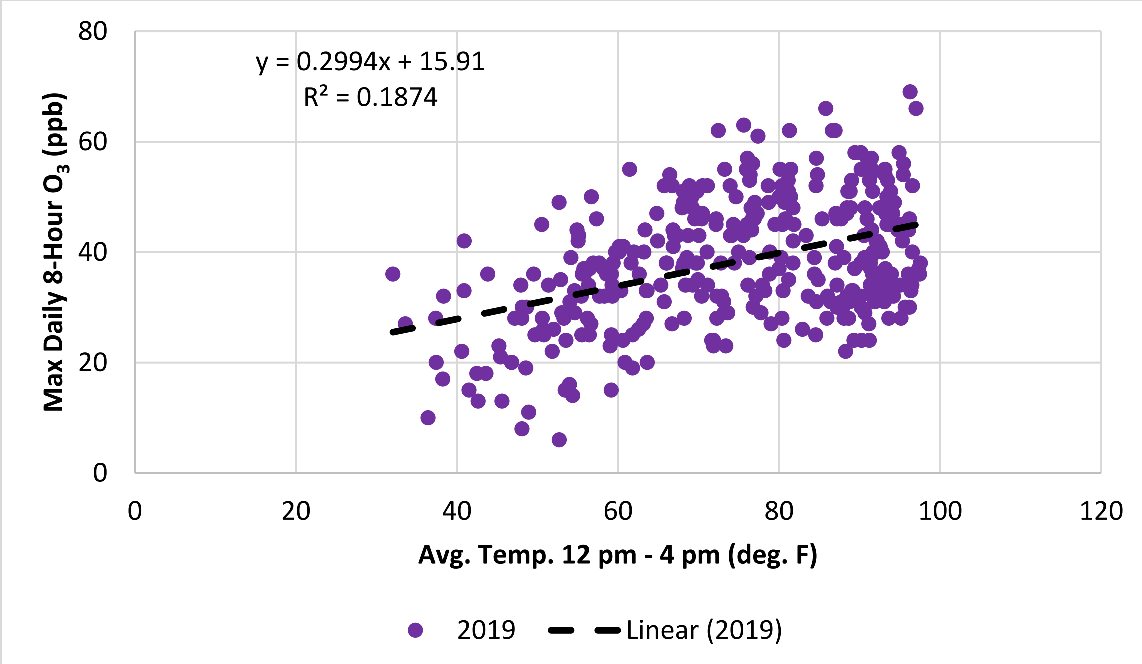
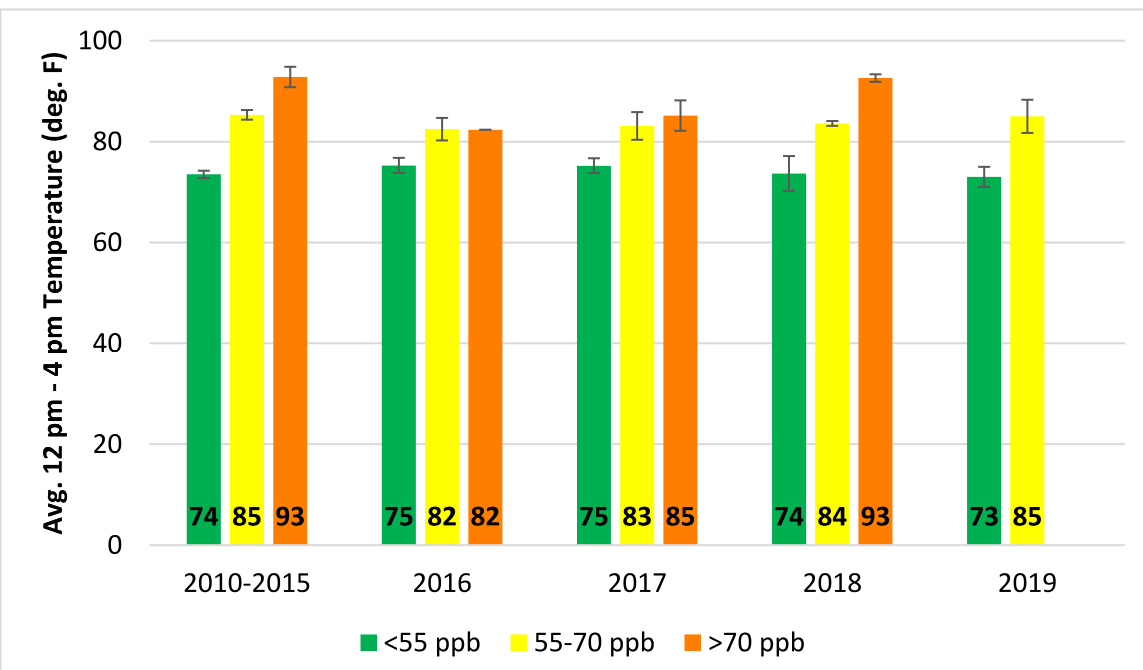


Figure 4-13. Scatter Plot of 12 pm – 4 pm Temperature at CAMS 3 v. MDA8 O_3 at CAMS 3, 2019



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 3 in 2019 compared to previous timeframes. Since there were no days with MDA8 O_3 >70 ppb at CAMS 3 in 2019, the figure below does not contain the average temperature for that interval.

Figure 4-14. Typical Temperature 12 pm – 4pm at CAMS 3 on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 3, 2010-2019

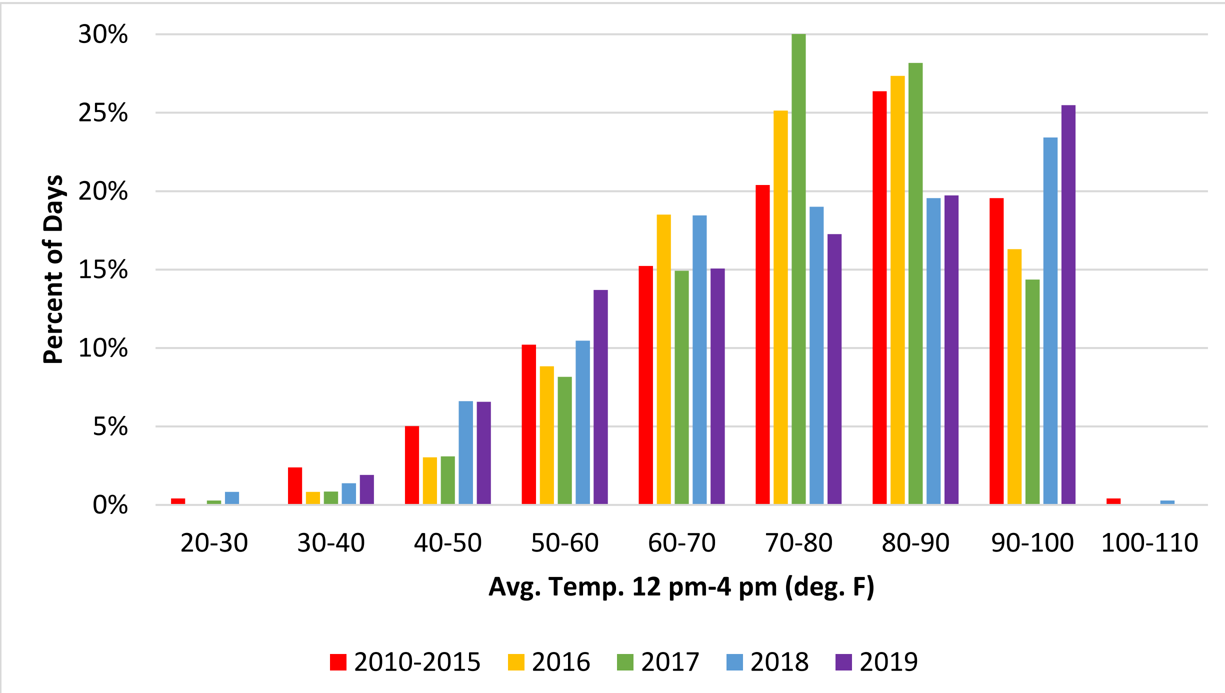


The average temperature and O_3 concentration relationship for 2019 follows the relationship from the previous years. This relationship indicates that higher temperatures can allow for higher O_3 formation.

4.2.2 Comparison of 2019 Temperatures to 2010-2018 Temperatures

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

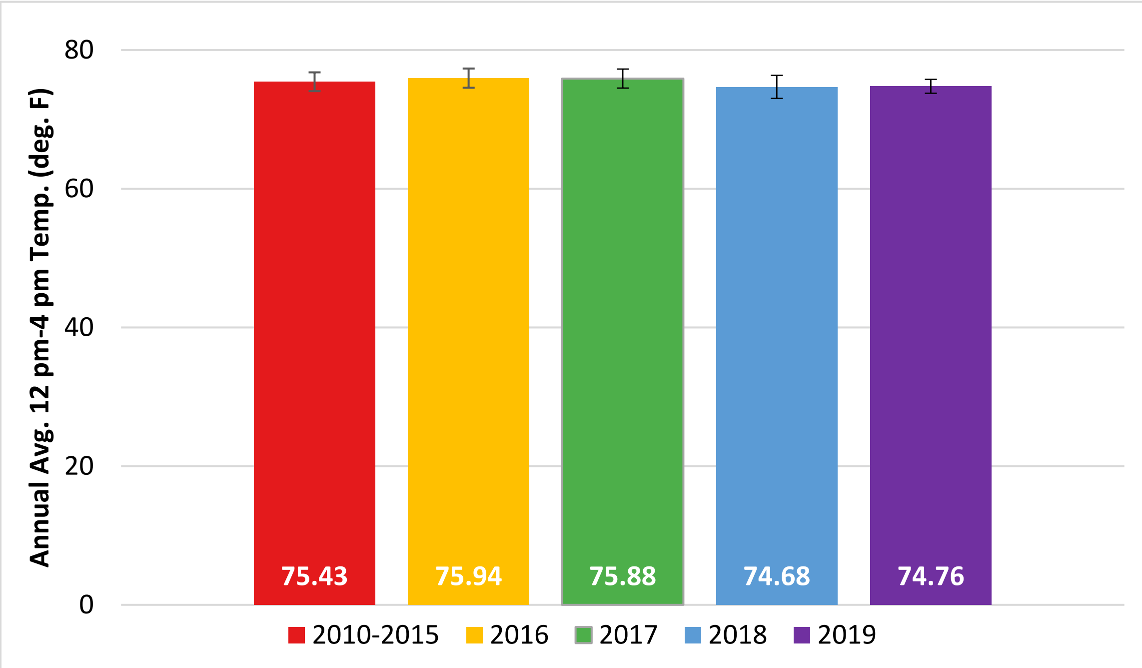
Figure 4-15. Histogram of 12 pm – 4 pm Temperatures at CAMS 3, 2010-2019



CAPCOG performed a chi-squared test of independence on the data to determine if the distribution of the average temperatures from 12 pm-4 pm into these 10°F bins was statistically different from the distribution in 2010-2018. There was not a significant statistical difference in the distribution using this test at a 0.05 significance level between 2019 and 2018; whereas, there was a statistical difference between temperatures in 2019 and 2010-2017.

CAPCOG also tested whether there was a significant statistical difference in the annual average of these daily 12 pm-4 pm temperature averages. The following figure shows the average from 2010-2019 along with the 95% confidence intervals.

Figure 4-16. Annual Avg. 12 pm-4 pm Temperature at CAMS 3, 2010-2019



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 2019 diurnal temperature changes were statistically different from temperature changes observed 2010-2018 or if the relationship between O_3 and temperature change was significantly than the relationship observed 2010-2018.

4.3.1 Comparison of Relationship between Diurnal Temperature Change and MDA8 O_3 in 2019 to 2010-2018

The figures below show scatter plots with MDA8 O_3 values and diurnal temperature changes 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 4-17. Scatter Plot of Diurnal Temperature Change at CAMS 3 v. MDA8 O_3 at CAMS 3, 2010-2015

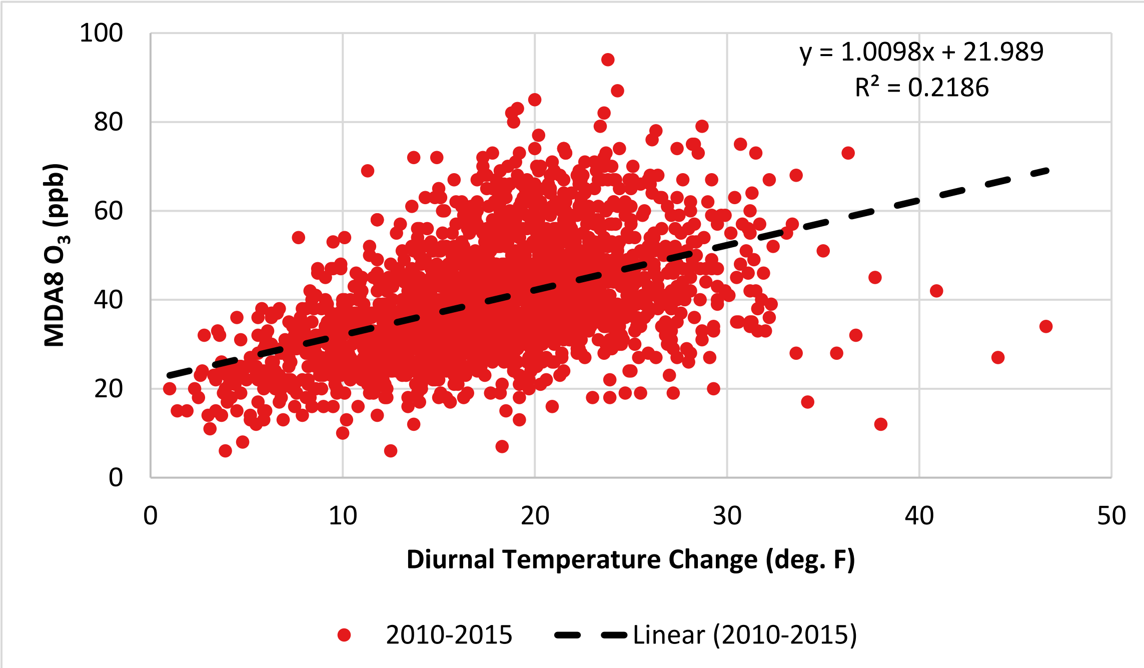


Figure 4-18. Scatter Plot of Diurnal Temperature Change at CAMS 3 v. MDA8 O_3 at CAMS 3, 2016

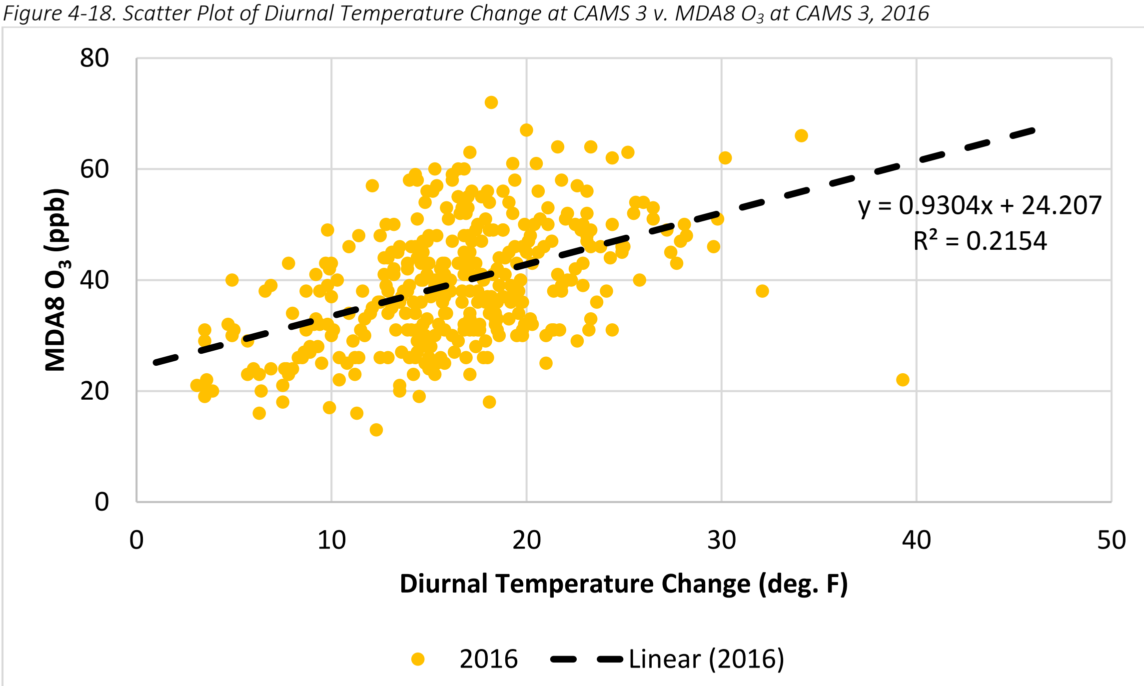


Figure 4-19. Scatter Plot of Diurnal Temperature Change at CAMS 3 v. MDA8 O_3 at CAMS 3, 2017

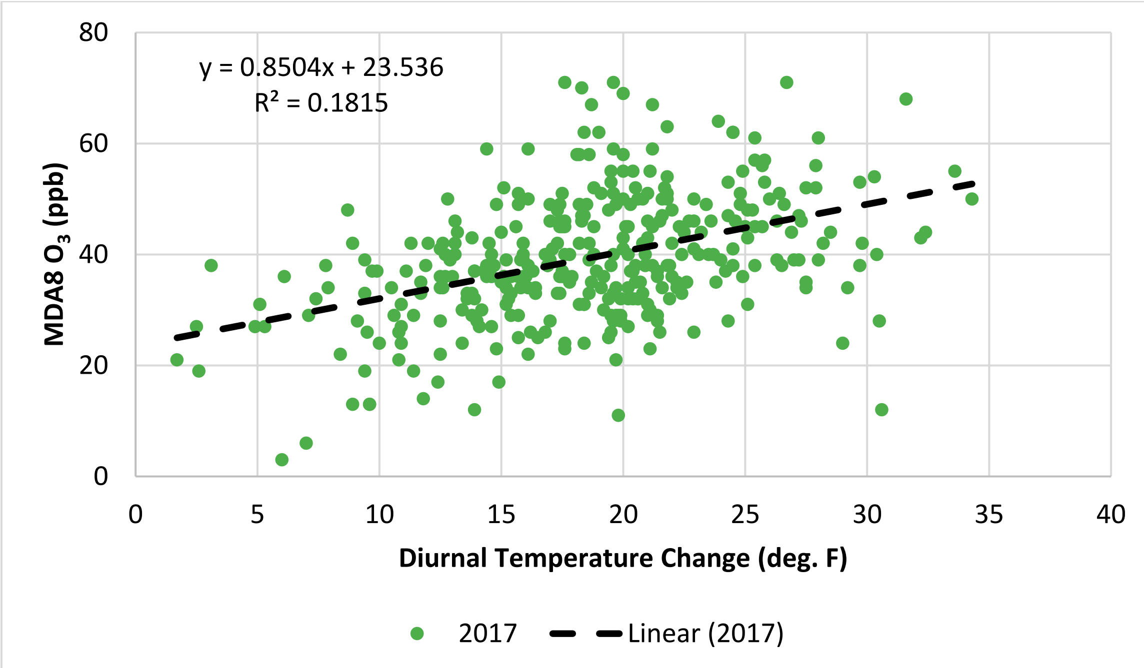


Figure 4-20. Scatter Plot of Diurnal Temperature Change at CAMS 3 v. MDA8 O_3 at CAMS 3, 2018

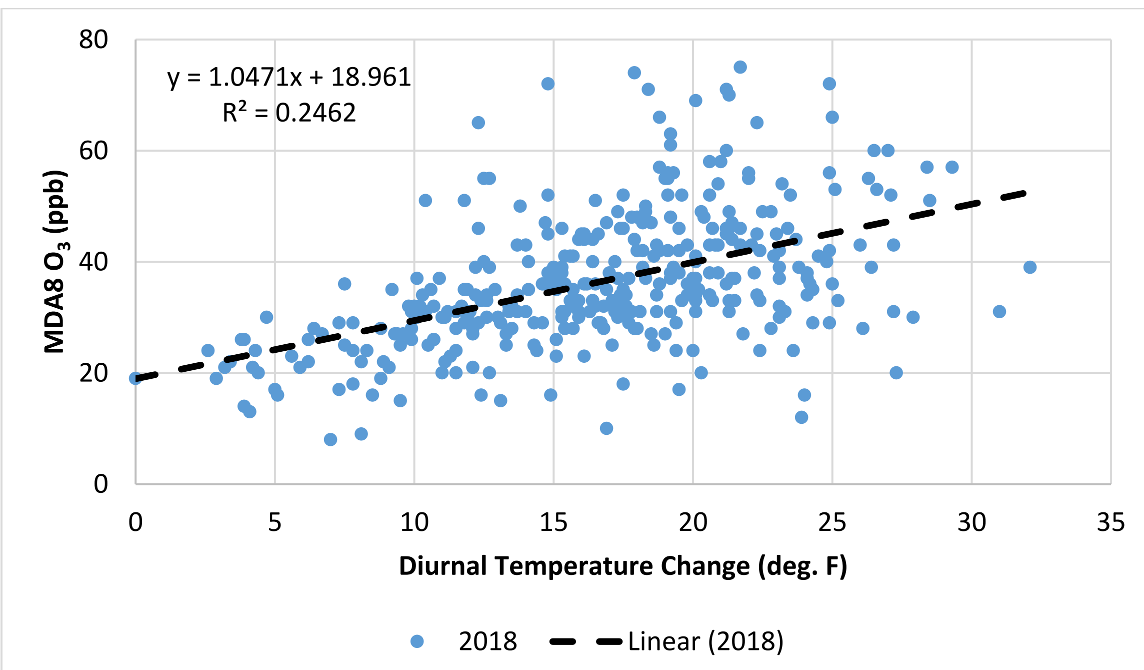
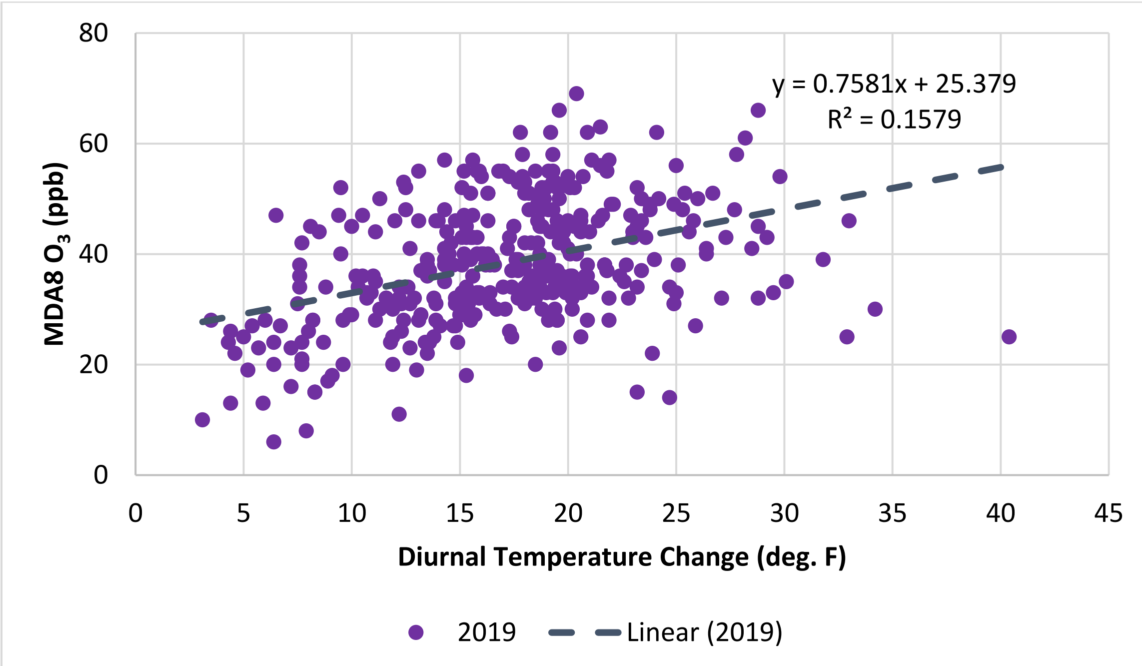


Figure 4-21. Scatter Plot of Diurnal Temperature Change at CAMS 3 v. MDA8 O_3 at CAMS 3, 2019



Of all of the time periods it was compared to, the 2019 MDA8 O_3 concentrations had the weakest correlation to diurnal temperature change, both in terms of the slope and R^2 values of the trend line.

The figure below shows a comparison of the typical diurnal temperature changes on days <55 ppb, 55-70 ppb, and >70 ppb in 2019 relative to 2010-2018. Since there were no days with MDA8 O_3 >70 ppb at CAMS 3 in 2019, the figure below does not contain the average diurnal temperature for that interval.

Figure 4-22. Typical Diurnal Temperature Change at CAMS 3 on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 3, 2010-2019

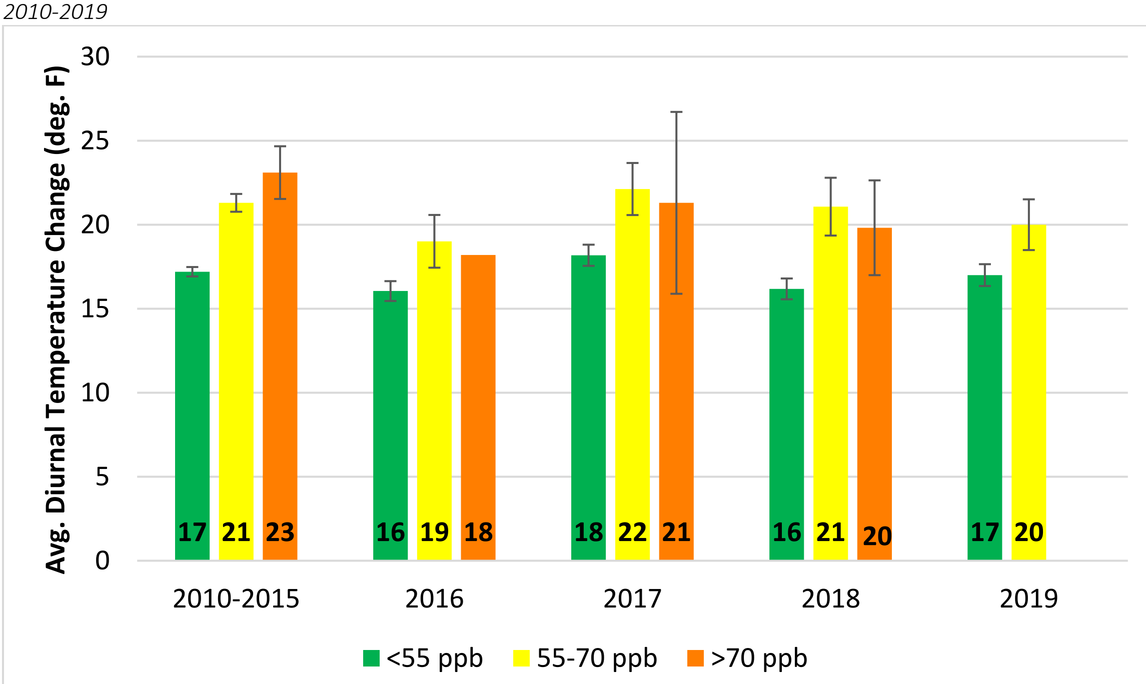
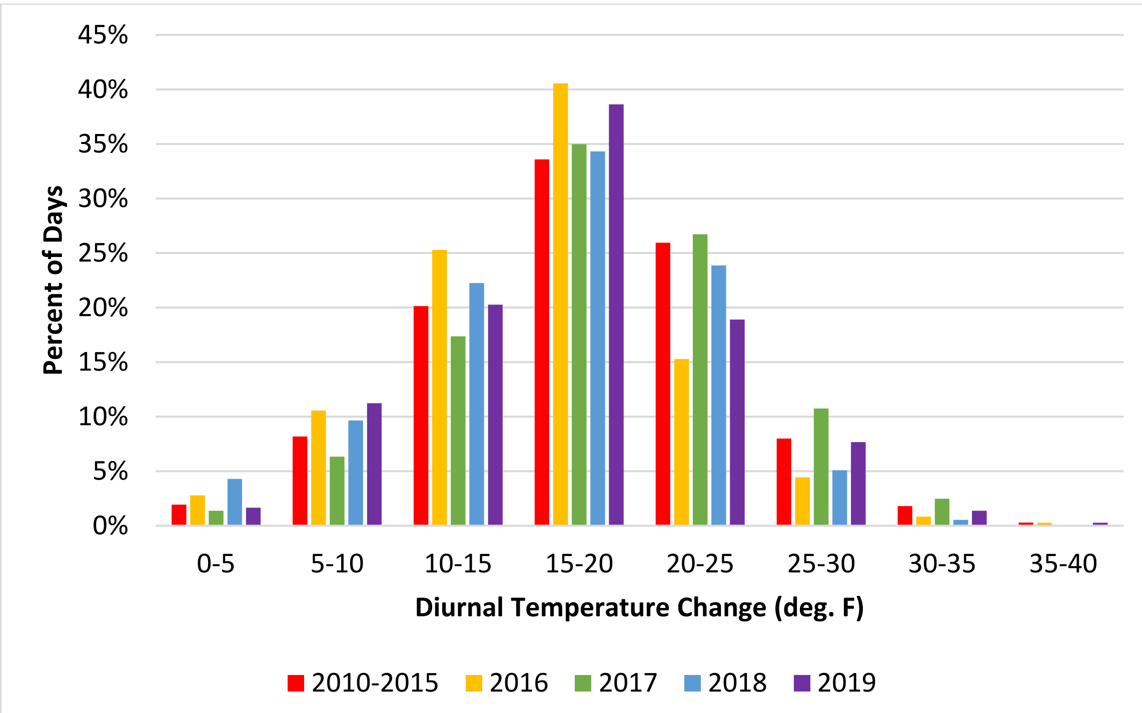


Figure 4-22 shows that there continued to be a statistically significant difference in temperature changes on days when MDA8 O_3 was 55 ppb or higher compared to days when it was lower than 55 ppb.

4.3.2 Comparison of 2019 Diurnal Temperature Changes to 2010-2018 Diurnal Temperature Changes

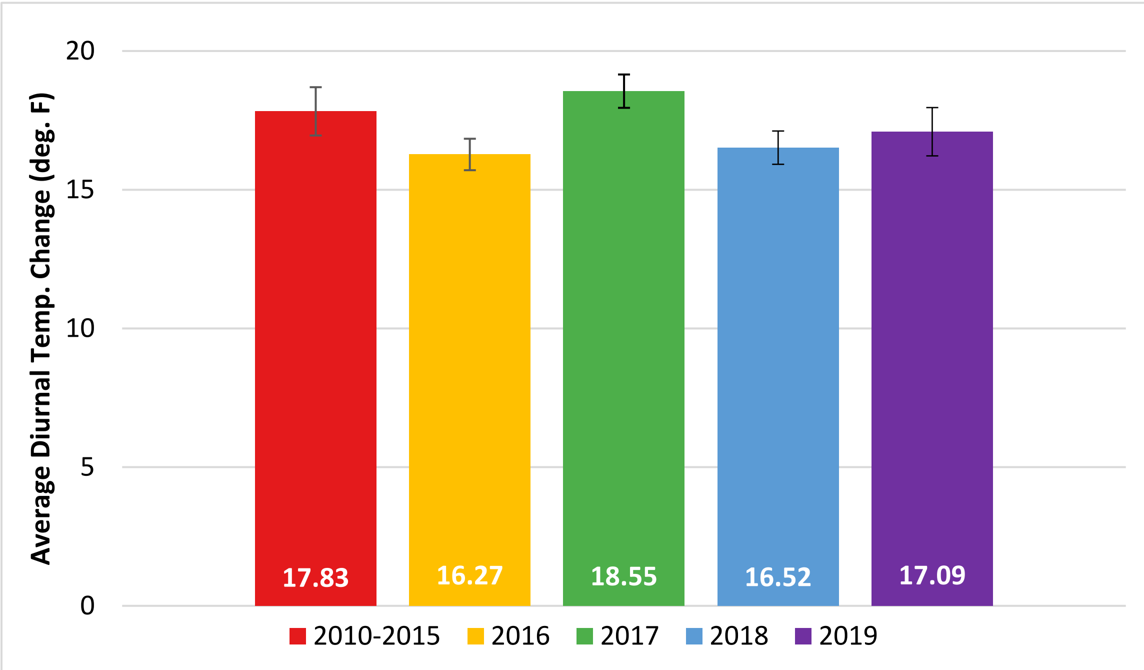
The distribution of days into 5-degree bins in the histogram below shows a similar distribution of diurnal temperature changes in 2019 compared to 2010-2018. In particular, there is little difference in the distributions of 2019 data compared to 2018 data that would help account for the large difference in the frequency and severity of high O_3 days in 2019 compared to 2018.

Figure 4-23. Histogram of Diurnal Temperature Changes at CAMS 3, 2010-2019



CAPCOG also performed a confidence interval analysis of the average annual daily diurnal temperature change. The average 17.09°F diurnal change in 2019 was within than the confidence interval for the 2018 average.

Figure 4-24. Annual Avg. Diurnal Temperature Change at CAMS 3, 2010-2015, 2016, 2017, and 2019



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4.4 Relative Humidity

CAPCOG's most recent O_3 conceptual model showed that average relative humidity 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 2019 12 pm-4 pm relative humidity measurements were statistically different from the relative humidity measurements in 2010-2018 or if the relationship between O_3 and relative humidity was different from the relationship observed 2010-2018.

4.4.1 Comparison of Relationship between Relative Humidity and MDA8 O_3 in 2019 to 2010-2018

The figures below show scatter plots with MDA8 O_3 values at CAMS 3 and 12 pm-4 pm relative humidity data at CAMS 5002 (Camp Mabry) for 2010-2018. As the figures show, the 2019 data was consistent in showing a negative correlation between these two factors.

Figure 4-235. Scatter Plot of 12 pm – 4 pm Relative Humidity at Camp Mabry v. MDA8 O_3 at CAMS 3, 2010-2015

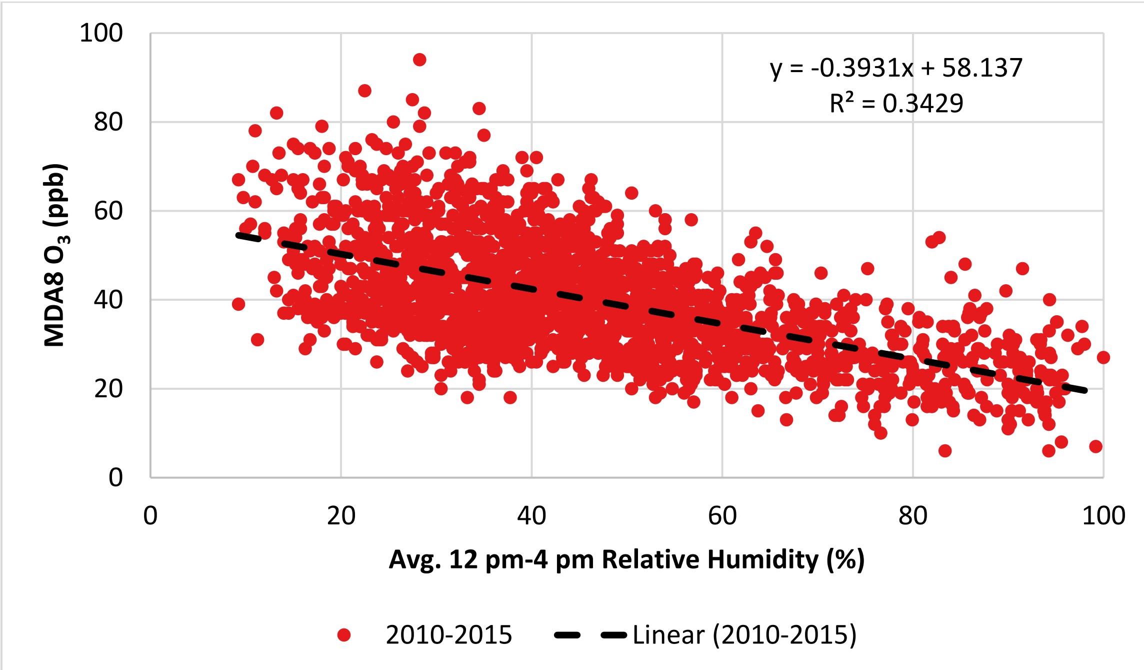


Figure 4-246. Scatter Plot of 12 pm – 4 pm Relative Humidity at Camp Mabry v. MDA8 O_3 at CAMS 3, 2016

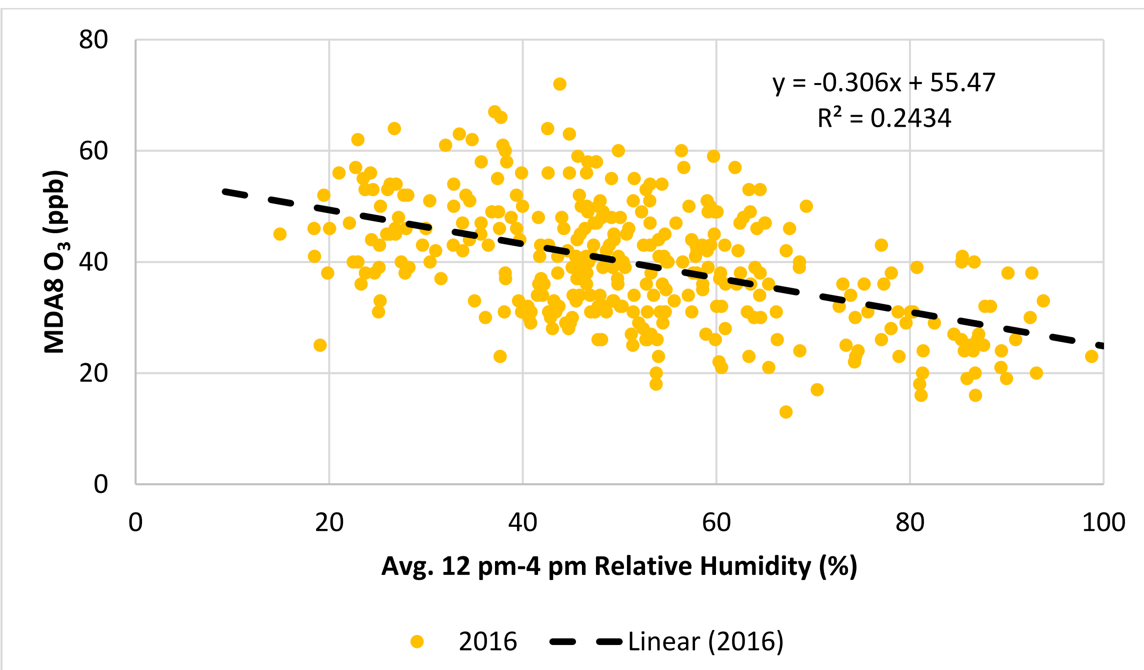


Figure 4-257. Scatter Plot of 12 pm – 4 pm Relative Humidity at Camp Mabry v. MDA8 O_3 at CAMS 3, 2017

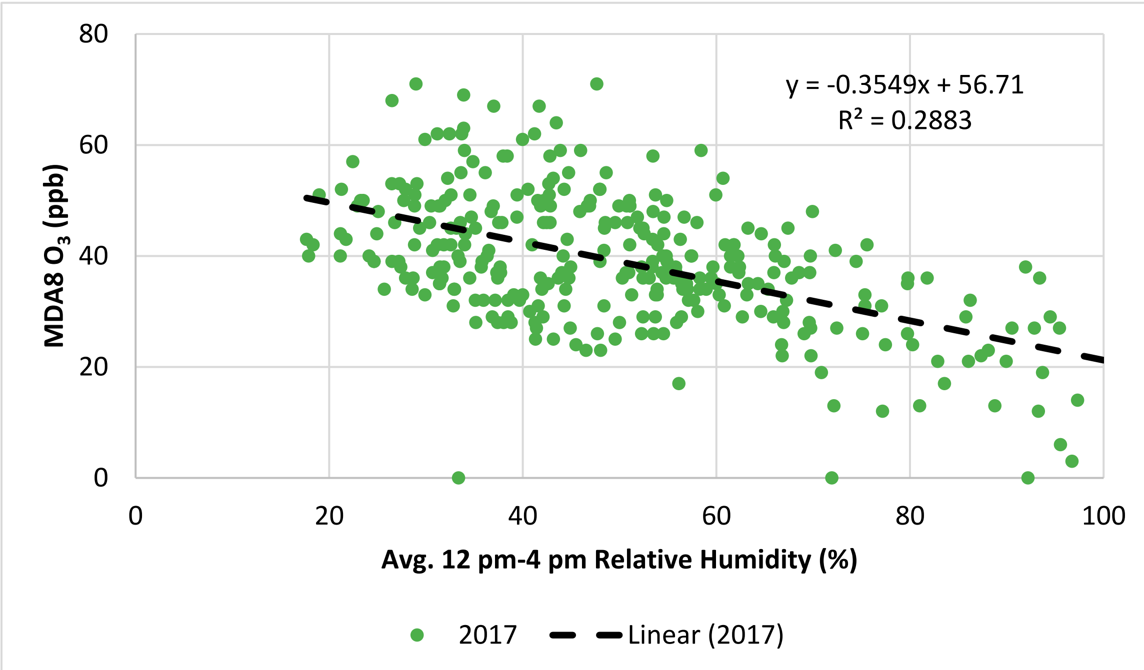


Figure 4-268. Scatter Plot of 12 pm – 4 pm Relative Humidity at Camp Mabry v. MDA8 O_3 at CAMS 3, 2018

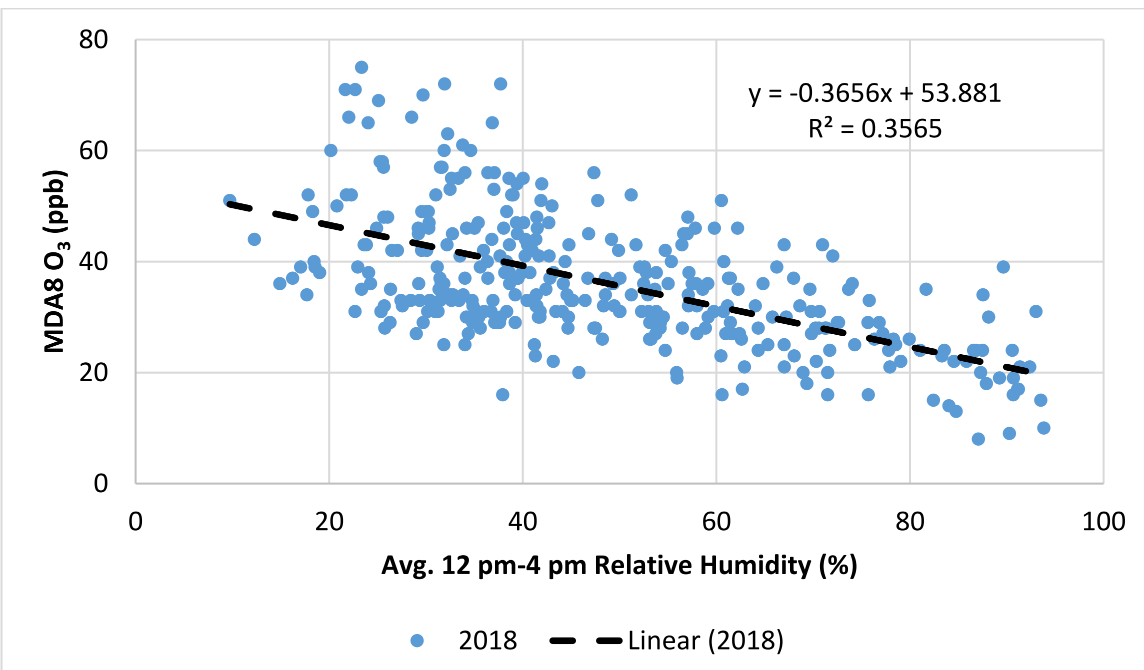
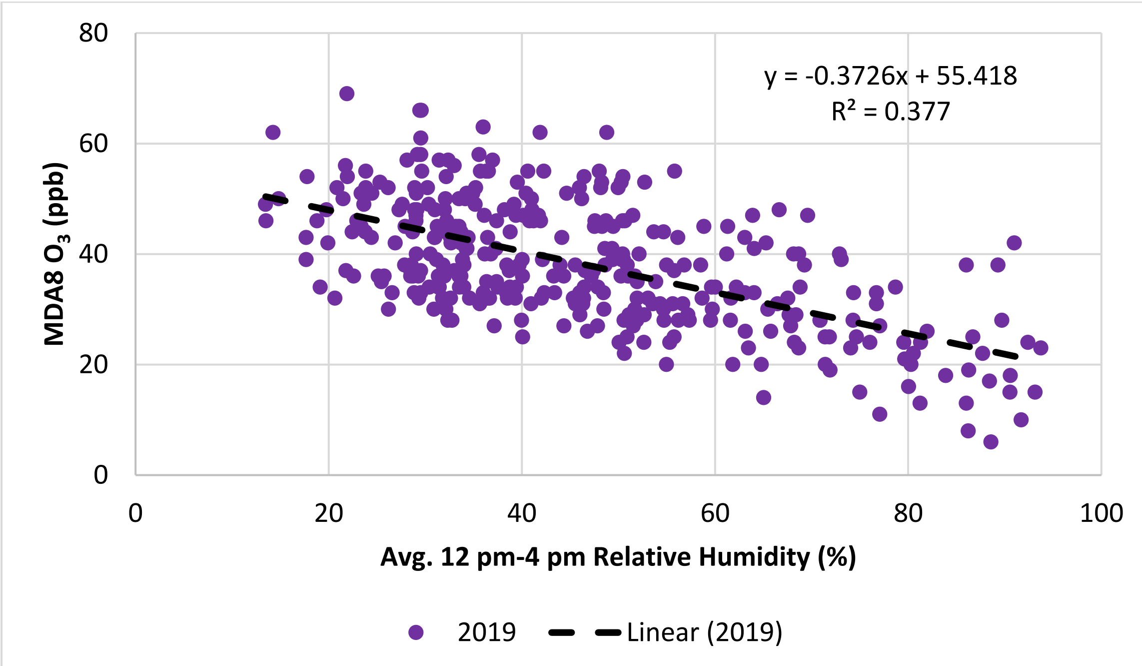
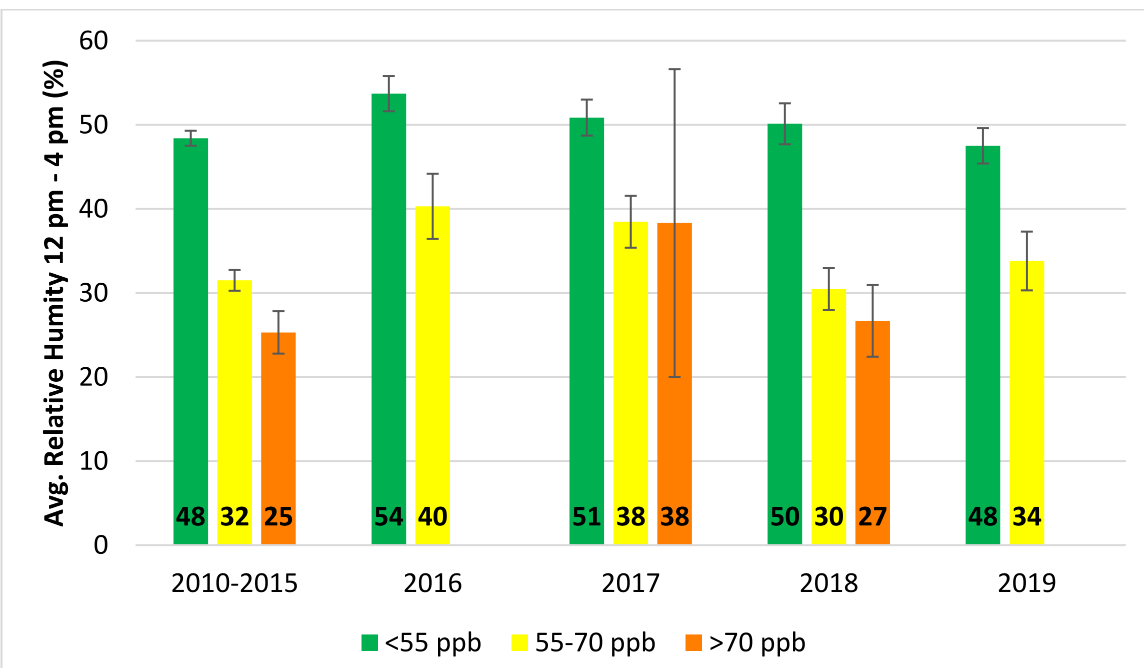


Figure 4-279. Scatter Plot of 12 pm – 4 pm Relative Humidity at Camp Mabry v. MDA8 O_3 at CAMS 3, 2019



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 in 2019 relative to 2010-2018. Since there were no days with MDA8 O_3 >70 ppb at CAMS 3 in 2019, the figure below does not contain the average relative humidity for that interval.

Figure 4-3028. Typical Relative Humidity 12 pm – 4pm at Camp Mabry on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 3, 2010-2019

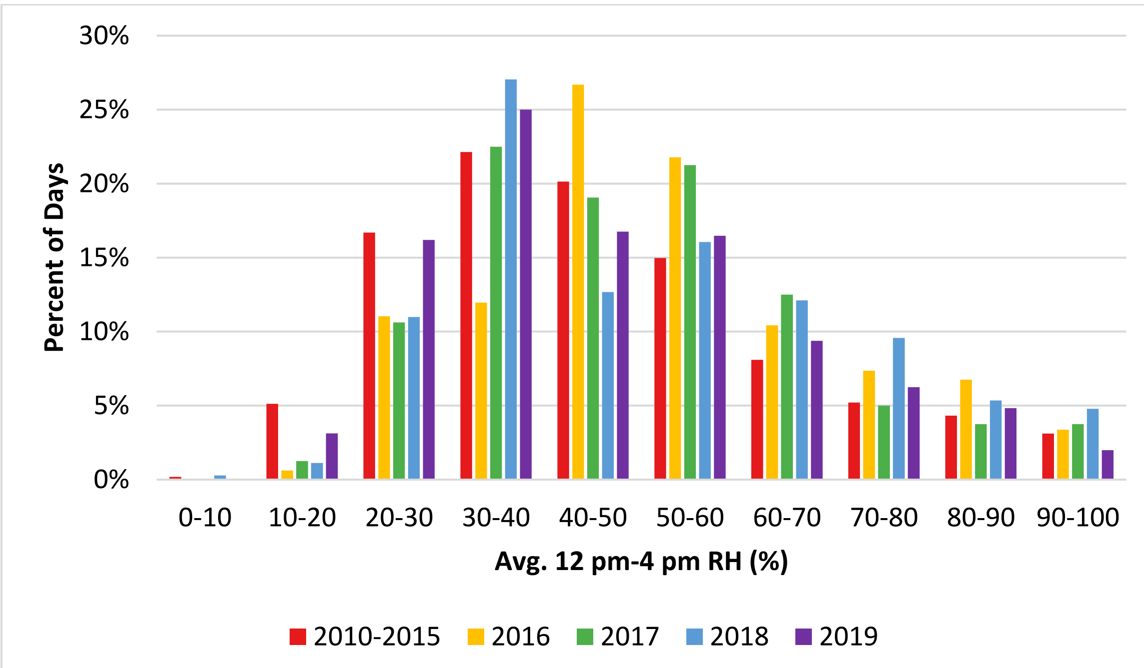


The average relative humidity and O_3 concentration relationship for 2019 follows the relationship from the previous years. This relationship indicates that high O_3 tends to form with low humidity.

4.4.2 Comparison of 2019 Relative Humidity to 2010-2018 Relative Humidity

The figure below shows the distribution of RH into ten bins and compares observed data in 2019 to previous studied timeframes. Overall this data suggests that 2019 had few days with RH above 70% which would suggest that there were more chances for the formation of high levels of O_3. However, 2019 had more days with 10%-30% RH than in 2016-2018. Since 2019 had a majority of low RH days and only two days of high O_3, other meteorological factors must have contributed to the high O_3.

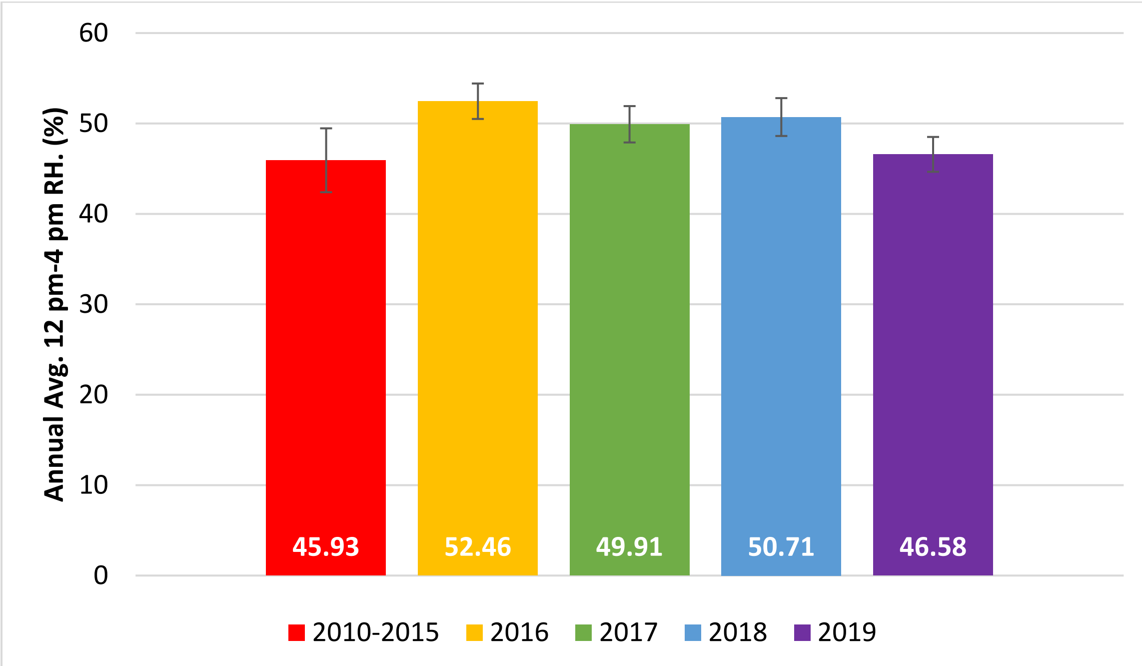
Figure 4-31. Histogram of 12 pm – 4 pm Relative Humidity at Camp Mabry, 2010- 2019



CAPCOG performed a chi-squared test for independence on these distributions and was able to determine that the distribution of days into these bins was statistically different from the 2010-2018 data at a 0.05 significance level.

CAPCOG also performed a confidence interval analysis of the average annual 12 pm-4 pm relative humidity. The average RH of 46.58% from 12 pm-4 pm in 2019 was lower than the confidence interval for the 2016-2018 averages.

Figure 4-292. Annual Avg. 12 pm-4 pm Relative Humidity at Camp Mabry, 2010- 2019



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 2019 12 pm- 4 pm solar radiation measurements were statistically different from the measurements in 2010-2017 or if the relationship between O_3 and solar radiation was different than the relationship observed 2010-2018.

4.5.1 Comparison of Relationship between Solar Radiation and MDA8 O_3 in 2019 to 2010-2018

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 2010-2018. As the figures show, the 2019 data was consistent in showing a positive correlation between these two factors.

Figure 4-303. Scatter Plot of 12 pm – 4 pm Solar Radiation at CAMS 38 v. MDA8 O_3 at CAMS 38, 2010-2015

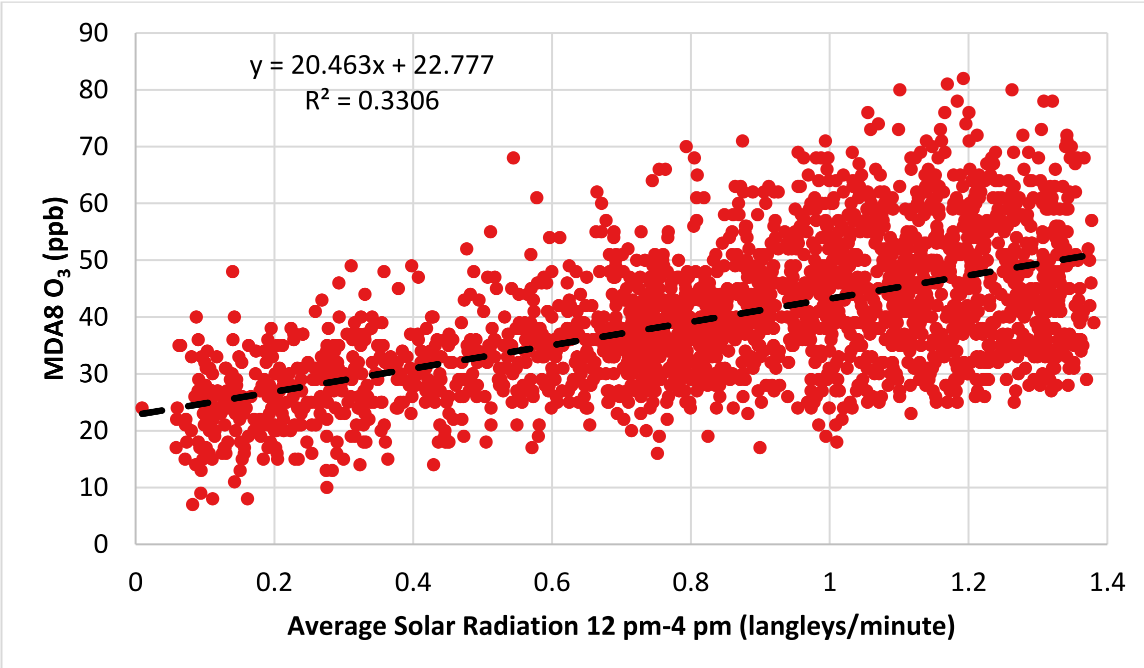


Figure 4-314. Scatter Plot of 12 pm – 4 pm Solar Radiation at CAMS 38 v. MDA8 O_3 at CAMS 38, 2016

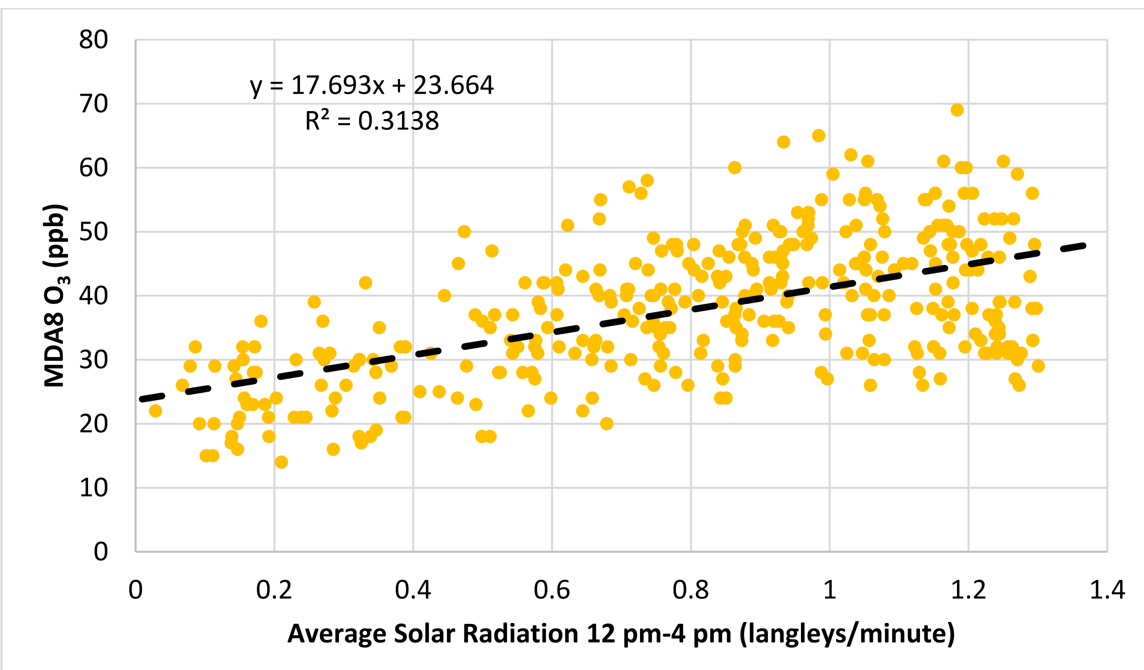


Figure 4-325. Scatter Plot of 12 pm – 4 pm Solar Radiation at CAMS 38 v. MDA8 O_3 at CAMS 38, 2017

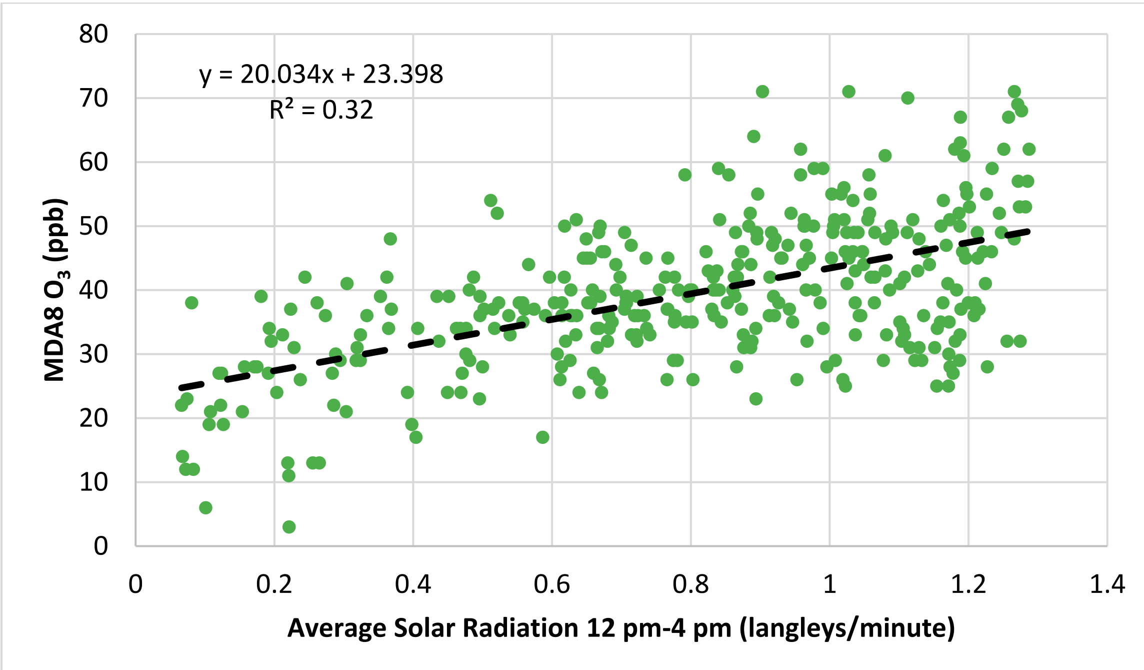


Figure 4-336. Scatter Plot of 12 pm – 4 pm Solar Radiation at CAMS 38 v. MDA8 O_3 at CAMS 38, 2018

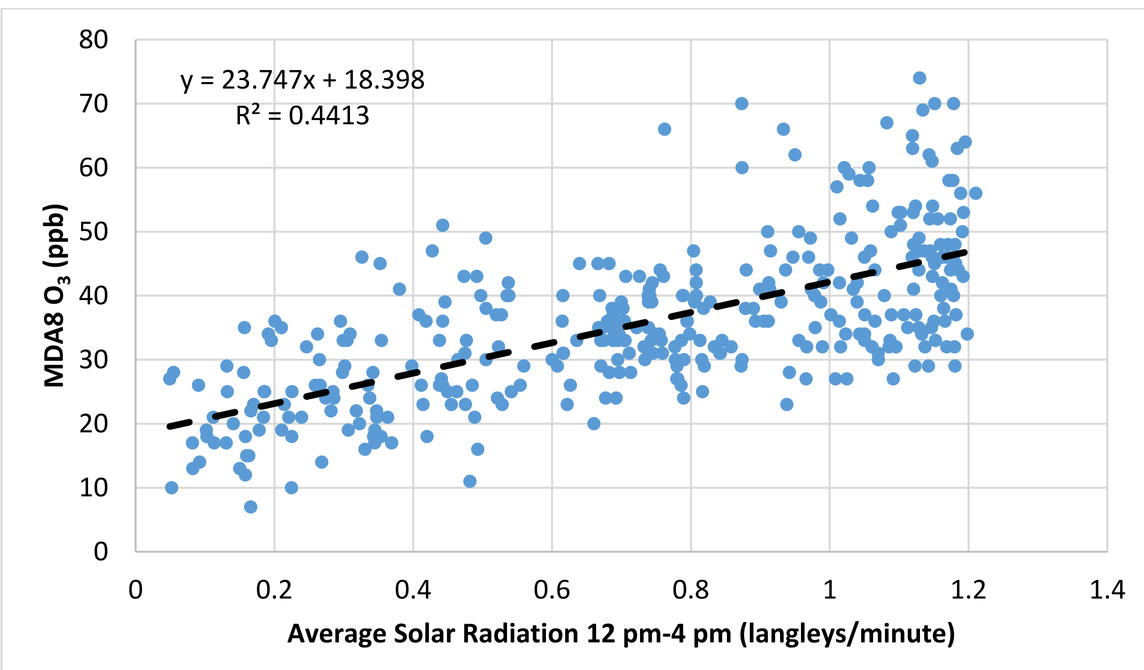
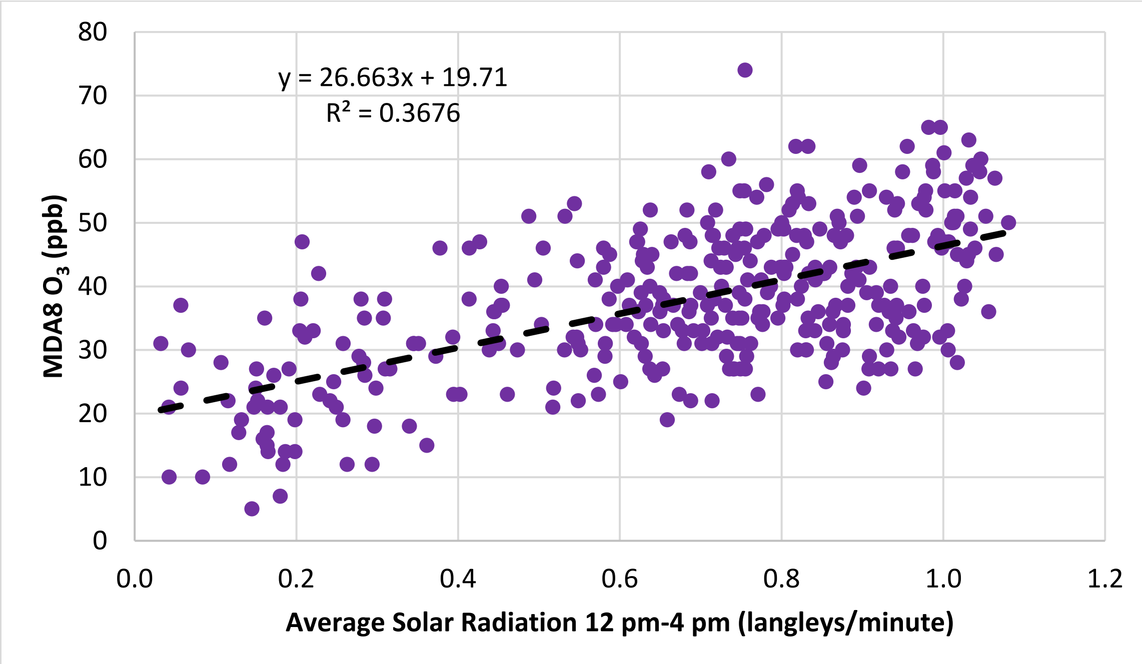


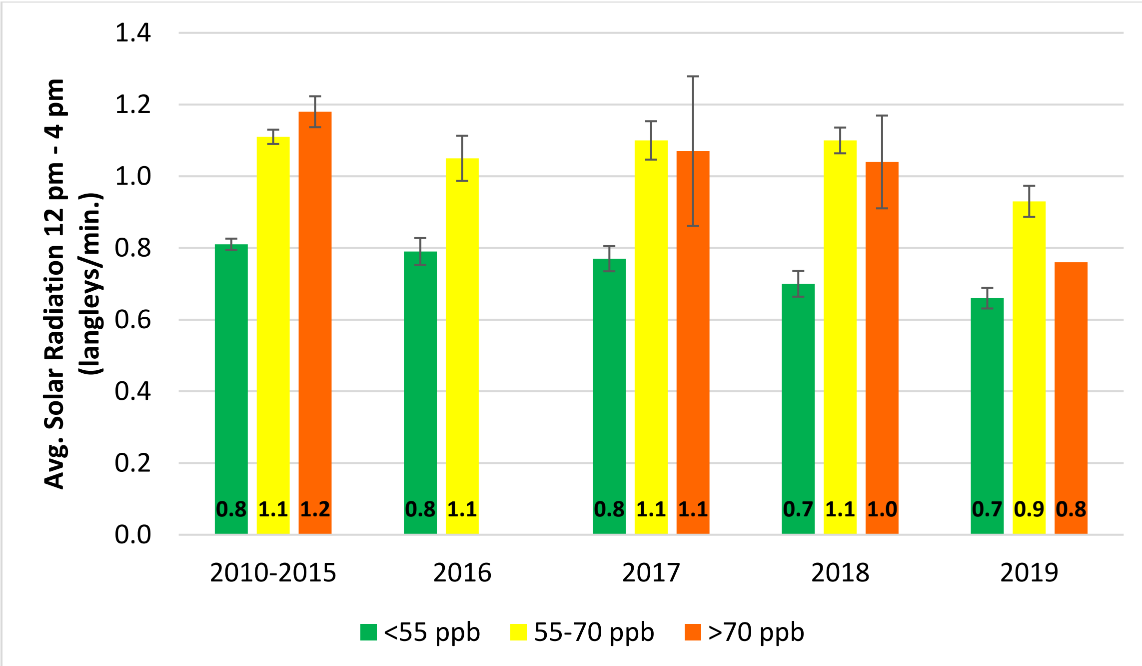
Figure 4-347. Scatter Plot of 12 pm – 4 pm Solar Radiation at CAMS 38 v. MDA8 O_3 at CAMS 38, 2019



In Figure 4-37, the trend line from 2019 shows a sharper slope which indicates that there was lower solar radiation in relation to MDA8 O_3 than in previous years.

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 2019 relative to 2010-2018. There was only one day in 2019 where O_3 measured >70 ppb at CAMS 38. As the graph below indicates, solar radiation for O_3 levels >55 ppb averaged lower in 2019 than in all of the previous years. This may indicate one of the reasons that 2019 only had two days of regional MDA8 O_3 greater than 70 ppb.

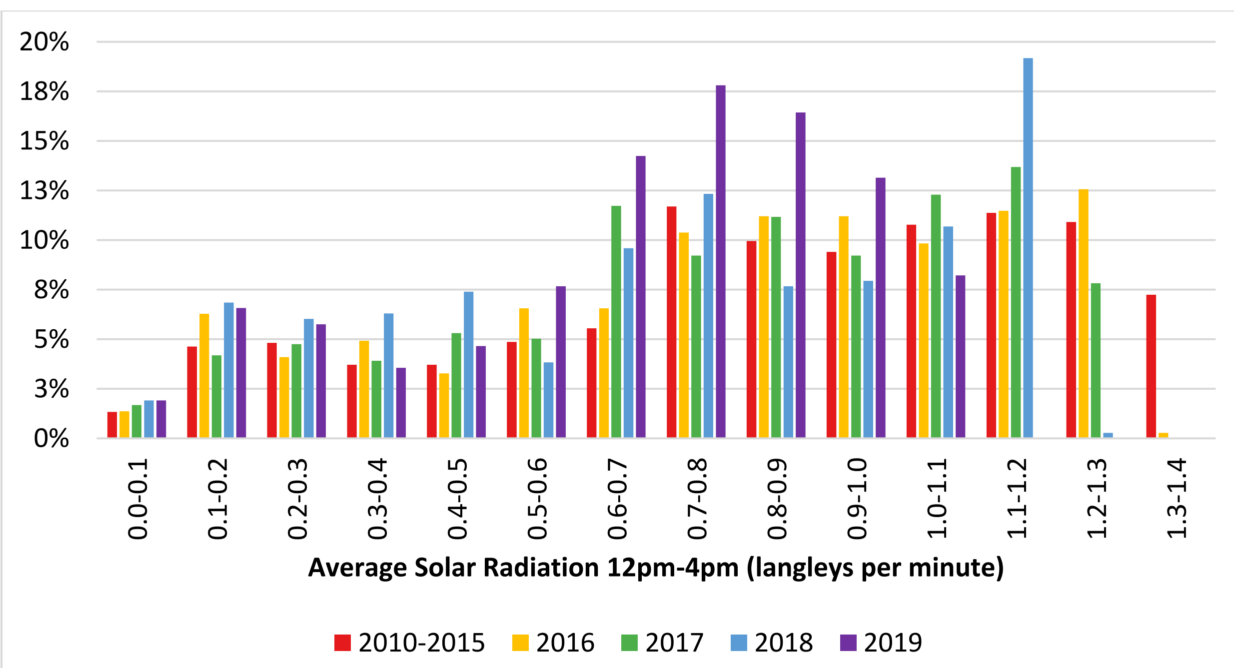
Figure 4-358. Typical Solar Radiation 12 pm – 4pm at CAMS 38 on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 38, 2010-2019



4.5.2 Comparison of 2019 Solar Radiation to 2010-2018 Radiation

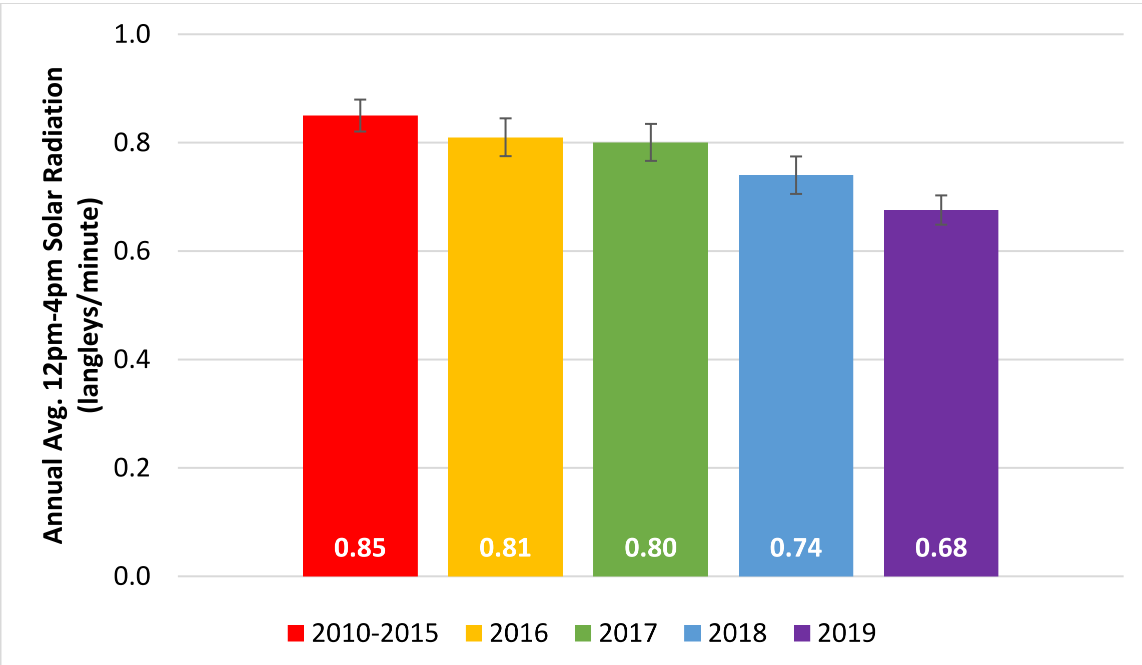
Based on a review of the meteorological data, CAPCOG was able to determine that there were statistical differences in the 12 pm-4 pm solar radiation at CAMS 38 in 2019 compared to 2010-2018. The distribution of days into 0.1 langley/minute bins in the histogram below shows that 2019 had substantially more days with solar radiation between 0.5-1.0 langleys/minute than previous timeframes.

Figure 4-39. Histogram of 12 pm – 4 pm Solar Radiation at CAMS 38, 2010-2019



CAPCOG also performed a confidence interval analysis of the average annual 12 pm-4 pm solar radiation. The 0.68 langley/minute average for 2019 was below the annual average and 95% confidence interval for the annual solar radiation values for 2010-2018.

Figure 4-40. Annual Avg. 12 pm-4 pm Solar Radiation at CAMS 38, 2010-2019



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. Additionally, solar cycles can vary by decade. NASA has observed unusually quiet magnetic activity from the Sun for the past two decades. The Sun is expected to enter a solar minimum in three years from 2017.[6] This solar minimum state would result in less solar radiation on Earth.

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 2019. In CAPCOG's 2010-2015 Conceptual Model, CAPCOG developed HYSPLIT[7] 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 2019 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)

[6] https://climate.nasa.gov/news/2659/four-decades-and-counting-new-nasa-instrument-continues-measuring-solar-energy-input-to-earth/

[7] Hybrid Single-Particle Lagrangian Integrated Trajectory

- 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 2019 when a CAPCOG region monitor recorded ground level O_3 >70 ppb.

Table 4-1. MDA8 O_3 >70 ppb, 2019

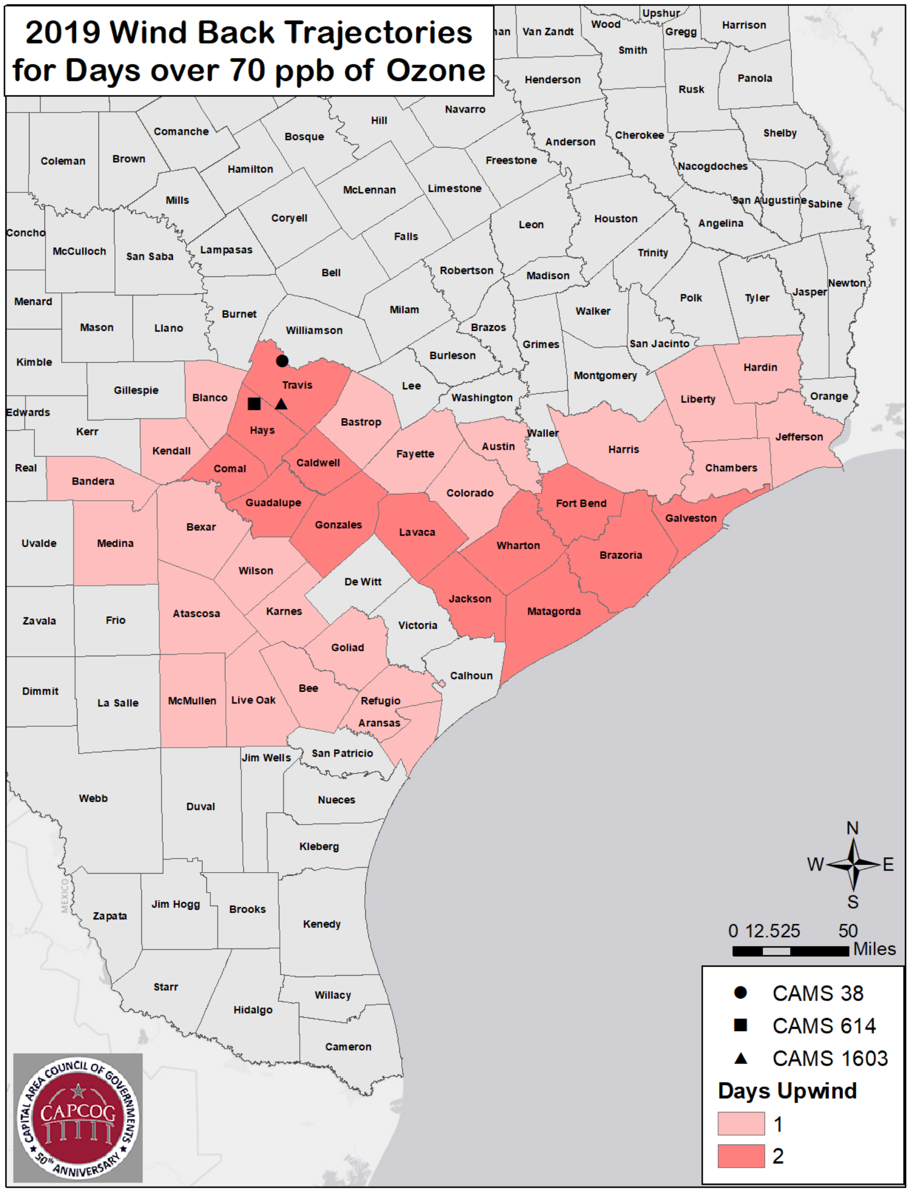
Date	MDA8 O_3 Level (ppb)	Location	Start Hour for Peak 1-hr. Avg.
7/26/2019	74	CAMS 614	10:00 AM
	72	CAMS 1603	11:00 AM
9/6/2019	74	CAMS 38	11:00 AM

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

and some counties were to the south-southwest of the region. This is consistent with previous years.

below displays the number of days that each county was upwind of a monitor in the MSA when it 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 2019, upwind counties were most often to the east-southeast of the region and some counties were to the south-southwest of the region. This is consistent with previous years.

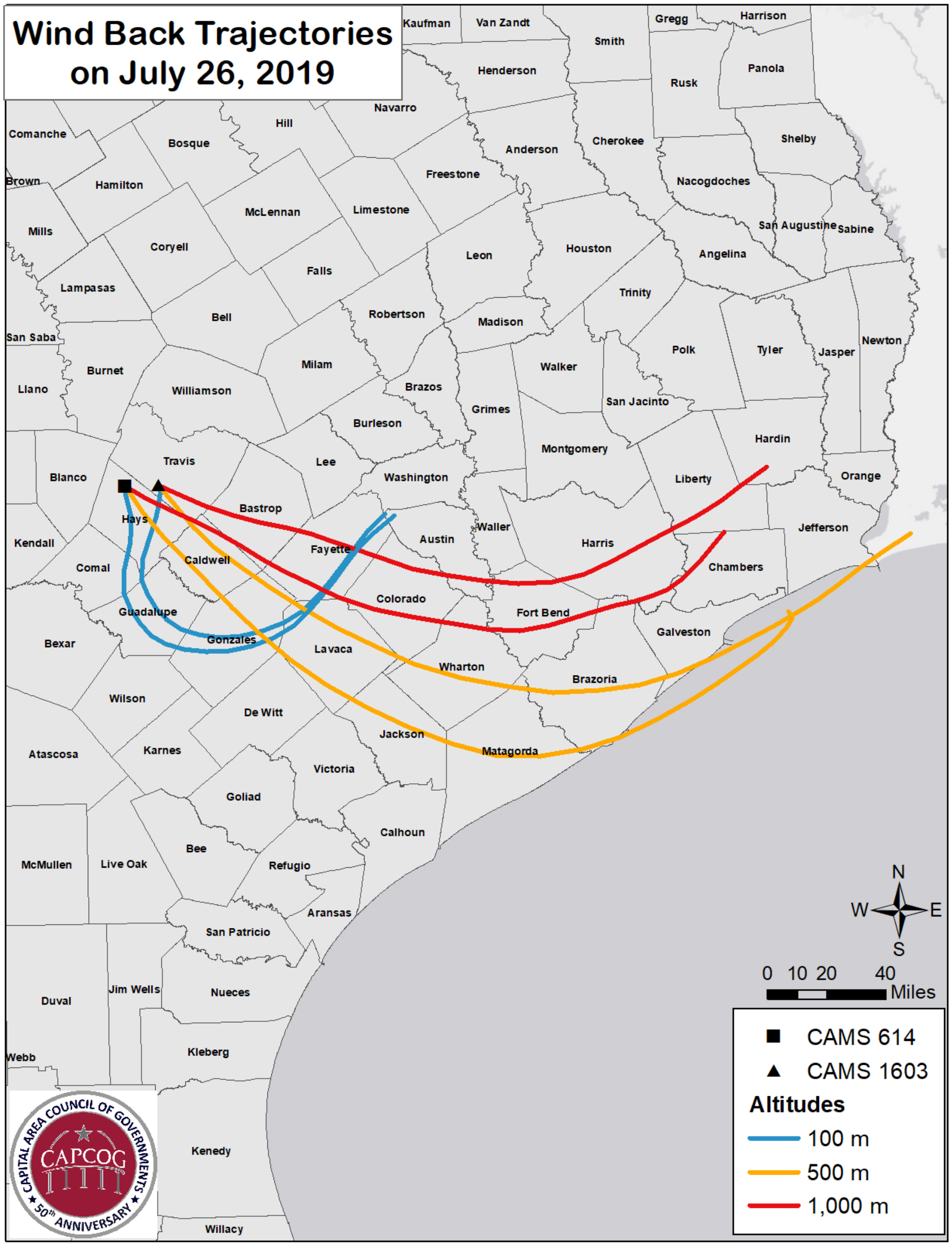
Figure 4-41. Number of Days Upwind in 2019 per County on Days with MDA8 O_3 days >70 ppb at a CAPCOG region monitor at altitudes of 100 m, 500 m, and 1,000 m



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

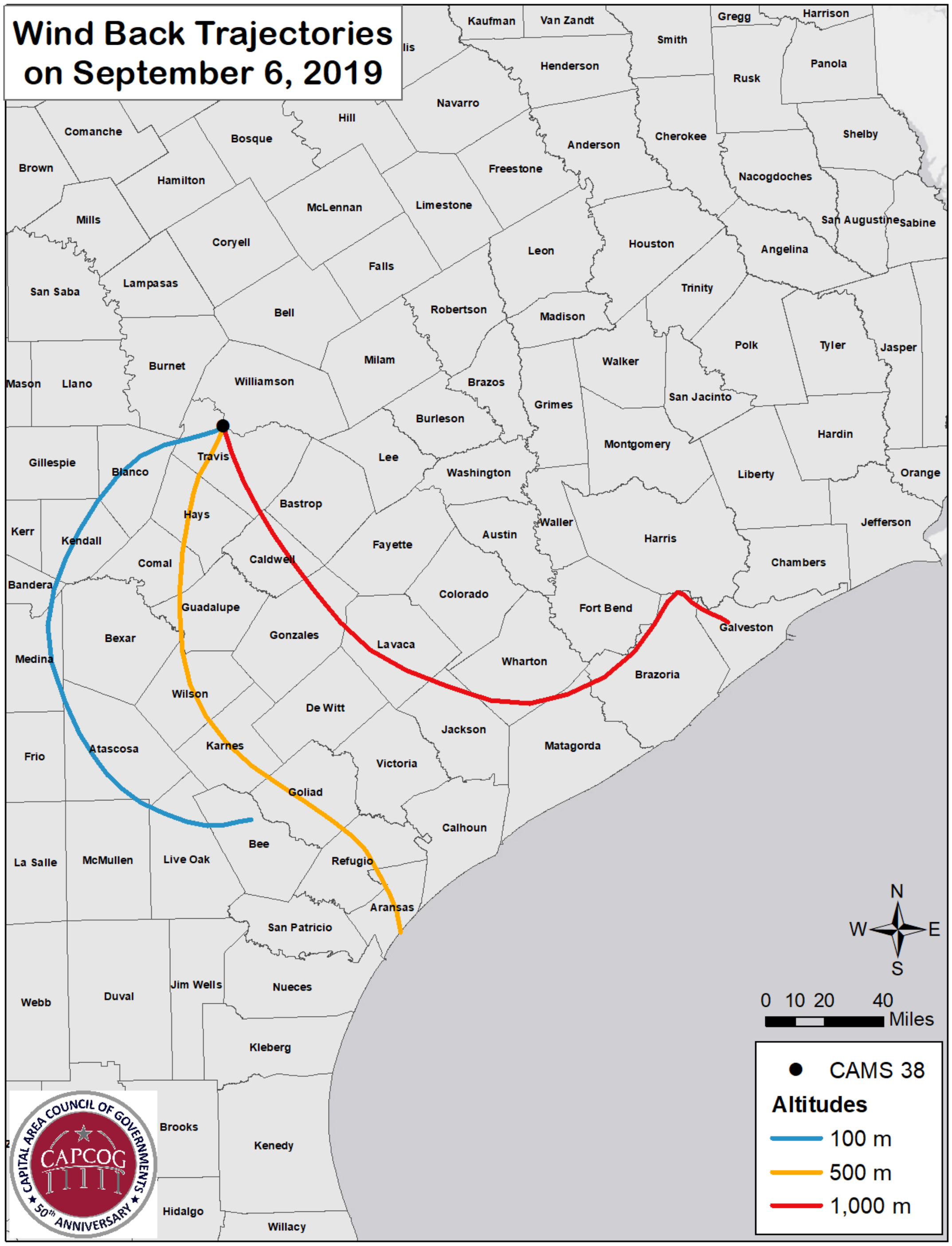
In 2019, the region experienced two days with MDA8 O_3 at 70 ppb or above, July 26 and September 6. On July 26, two CAPCOG monitors recorded such values, CAMS 614 and CAMS 1603. The back trajectories for both CAMS on July 26 indicate that the wind came from east-southeast of the region, which includes the 2015 O_3 non-attainment area of Houston-Galveston-Brazoria and the near-attainment area of Beaumont-Port Arthur.

Figure 4-42. Wind Back-Trajectories on July 26, 2019, for Monitors over 70 ppb.



On September 6, 2019, one of the TCEQ regulatory monitors, CAMS 38, recorded MDA8 O_3 at 70 ppb or above. Unlike the wind back trajectory on July 26, this 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, at altitudes of the 100 m. and 500 m. This wind direction is consistent with previous years in which regional monitors recorded high O_3. However, at 1,000 m., the wind originated from the Houston-Galveston-Brazoria area, similar to July 26, 2019.

Figure 4-363. Wind Back-Trajectories on September 6, 2019, for Monitors over 70 ppb.



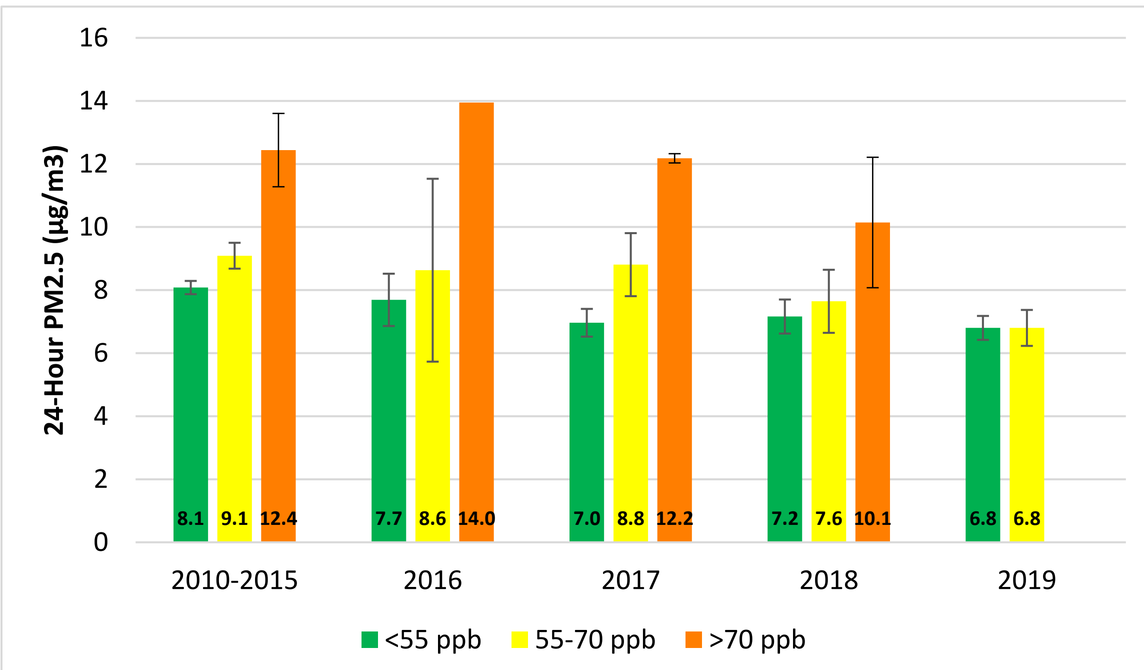
5 Correlation between MDA8 O_3 and Other Criteria Pollutants

CAPCOG's 2010-2015 Conceptual Model indicated that there were significant, statistical, positive correlations between MDA8 O_3 values and other pollutants. Therefore, this section includes an analysis of the 2019 data compared to 2010-2018. For this analysis, CAPCOG only analyzed the data for CAMS 3, since it includes analyzers for all three of the pollutants analyzed in the Conceptual Model – $PM_{2.5}$, NO_2, and SO_2.

5.1 $PM_{2.5}$

CAPCOG calculated the average 24-hour $PM_{2.5}$ concentrations when the MDA8 O_3 values at CAMS 3 were >70 ppb, 55-70 ppb, and <55 ppb. The following figure shows a comparison of these data. Since CAMS 3 did not measure MDA8 O_3 >70 ppb in 2019, that interval is not included on the figure.

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

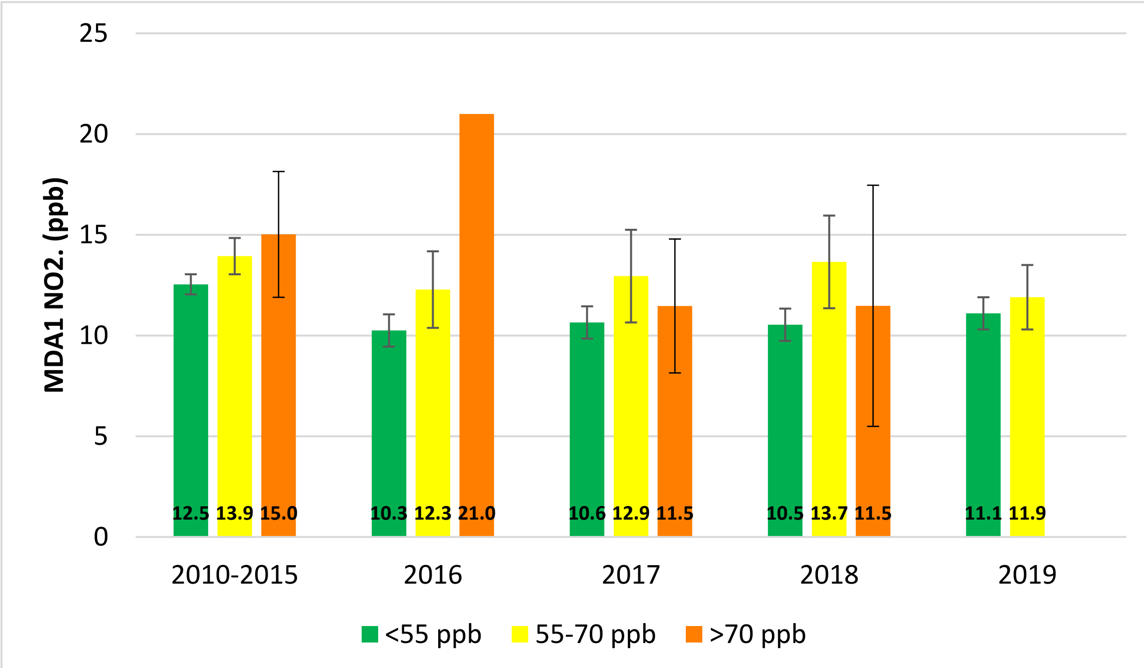


$PM_{2.5}$ concentrations at CAMS 3 in 2019 were lower than any previous timeframe, but 2019's 24-hour $PM_{2.5}$ was within the confidence interval for 2016-2018. As the conceptual model indicates, MDA8 O_3 and $PM_{2.5}$ have a positive relationship, so low $PM_{2.5}$ correlates with the low O_3 concentrations measured in 2019.

5.2 NO_2

CAPCOG calculated the average maximum daily 1-hour (MDA1) NO_2 concentrations when the MDA8 O_3 values at CAMS 3 were >70 ppb, 55-70 ppb, and <55 ppb. The following figure shows a comparison of these data. Since CAMS 3 did not measure MDA8 O_3 >70 ppb in 2019, that interval is not included on the figure.

Figure 5-2. 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

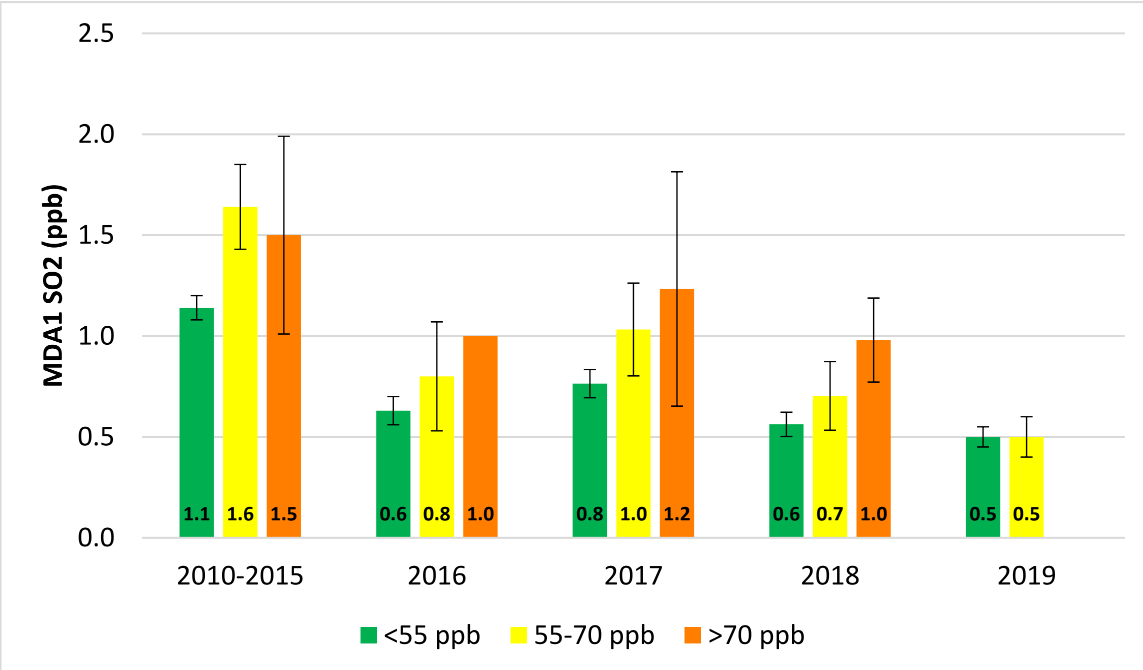


MDA1 NO_2 concentrations in 2019 continued a trend from 2018 where the relationship with MDA8 O_3 is not consistent or strong enough to show that high MDA1 NO_2 concentrations are significantly correlated with high MDA8 O_3 concentrations in the region.

5.3 SO_2

CAPCOG calculated the average MDA1 SO_2 concentrations when the MDA8 O_3 values at CAMS 3 were >70 ppb, 55-70 ppb, and <55 ppb. The following figure shows a comparison of these data. Since CAMS 3 did not measure MDA8 O_3 >70 ppb in 2019, that interval is not included on the figure.

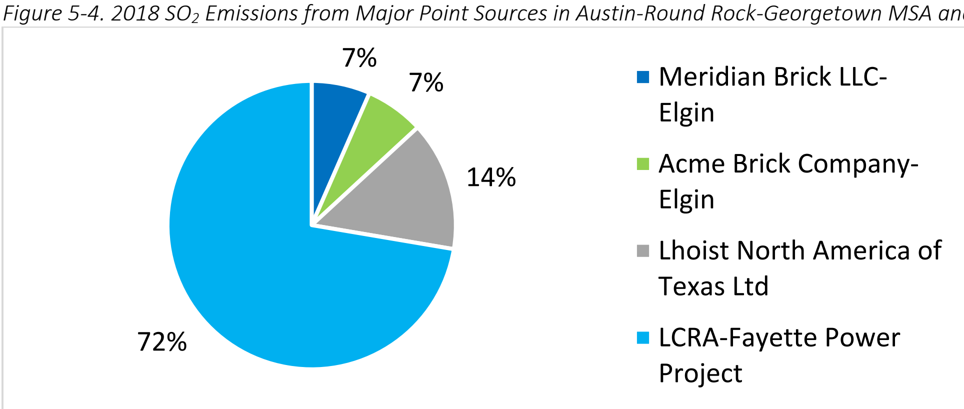
Figure 5-3. Typical MDA1 SO_2 Concentrations at CAMS 3 on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 3, 2010- 2019



In 2019, SO_2 concentrations were lower than the other analysis years. The 2019 MDA1 SO_2 levels and the relationship with MDA8 O_3 did not show the trend that was seen from 2016-2018, which is that higher MDA1 SO_2 concentrations correlate with higher MDA8 O_3 levels.

The following figure shows the major sources of point source SO_2 emissions (>100 tpy) within the Austin-Round Rock-Georgetown MSA and adjacent counties (Comal and Fayette) from TCEQ's point source emissions inventory summary for 2018 (the most recent year for which a comprehensive point source emissions inventory is available for all facilities).[8] Since the closure of the Sandow coal power plant in Milam County in 2018, the region has seen lower SO_2 levels. In 2019, Gibbons Creek Power Plant in Grimes County, east of the region, also ceased operations, which may contribute to the lower SO_2 concentrations within the region.

Figure 5-4. 2018 SO_2 Emissions from Major Point Sources in Austin-Round Rock-Georgetown MSA and Adjacent Counties



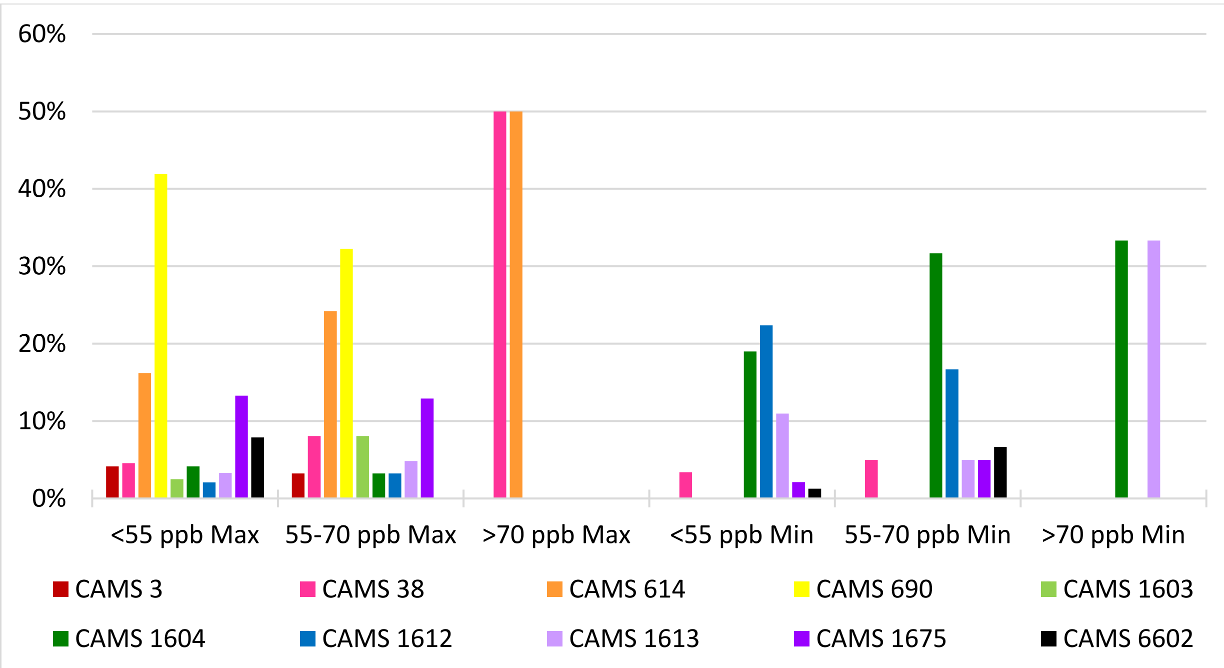
[8] https://www.tceq.texas.gov/assets/public/implementation/air/ie/pseisums/2014_2018statesum.xlsx

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 2019.

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, 2019 – November 15, 2019. 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 2019



A few significant notes about this figure:

- There were two days in which three CAMS recorded MDA8 O_3 >70 ppb; TCEQ's CAMS 38 and CAPCOG's CAMS 614 recorded the 2 highest values.
- For days when MDA8 O_3 was 55-70 ppb and <55 ppb, CAPCOG's CAMS 690 most frequently recorded the region-wide maximum.
- For days when MDA8 O_3 was 55-70 ppb and <55 ppb, CAPCOG's CAMS 1604 and CAMS 1613 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 2010-2019.

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

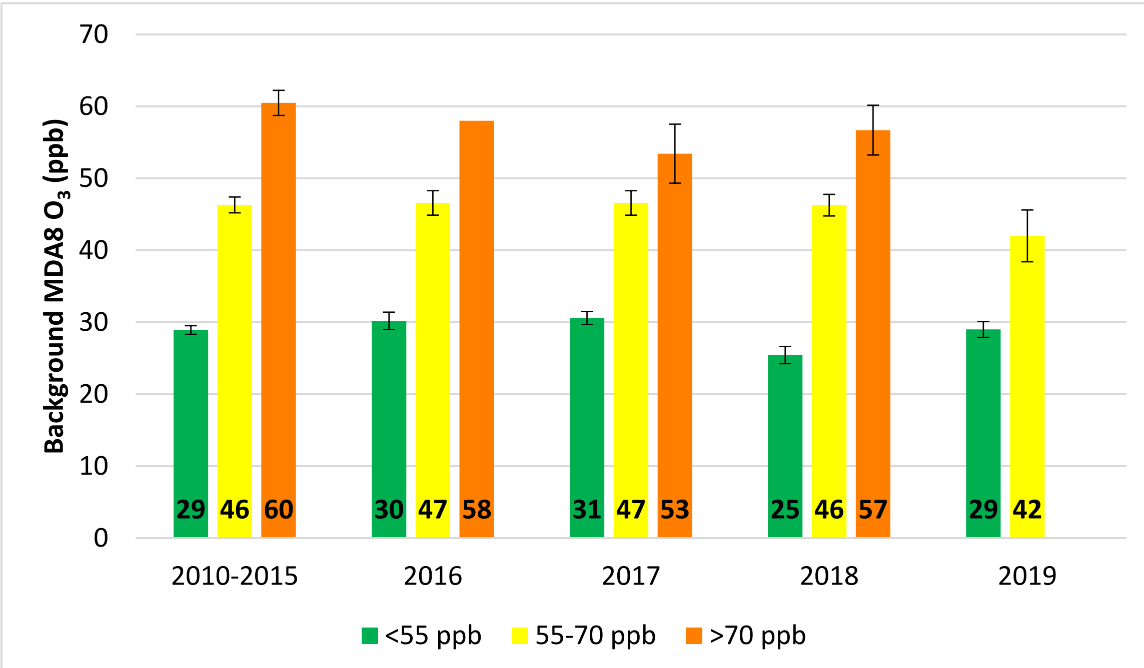
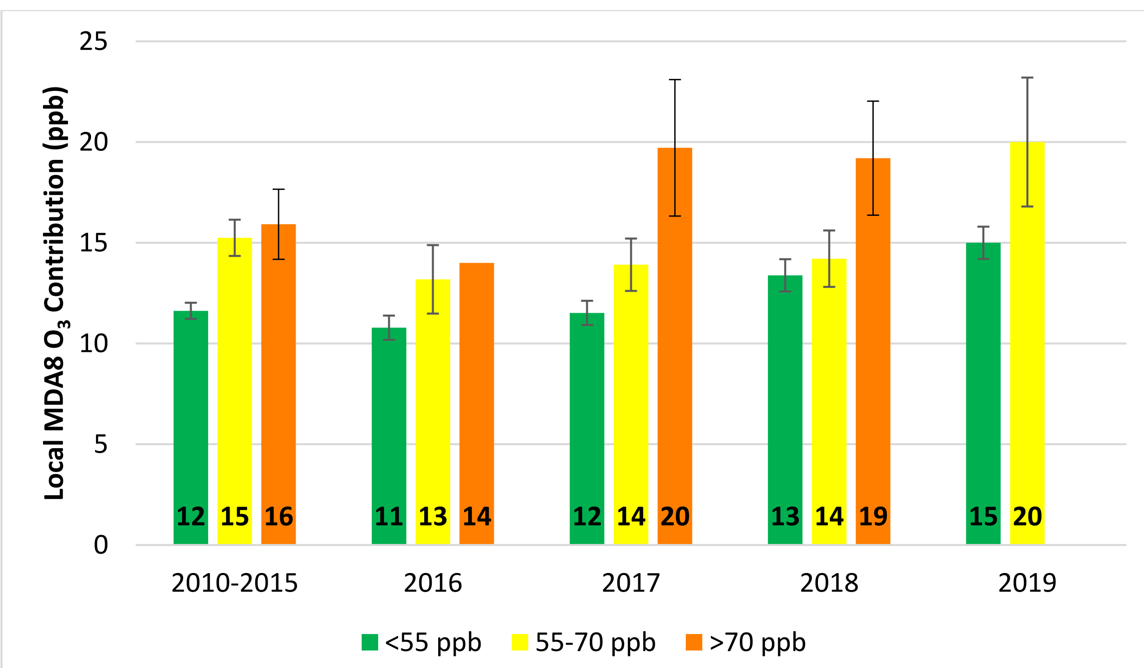


Figure 6-3. Comparison of Local Contribution to MDA8 O_3 on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 3, 2010-2019

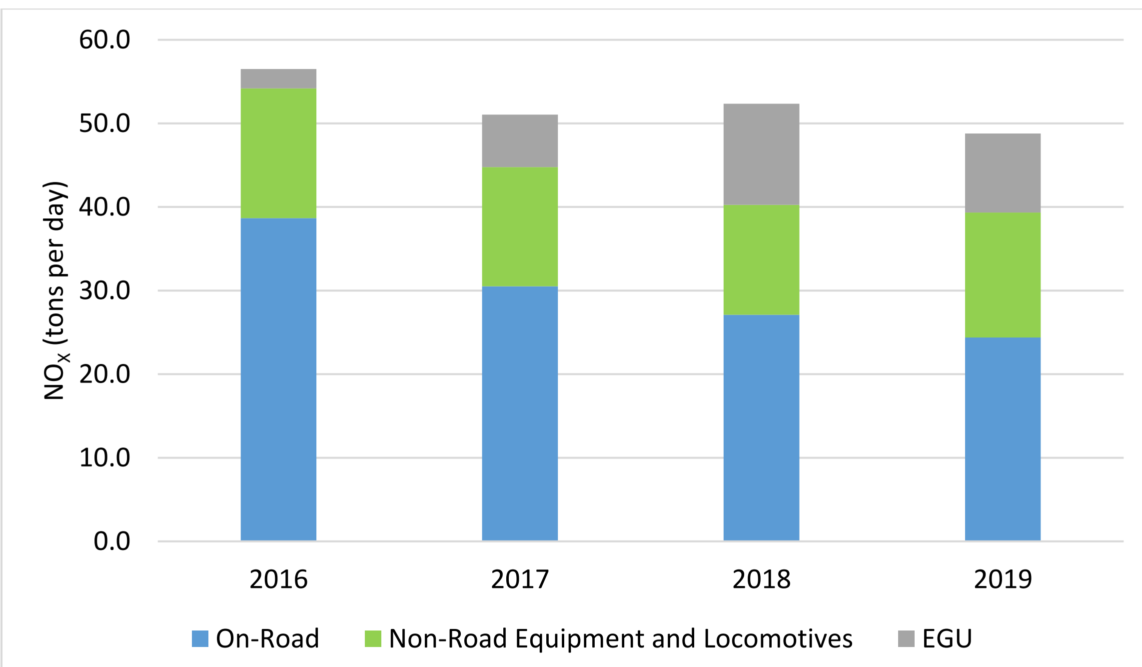


The graphs show that "background" levels in 2019 were equal to 2010-2015 MDA8 O_3 levels on days with <55 ppb. However, "background" levels in 2019 for days with MDA8 O_3 levels between 55-70 ppb were lower than 2010-2015 MDA8 O_3 levels. Local contributions were higher in 2019 compared to 2010-2015 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 2019 than they were in 2018. However, power plant NO_X emissions were much higher in 2019 than 2018. In 2019, this increase in NO_X from power plants actually appears to have been enough to push overall regional NO_X emissions higher on high O_3 days. Partially, this could explain some of the design value increase in O_3 from 2018 to 2019 due to the higher concentration of emissions from point sources compared to mobile sources. Note that on the figure below, only categories for which CAPCOG has OSD NO_X emissions estimates available for 2016, 2017, 2018, and 2019 are shown.

Figure 7-1. Summary of NO_X Emissions from On-Road, Non-Road, and EGU Point Source NO_X Emissions at top 4 days at CAMS 3 2016-2019



7.1 EGU Point Sources

2019 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.[9]

Figure 7-2. Average Daily May – September NO_X Emissions from EGU Point Sources in Austin-Round Rock-Georgetown MSA and Surrounding Counties, 2010-2019

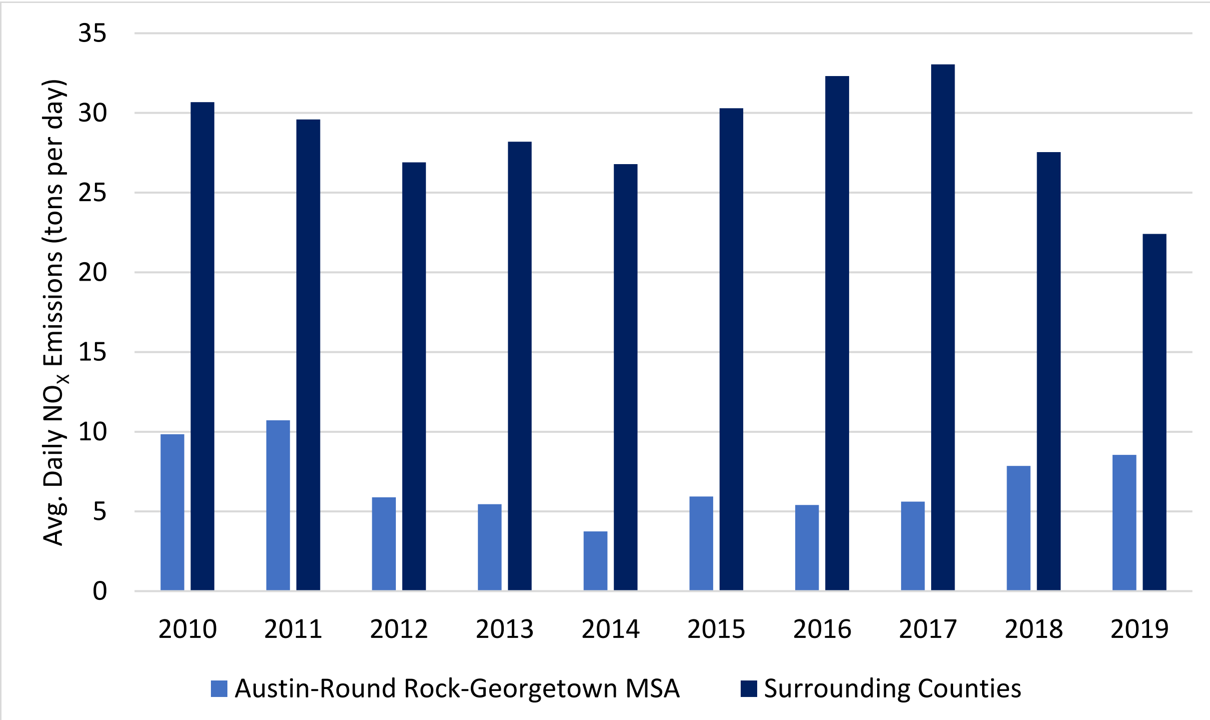
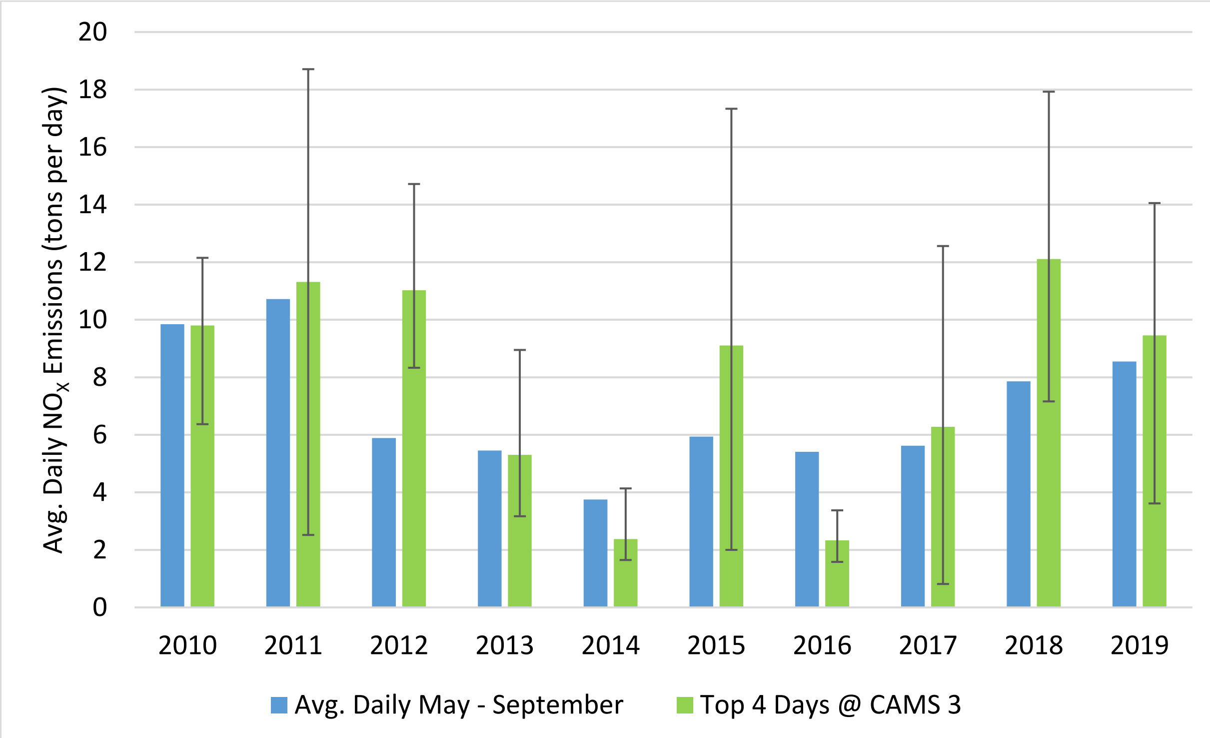


Figure 7-3 provides another perspective on the MSA's EGU emissions, comparing the standard "Ozone Season Day" emissions (considered to be May 1 – September 30) to the average emissions on the days when the top 4 MDA8 O_3 were recorded at CAMS 3 dating back to 2010.[10] The error bars represent the range of values above and below the averages recorded among the top 4 MDA8 O_3 values for each year. As these figures show, the MSA's EGU NO_X emissions tended to be higher on the top 4 days at CAMS 3 than the average from May 1 to September 30. As the error bars indicate, however, there is also often a wide range of total EGU NO_X emissions among the days with the top 4 MDA8 O_3 values each year. Looking at data just from 2018 to 2019, while average OSD NO_X emissions were higher, average NO_X emissions from the top 4 days was lower, which would have contributed to some extent to the lower 4^{th}-highest MDA8 O_3 value at CAMS 3 of 65 ppb in 2019 compared to 72 ppb in 2018.

[9] 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 the reflect worst case scenario emissions rates.

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



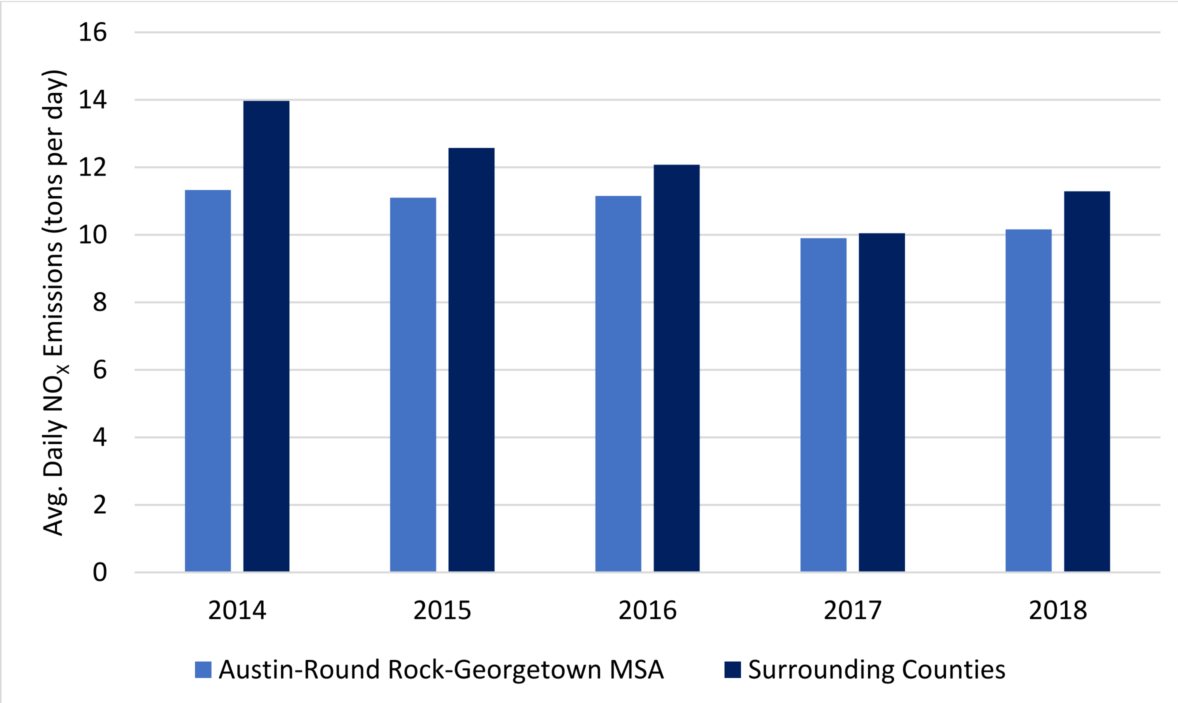
This increase in average daily NO_X emissions is due high emissions from the Sim Gideon Plant in Bastrop County. Sim Gideon is an older power plant that has been used to generate electricity during high demand periods. However, two power plants in nearby counties have changed operations in the past two years; the Sandow Power Plant in Milam County closed in 2018[11], and the Gibbons Creek Power Plant in Grimes County was not used in 2019[12], 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 Sim Gideon, picked up some of the load.

7.2 Non-EGU Point Sources

2019 non-EGU point source emissions data has not yet been posted online by TCEQ – that will likely happen in January 2021. 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 – 2018 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 (standard deviation of +/- 0.65 tpd), suggesting that 2019 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 (+/- 1.46 tpd), 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.

[11] https://www.bizjournals.com/austin/news/2017/10/16/central-texas-energy-plant-to-shut-down-as-part-of.html
[12] 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, 2014-2018[13]

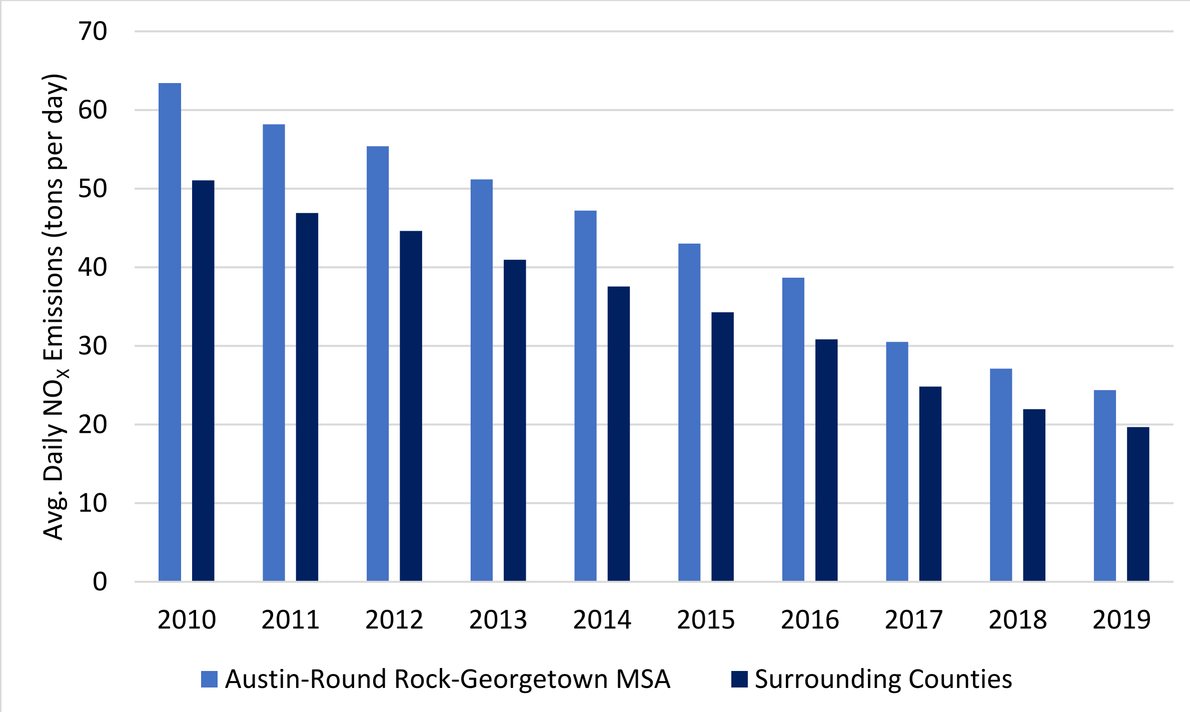


7.3 On-Road Mobile Sources

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 – 2019 NO_X trends inventory emissions estimates for the MSA and adjacent counties. As the figure shows, NO_X emissions decreased in the MSA by 3 tpd (approximately 10% from 2018-2019), and in adjacent counties by 2 tpd (also 10%).

[13] 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.

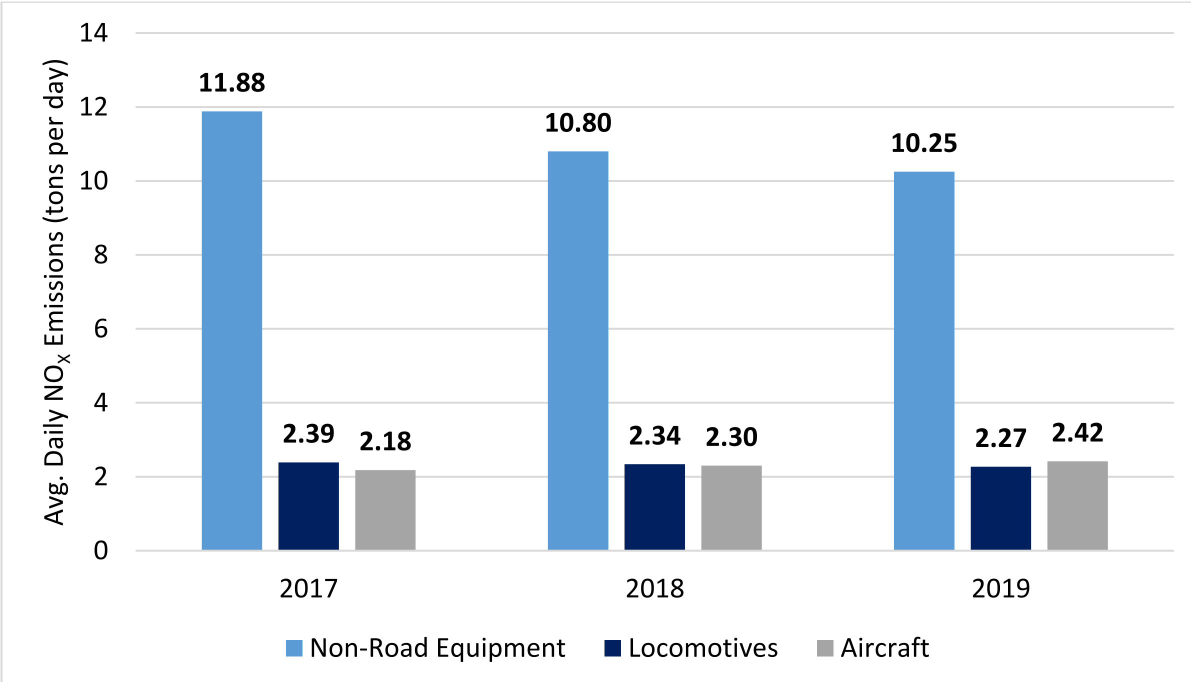
Figure 7-5. Average Summer Weekday NO_X Emissions from On-Road Sources in Austin-Round Rock-Georgetown MSA and Surrounding Counties, 2010-2019



7.4 Non-Road Mobile Sources

Mobile sources emissions from non-road equipment and locomotives are lower in 2019 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 0.50 tpd lower in 2019 than they were in 2018.

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



8 Conclusions

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 there were fewer number of days when MDA8 O_3 levels were >70 ppb than usual, there were significantly more days when MDA8 O_3 was > 55 ppb than in 2016-2018.
- While the 2019 O_3 levels were substantially lower than in 2018 or 2017, they would not be considered “outliers” based on year-to-year variation across the 2016 – 2018 period.
- One local meteorological factor stands out as a potential explanation for the lower O_3 observed in the MSA in 2019 compared to 2017 and 2018: more days with lower solar radiation, which was lower in 2019 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 actually *more* prevalent in 2019, including low wind speed and low relative humidity.
- The “transport” analysis suggests that the local contribution to O_3 was 20 ppb for days 55-70 ppb, which is similar to the average in 2018 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 CAMS 3 when MDA8 O_3 levels were >70 ppb.
- Similar to O_3, $PM_{2.5}$ levels at CAMS 3 were lower in 2019 than in 2010-2018. This is consistent with the previously noted correlations between O_3 and $PM_{2.5}$.
- NO_X emissions from on-road, non-road, and point source EGU sources within the MSA likely decreased from 2018 to 2019, contributing to the reduced O_3 concentrations.
- Overall, 2019 meteorological data trends were consistent with the relationship between MDA8 O_3 and weather conditions observed in 2010-2018.
- Observed wind speeds, peak temperatures, and temperature changes from 12 pm – 4 pm were consistent with observations in 2010-2018.
- Relative humidity from 12 pm – 4 pm was statistically significantly lower than levels observed in 2016, 2017, and 2018.

9 Appendix

Additional data collected for this analysis can be reviewed in the appendix including CAMS calibration data and monitor-by-monitor ozone and meteorological statistics. The appendix is an Excel workbook, which is included as a supplemental file to this report.