2018 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 2018 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 O3 monitoring stations and two National Weather Service (NWS) station in the MSA, comparing the 2018 data with CAPCOG's most recent O_3 "conceptual model," which evaluated data from 2010-2015[1], and similar reports that analyzed 2016 and 2017 monitoring data.

Some of the most noteworthy findings of this report include the following:

- Most of the increase in O_3 observed in 2018 compared to 2017 and 2016 is likely attributable to more days with high temperatures (>90 deg. F) and fewer days with high humidity (>40%).
- Some of the increase in O_3 since 2016 may be attributable to increases in local power plant nitrogen oxides (NO_X) emissions.
- The areas to the southwest of the MSA were by far the most common upwind areas when O_3 was high in the region, similar to patterns observed in 2010-2017.
- Within the region, Williamson County was the least likely to be upwind of observed maximum daily 8-hour average (MDA8) O_3 values >70 ppb, while Hays County and Bastrop County were upwind of the region's key regulatory monitor on all of the days then 8-hour O_3 there reached > 70 ppb.
- The timing of high O_3 in the region was unusual in the 2nd half of 2018, with far more days with 8-hour O_3 exceeding 70 parts per billion (ppb) in July than had occurred during the entire prior 8-year period, with O_3 levels not even reaching "moderate" levels after early August.

This report includes:

- General summaries of O_3 data in the region from 2018 compared to 2010-2015, 2016 and 2017 (Section 2);
- Analysis of the temporal profiles and features of O_3 pollution in the region in 2018 compared to 2010-2015, 2016 and 2017 (Section 3);
- Investigations of potential relationships between meteorology and O_3 pollution in 2018 compared to 2010-2015, 2016 and 2017 (Section 4);
- Analysis of correlations between O_3 pollution and ambient $PM_{2.5}$, NO_2, and SO_2 concentrations in 2018 compared to 2010-2015, 2016 and 2017 (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 2018 compared to 2010-2015, 2016 and 2017 (Section 6); and
- Analysis of the potential changes in NO_X emissions between 2010-2018 that could explain the increase in the O_3 levels observed within the region in 2018 compared to 2016 and 2017 (Section 7).
- Conclusion (Section 8) and Appendices (Section 9).

[1] http://www.capcog.org/documents/airquality/reports/2016/Deliverable_3.2-CAPCOG_Ozone_Conceptual_Model_2016.pdf

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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

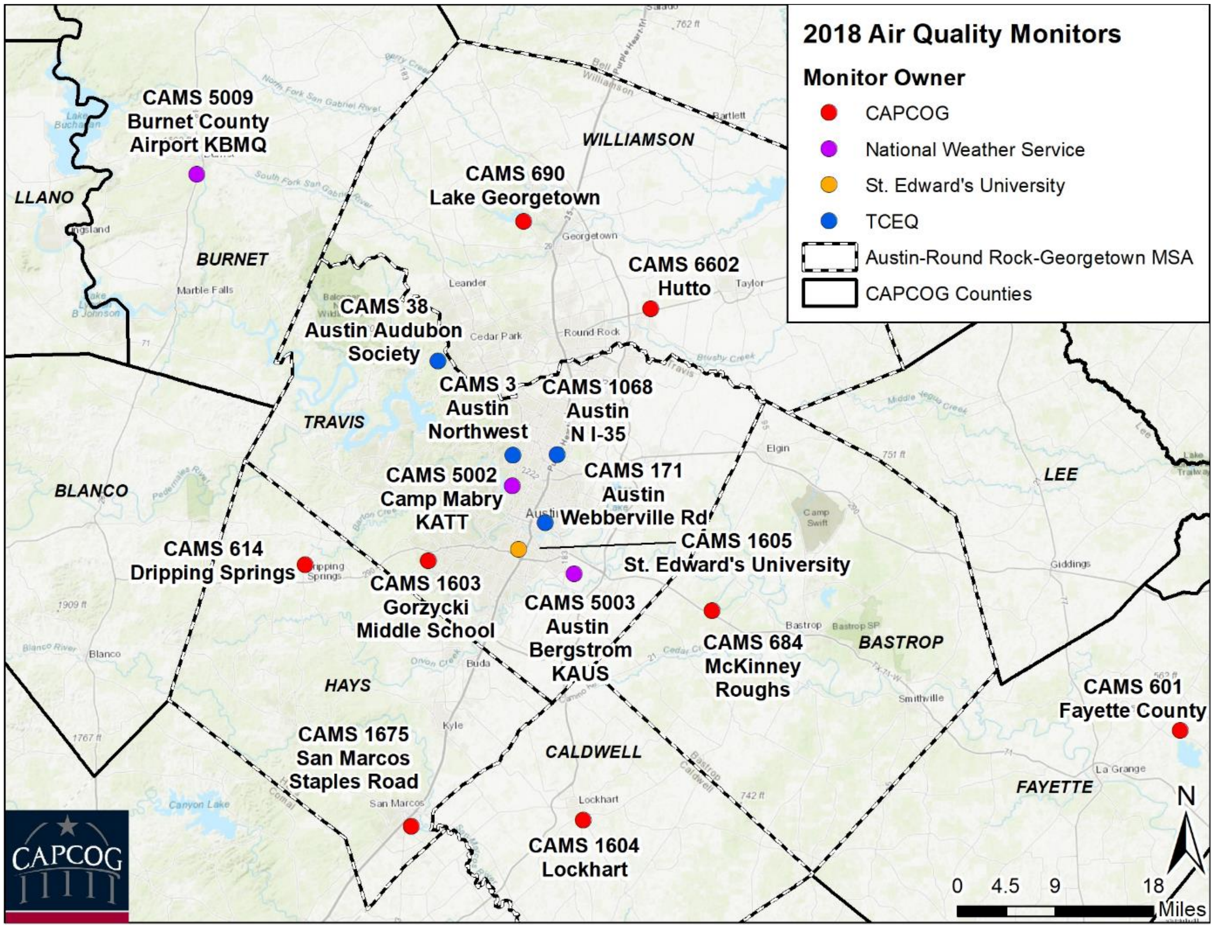
The purpose of this project is to analyze 2018 ambient air monitoring data collected in the Austin-Round Rock-Georgetown Metropolitan Statistical Area (MSA) that consists of Bastrop, Caldwell, Hays, Travis, and Williamson Counties, including comparing it with data from prior years dating back to 2010.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

- Blue circles are Texas Commission on Environmental Quality (TCEQ) stations that collected regulatory air pollution and meteorological data in 2018.
  - CAMS 3 collected hourly O_3, 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 and particulate matter smaller than 10 micrometers (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.
- 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. 2018 Air Quality Monitors in the Austin-Round Rock-Georgetown MSA and CAPCOG Counties

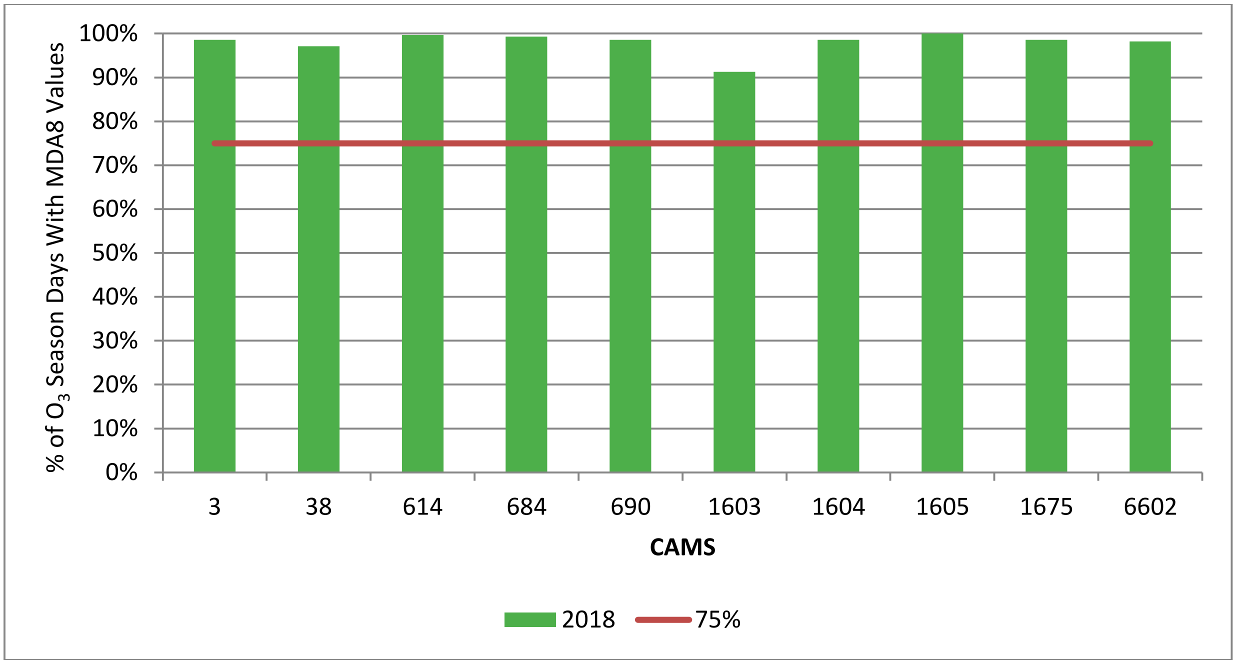


TCEQ's monitoring stations are "regulatory" because they equipped with Federal Reference Method (FRM) monitoring equipment in accordance with federal regulations, and are therefore used as the basis for assessing the region's compliance with the National Ambient Air Quality Standards (NAAQS). CAPCOG's monitoring stations are "non-regulatory" because they are not FRM or 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

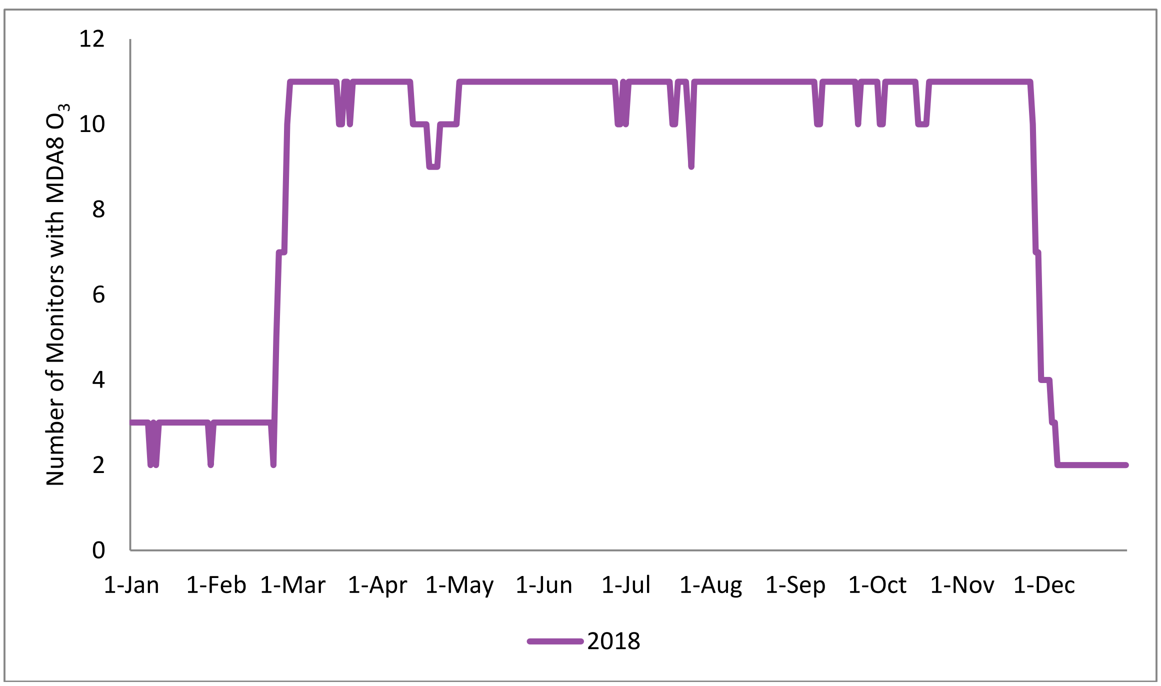
In order to provide perspective on the overall availability of maximum daily 8-hour average (MDA8) O_3 values for analysis, the following figure shows the percentage of O_3 season MDA8 values available for each monitoring station in 2018. TCEQ's two O_3 monitors collected data year-round, the eight CAPCOG 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 in a 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 values available each year during these 275 days. EPA's regulations require at least 75% data completeness statistics for O_3 data to be considered valid.

Figure 1-2. CAMS MDA8 O_3 Value Data Completeness for the 2018 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 2018.

Figure 1-3. Number of Monitors with Recorded MDA8 O_3 Values by Date in 2018



1.3 Attainment Status

The two FRM O_3 monitors in the region (CAMS 3 and 38) have official 3-year O_3 design values of 0.068 parts per million (ppm) at CAMS 3 and 0.066 ppm at CAMS 38, meaning that they that are attaining the 2015 O_3NAAQS of 0.070 ppm. The research monitors that CAPCOG operates are not FRM stations and therefore are not used to establish the region's compliance with the NAAQS. However, their data can indicate if there are O_3 problems that are not getting picked up by TCEQ's FRM monitors. CAMS 3 had the highest 3-year average of its 4th highest MDA8 in the region (0.068 ppm) among all monitors in the region. Among the research monitors, CAMS 614 had the highest 3-year average of its 4th highest MDA8 (0.067 ppm) which continues a trend from 2017.

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:

- There were statistically significant differences in high MDA8 O_3 (>70 ppb) formation in the Austin-Round Rock-Georgetown MSA compared to high O_3 formation in Fayette County.
- 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 with a much wider range of values for Fayette County.
- 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 2018 similar to the conditions that were typical of high O_3 levels in 2010-2015, 2016, and 2017?
- Did factors that lead to high MDA8 O_3 levels in the region between 2010-2015, in 2016, and in 2017 occur with any greater or less frequency in 2018?

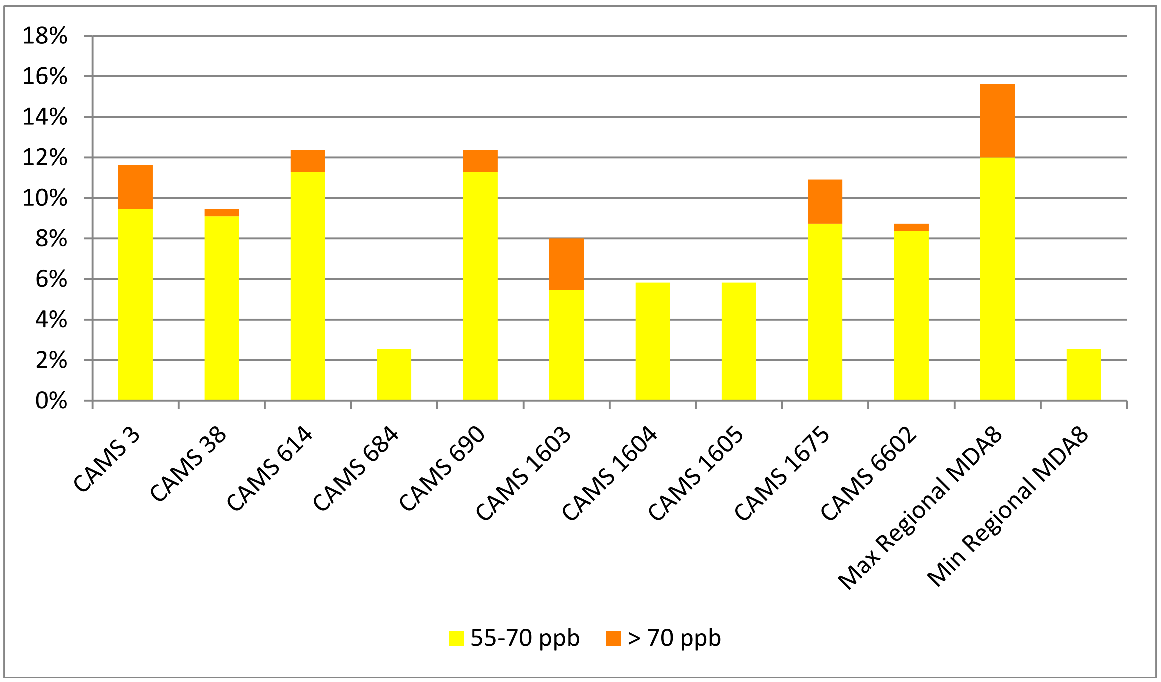
2 Analysis of Daily Maximum 8-Hour O_3 Data and Seasonal O_3 Exposure

This section provides general data on the MDA8 levels measured in the region in 2018. This includes analysis of days when MDA8 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" or "unhealthy for sensitive groups" (85-105 ppb and 71-85 ppb, respectively), "moderate" (55-70 ppb), and "good" (<55 ppb). Data is analyzed both monitor-by-monitor and region-wide. For regional analysis, the highest MDA8 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 values that were 55-70 ppb, and >70 ppb for each monitoring station and region-wide during the official O_3 season in 2018 (March-November). These ranges correspond to levels considered "moderate" and "unhealthy for sensitive groups" on EPA's AQI for O_3. The highest MDA8 value recorded in the region was 84 ppb, meaning there were no days considered "unhealthy" for the general population. There were 10 days in 2018 with MDA8 levels measured above 70 ppb. MDA8 was measured at 55 ppb or above on 15% of days in O_3 season.

Figure 2-1. Percentage of O3 season days when monitored MDA8 was 55-70 ppb or > 70 ppb, 2018



The following tables provide more detailed data on the number of days that each monitor measured MDA8 values >70 ppb, 55-70 ppb, and <55 ppb in each year from 2010-2018. 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, 2010-2018

CAMS	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
3	8	13	6	1	0	8	1	3	6	46
38	3	6	6	3	0	7	0	1	1	27
614	4	9	6	0	0	5	0	1	3	28

CAMS	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
684	0	5	4	0	0	1	0	0	0	10
690	1	6	8	9	0	5	0	3	3	35
1603	n/a	n/a	n/a	n/a	0	6	0	0	7	13
1604	n/a	n/a	n/a	n/a	0	0	0	2	0	2
1605	n/a	n/a	n/a	n/a	n/a	n/a	0	0	0	0
1675	n/a	2	6	3	0	3	0	0	6	20
6602	n/a	13	0	1	0	4	0	0	1	19
Region-Wide	**11**	**20**	**12**	**10**	**0**	**12**	**1**	**7**	**10**	**83**

Table 2-2. Days with MDA8 O_3 55-70 ppb by monitoring station and year, 2010-2018

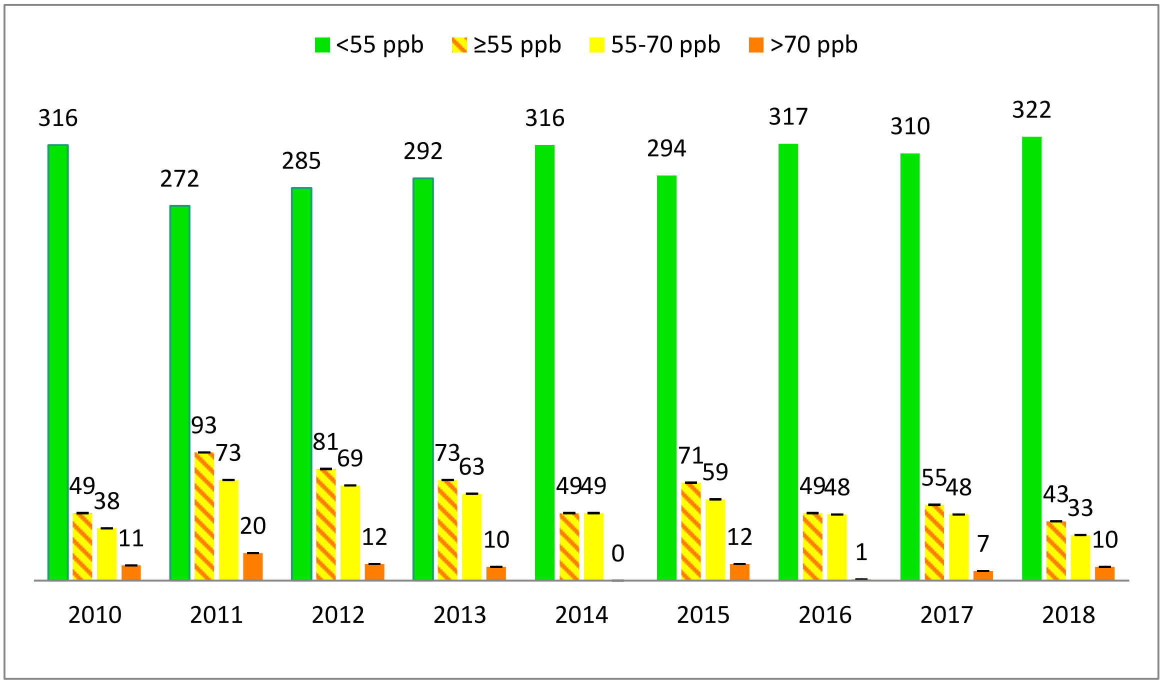
CAMS	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
3	32	57	45	49	28	49	34	31	26	351
38	30	65	54	44	36	47	28	32	25	361
614	26	69	38	19	24	45	22	25	31	274
684	23	54	42	24	2	32	8	8	7	200
690	17	64	43	45	29	40	20	41	31	330
1603	n/a	n/a	n/a	n/a	8	44	23	15	15	105
1604	n/a	n/a	n/a	n/a	21	31	23	34	16	125
1605	n/a	n/a	n/a	n/a	n/a	n/a	2	12	16	30
1675	n/a	16	41	28	17	41	16	23	24	206
6602	n/a	41	31	38	0	34	15	27	23	209
Region-Wide	**38**	**73**	**69**	**63**	**49**	**59**	**48**	**48**	**33**	**480**

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	Total
3	316	267	298	310	329	302	329	323	327	2,801
38	326	286	297	300	315	296	334	323	331	2,807
614	152	138	164	178	170	188	243	233	245	1,466
684	169	149	166	191	198	219	266	254	267	1,879
690	179	136	145	158	177	198	250	219	241	1,704
1603	n/a	n/a	n/a	n/a	155	204	239	244	230	1072
1604	n/a	n/a	n/a	n/a	163	217	240	219	257	1096
1605	n/a	n/a	n/a	n/a	n/a	n/a	318	295	322	935
1675	n/a	26	168	184	176	205	250	227	247	1,483
6602	n/a	117	168	174	0	164	257	211	250	1,342
Region-Wide	**316**	**272**	**285**	**292**	**316**	**294**	**317**	**310**	**322**	**2,724**

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 2018, there were fewer days when MDA8 O_3 levels were 55 ppb or higher than in 2017, but more of these days resulted in MDA8 O_3 levels >70 ppb.

2.2 Average of 4th Highest MDA8 O_3 in 2018

Compliance with the 2015 O_3 NAAQS is based on the average of the yearly 4th high MDA8 values over three years. EPA's modeling guidance recommends the use of the top 10 modeled MDA8 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 values. Therefore, the following tables present the top 10 days measured at each monitoring station 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 2018 values were lower than, higher than, or within the 95% confidence intervals (C.I.) for 2010-2012, 2013-2015, 2014-2016, and 2015-2017.

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

Rank	2010	2011	2012	2013	2014	2015	2016	2017	2018	2018 in C.I. for 2010-2012	2018 in C.I. for 2013-2015	2018 in C.I. for 2014-2016	2018 in C.I. for 2015-2017
1	77	82	94	79	69	85	72	71	75	Yes	Yes	Yes	Yes
2	76	79	87	70	65	83	67	71	74	Low	Yes	Yes	Yes
3	75	78	80	69	63	82	66	71	72	Low	Yes	Yes	Yes
4	74	75	74	69	62	73	64	70	72	Low	Yes	Yes	Yes
5	73	75	73	68	62	73	64	69	71	Low	Yes	Yes	Yes
6	72	74	71	68	62	73	63	68	71	Yes	Yes	Yes	Yes
7	72	74	68	67	61	72	63	67	70	Yes	Yes	Yes	Yes
8	71	74	68	67	61	71	62	67	69	Yes	Yes	Yes	Yes
9	69	73	67	66	61	70	62	64	66	Low	Yes	Yes	Yes
10	68	73	67	65	60	69	61	63	66	Yes	Yes	Yes	Yes
Avg. Top 4	75.5	78.5	83.8	71.8	64.8	80.8	67.3	70.8	73.25	Low	Yes	Yes	Yes
Avg. Top 10	72.7	75.7	74.9	68.8	62.6	75.1	64.4	68.1	70.6	Low	Yes	Yes	Yes

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

Rank	2010	2011	2012	2013	2014	2015	2016	2017	2018	2018 in C.I. for 2010-2012	2018 in C.I. for 2013-2015	2018 in C.I. for 2014-2016	2018 in C.I. for 2015-2017
1	76	78	80	74	68	82	69	73	74	Low	Yes	Yes	Yes
2	72	76	78	73	63	81	65	68	70	Low	Yes	Yes	Yes
3	71	73	78	72	63	80	64	67	70	Yes	Yes	Yes	Yes
4	70	73	76	70	63	73	62	67	70	Yes	Yes	Yes	Yes
5	69	71	74	68	63	71	61	66	69	Yes	Yes	Yes	Yes
6	68	71	72	68	62	71	61	66	67	Low	Yes	Yes	Yes
7	66	69	70	68	62	71	61	65	66	Yes	Yes	Yes	Yes
8	65	69	70	68	62	69	60	63	66	Yes	Yes	Yes	Yes
9	65	68	69	67	61	68	60	63	65	Yes	Yes	Yes	Yes
10	64	68	69	66	61	67	60	63	64	Low	Yes	Yes	Yes
Avg. Top 4	72.3	75	78	72.3	64.3	79	65	68.8	71	Low	Yes	Yes	Yes
Avg. Top 10	68.6	71.6	73.6	69.4	62.8	73.3	62.3	66.1	68.1	Low	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	2018 in C.I. for 2010-2012	2018 in C.I. for 2013-2015	2018 in C.I. for 2014-2016	2018 in C.I. for 2015-2017
1	80	86	77	69	70	79	66	72	77	Yes	Yes	Yes	Yes
2	78	83	76	69	64	76	66	68	71	Low	Yes	Yes	Yes
3	73	79	73	68	63	72	66	67	71	Low	Yes	Yes	Yes
4	72	77	73	67	63	71	65	67	69	Low	Yes	Yes	Yes
5	70	77	73	64	62	71	64	66	69	Low	Yes	Yes	Yes
6	70	76	71	64	61	70	63	66	68	Low	Yes	Yes	Yes
7	69	74	70	62	61	70	61	65	68	Low	Yes	Yes	Yes
8	67	71	70	62	61	69	61	63	66	Low	Yes	Yes	Yes
9	66	71	68	62	61	69	61	62	65	Low	Yes	Yes	Yes
10	64	70	68	59	61	68	59	62	65	Yes	Yes	Yes	Yes
Avg. Top 4	75.8	81.3	74.8	68.3	65	74.5	65.8	68.5	72	Low	Yes	Yes	Yes
Avg. Top 10	70.9	76.4	71.9	64.6	62.7	71.5	63.2	65.8	68.9	Low	Yes	Yes	Yes

Table 2-7. CAMS 684 top 10 measured MDA8 O_3 values by year

Rank	2010	2011	2012	2013	2014	2015	2016	2017	2018	2018 in C.I. for 2010-2012	2018 in C.I. for 2013-2015	2018 in C.I. for 2014-2016	2018 in C.I. for 2015-2017
1	68	81	80	68	58	73	64	62	67	Low	Yes	Yes	Yes
2	67	76	75	66	55	69	62	60	66	Low	Yes	Yes	Yes
3	67	75	72	65	53	69	59	59	65	Low	Yes	Yes	Yes
4	66	72	71	64	53	69	59	57	60	Low	Yes	Yes	Yes
5	65	71	68	63	52	67	56	56	60	Low	Yes	Yes	Yes
6	65	70	66	63	51	63	56	56	60	Low	Yes	Yes	Yes
7	64	70	66	62	51	63	56	55	57	Low	Yes	Yes	Yes
8	64	69	65	60	50	63	56	55	54	Low	Yes	Yes	Yes
9	61	68	65	60	49	63	54	54	53	Low	Yes	Yes	Yes
10	61	68	64	60	49	62	53	53	52	Low	Yes	Yes	Yes
Avg. Top 4	67	76	74.5	65.8	54.8	70	61	59.5	64.5	Low	Yes	Yes	Yes
Avg. Top 10	64.8	72	69.2	63.1	52.1	66.1	57.5	56.7	59.4	Low	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	2018 in C.I. for 2010-2012	2018 in C.I. for 2013-2015	2018 in C.I. for 2014-2016	2018 in C.I. for 2015-2017
1	71	79	81	89	70	83	70	75	77	Yes	Yes	Yes	Yes
2	70	79	81	79	69	79	68	73	73	Yes	Yes	Yes	Yes
3	66	77	78	78	66	78	66	73	73	Yes	Yes	Yes	Yes
4	65	73	73	75	66	75	61	70	69	Yes	Yes	Yes	Yes
5	65	71	73	74	65	73	60	69	69	Yes	Yes	Yes	Yes
6	65	71	71	73	63	67	60	68	67	Yes	Yes	Yes	Yes
7	64	70	71	72	62	66	60	67	67	Yes	Yes	High	Yes
8	62	70	71	71	62	65	59	67	66	Yes	Yes	High	Yes
9	61	69	69	71	62	65	58	67	65	Yes	Yes	Yes	Yes
10	59	69	69	70	61	64	58	66	63	Yes	Yes	Yes	Yes
Avg. Top 4	68	77	78.3	80.3	67.8	78.8	66.3	72.8	73	Yes	Yes	Yes	Yes
Avg. Top 10	64.8	72.8	73.7	75.2	64.6	71.5	62	69.5	68.9	Yes	Yes	Yes	Yes

Table 2-9. CAMS 1603 top 10 measured MDA8 O_3 values by year

Rank	2014	2015	2016	2017	2018	2018 in C.I. for 2014-2016	2018 in C.I. for 2015-2017
1	63	76	64	62	82	High	High
2	59	72	64	60	80	High	High
3	58	72	63	60	74	High	High
4	57	72	63	59	73	High	High
5	57	72	63	59	72	Yes	Yes
6	56	72	62	58	72	Yes	Yes
7	56	69	62	58	71	High	High
8	55	69	61	58	66	Yes	Yes
9	54	68	61	58	66	Yes	Yes
10	53	67	61	57	63	Yes	Yes
Avg. Top 4	59.3	73	63.5	60.3	77.25	High	High
Avg. Top 10	56.8	70.9	62.4	58.9	71.9	High	High

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

Rank	2014	2015	2016	2017	2018	2018 in C.I. for 2014-2016	2018 in C.I. for 2015-2017
1	66	69	63	74	68	Yes	Yes
2	65	68	62	74	67	Yes	Yes
3	64	67	62	70	66	Yes	Yes
4	64	67	60	67	66	Yes	Yes
5	61	65	59	65	65	Yes	Yes
6	61	64	59	64	64	Yes	Yes
7	61	64	59	64	64	Yes	Yes
8	60	63	58	64	63	Yes	Yes
9	60	63	57	63	63	Yes	Yes
10	59	63	57	63	61	Yes	Yes
Avg. Top 4	64.8	67.8	61.75	71.3	66.75	Yes	Yes
Avg. Top 10	62.1	65.3	59.6	66.8	64.7	Yes	Yes

Table 2-11. CAMS 1605 top 10 measured MDA8 O_3 values by year

Rank	2016	2017	2018
1	56	66	70
2	56	64	70
3	53	62	66
4	52	61	66
5	52	60	64
6	51	59	64
7	51	58	64
8	51	57	64
9	51	56	63
10	50	55	63
Avg. Top 4	54.25	63.3	68
Avg. Top 10	52.3	59.8	65.4

Table 2-12. CAMS 675/1675 top 10 measured MDA8 O_3 values by year

Rank	2010	2011	2012	2013	2014	2015	2016	2017	2018	2018 in C.I. for 2010-2012	2018 in C.I. for 2013-2015	2018 in C.I. for 2014-2016	2018 in C.I. for 2015-2017
1	72	86	81	82	68	76	65	69	84	Yes	High	High	High
2	71	82	75	74	65	73	64	67	82	Yes	High	High	High
3	69	79	74	72	62	73	63	66	76	Yes	High	High	High
4	68	78	72	70	61	70	62	63	74	Yes	High	High	High
5	67	77	72	69	61	70	61	62	72	Yes	Yes	High	High
6	67	75	71	67	61	69	60	61	72	Yes	High	High	High
7	67	75	70	67	60	67	60	61	70	Yes	High	High	High
8	64	73	69	66	60	67	60	60	69	Yes	High	High	High
9	64	72	69	66	60	66	59	60	68	Yes	High	High	High
10	64	72	68	65	59	66	59	60	66	Yes	Yes	High	High
Avg. Top 4	70	81.3	75.5	74.5	64	73	63.5	66.3	79	Yes	High	High	High
Avg. Top 10	67.3	86	72.1	69.8	61.7	69.7	61.3	62.9	73.3	Yes	High	High	High

Table 2-13. CAMS 6602 top 10 measured MDA8 O_3 values by year

Rank	2011	2012	2013	2014	2015	2016	2017	2018	2018 in C.I. for 2010-2012	2018 in C.I. for 2013-2015	2018 in C.I. for 2014-2016	2018 in C.I. for 2015-2017
1	80	70	77	n/a	77	62	68	71	Yes	Yes	Yes	Yes
2	80	70	70	n/a	75	59	67	70	Yes	Yes	Yes	Yes
3	79	69	70	n/a	72	58	66	68	Yes	Yes	Yes	Yes
4	75	69	69	n/a	71	58	65	68	Yes	Yes	Yes	Yes
5	74	69	65	n/a	70	58	63	66	Yes	Yes	Yes	Yes
6	72	67	64	n/a	69	57	63	65	Yes	Yes	Yes	Yes
7	72	66	63	n/a	68	57	62	65	Yes	Yes	Yes	Yes
8	72	64	63	n/a	65	57	62	63	Yes	Yes	Yes	Yes
9	71	64	63	n/a	64	56	61	62	Yes	Yes	Yes	Yes
10	71	63	63	n/a	62	56	60	61	Yes	Yes	Yes	Yes
Avg. Top 4	78.5	69.5	71.5	n/a	73.8	59.25	66.5	69.25	Yes	Yes	Yes	Yes
Avg. Top 10	74.6	67.1	66.7	n/a	69.3	57.8	63.7	65.9	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 values at all of the monitoring stations that had data used in this report for 2013 - 2018. Consistent with the data-handling conventions for the 2015 O_3 NAAQS, values beyond the units' digit are truncated.

Table 2-14. 4th-highest MDA8 values at Regional O_3 Monitors, 2013-2018 (ppb)

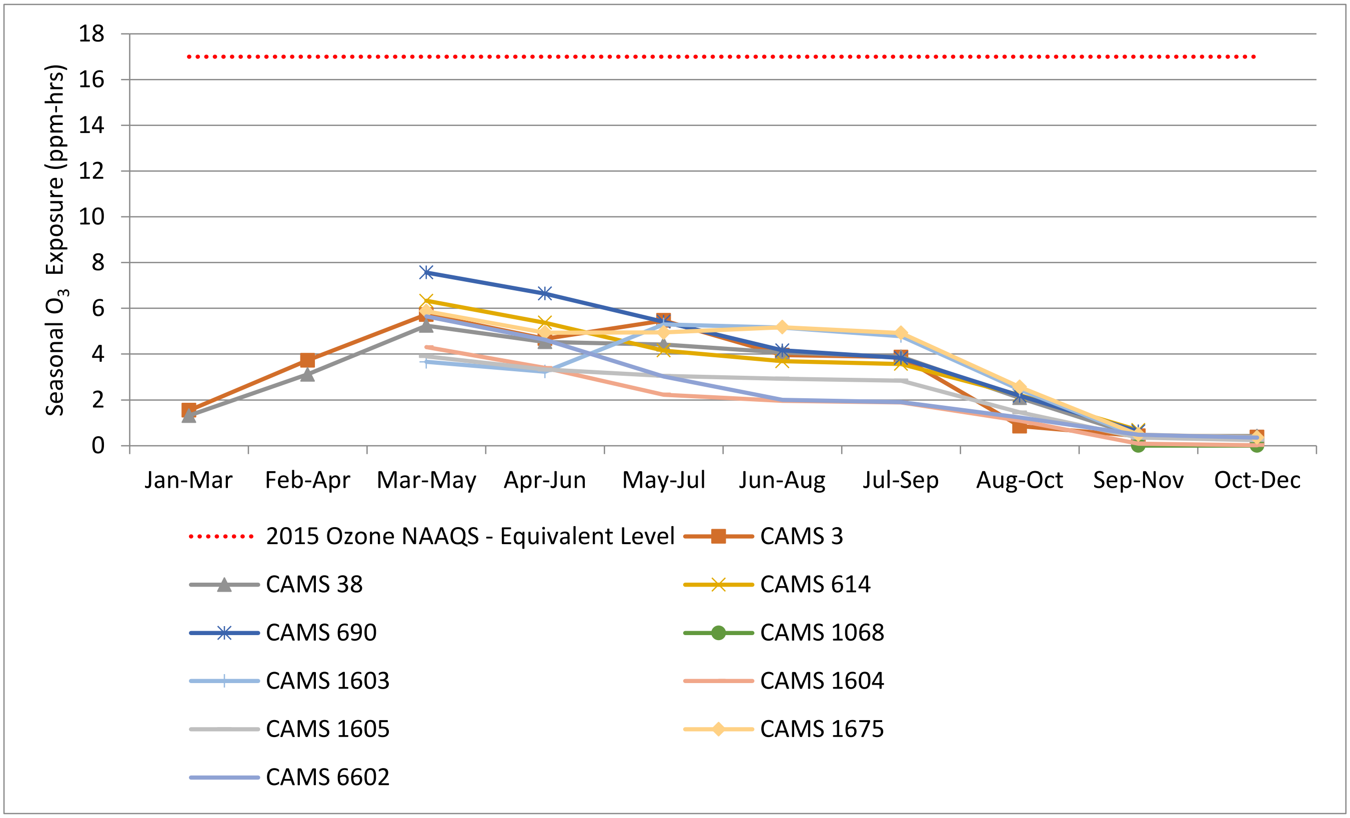
CAMS	2013	2014	2015	2016	2017	2018	2013-2015 Avg.	2014-2016 Avg.	2015-2017 Avg.	2016-2018 Avg.
3	69	62	73	64	70	72	68	66	69	68
38	70	63	73	62	67	70	68	66	67	66
614	67	63	71	65	67	60	67	66	68	64
684	64	53	69	59	57	69	62	60	62	61
690	75	66	75	61	70	73	72	67	69	68
1603	n/a	57	72	63	59	66	n/a	64	65	62
1604	n/a	64	67	60	67	66	n/a	63	65	64
1675	70	61	70	62	63	74	67	64	65	66
6602	69	n/a	71	58	65	68	n/a	n/a	65	63

As the table shows, CAMS 684 (McKinney Roughs) has the lowest three-year average from 2016-2018, which continues this monitor's trend of registering the lowest averages in the region. However, due to the proximity of trees to this monitoring station, which has since led CAPCOG to move this station, these values may be artificially low. CAMS 3 again had the highest three-year average from 2016-2018 at 68 ppb. Most O_3 monitors in the region averaged a lower three-year average from 2016-2018 than from 2015-2017. This is chiefly due to the high O_3 levels recorded in 2015 falling out of the three-year average, although O_3 levels in 2018 were actually higher than in 2017 or 2016. There is one research monitoring station operated by CAPCOG (CAMS 690) that had a three-year average >70 ppb from 2013-2015. However, the three-year average has since dropped below 70 ppb.

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." However, a recent U.S. Court of Appeals for the D.C. Circuit ruling strongly suggests that EPA is eventually going to need to establish a separate secondary NAAQS along the lines recommended by their Clean Air Scientific Advisory Committee (CASAC). 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 3-month seasonal exposure levels at each monitoring station by each 3-month period during the year.

Figure 2-3. Weighted Seasonal O_3 Exposure by Monitoring Station and 3-month period, 2018 (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, 2017, and 2018 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.

CAPCOG compared the 2018 data to the 2010-2015, 2016, and 2017 data in order to evaluate whether there was evidence that the temporal patterns MDA8 O_3 values in the region were different in 2018.

3.1 Earliest and Latest Dates for High O_3 in 2018

One of the key issues for CAPCOG to understand is when are the earliest and latest dates in the year when 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., will be considered in determining whether the area is in compliance with the NAAQS or not)
- 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 2010-2015, 2016, 2017, and 2018.

Table 3-1. Earliest and latest dates for high MDA8 O_3 in the CAPCOG Region

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

The 2018 data continued to show that "moderate" O_3 levels can occur quite early within the region's official O_3 monitoring season. The lack of any "moderate" or worse O_3 days after August was also noteworthy for how abnormal that is compared to 2010-2017.

3.2 High O_3 Days by Month

The following tables shows the number of days when MDA8 values were 55-70 ppb and >70 ppb by month between 2010 - 2015, 2016, 2017, and 2018.

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

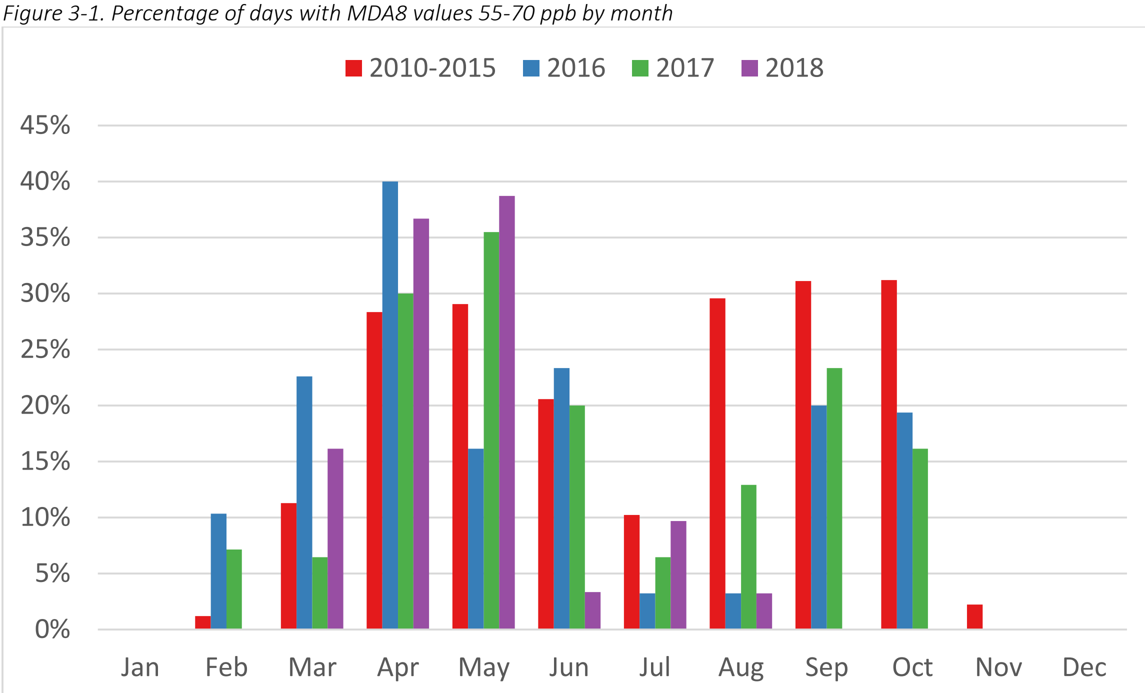
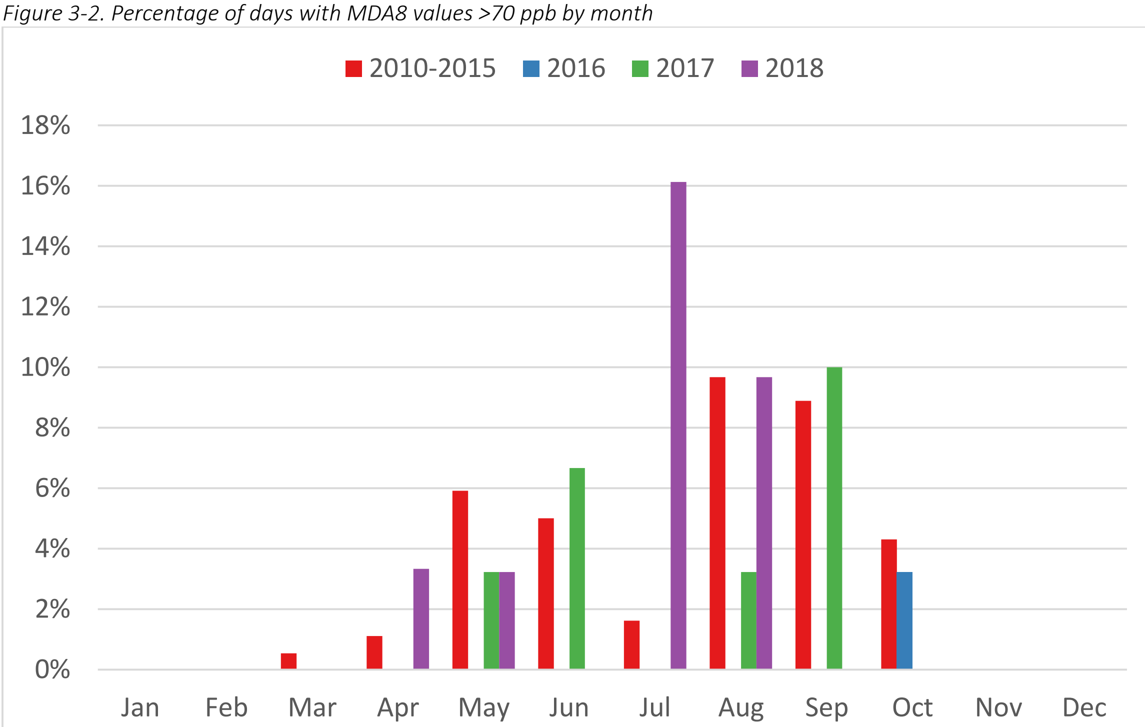


Figure 3-2. Percentage of days with MDA8 values >70 ppb by month



As mentioned in the previous section, the lack of high O_3 data in 2018 was notable. Perhaps more notable, however, was the large number July when MDA8 O_3 levels exceeded 70 ppb in 2018. MDA8 O_3

levels exceeded 70 ppb in July five times in 2018, but only three times in the prior eight years from 2010-2017.

After two years, 2016 and 2017, where MDA8 O_3 values reached 55 ppb or higher in February, 2018 returned to the trend from 2010-2015, when MDA8 O_3 values rarely reached 55 ppb in February.

As the table below shows, the distribution of MDA8 O_3 values of 55 ppb or higher in 2018 by month was statistically significantly different than all previously analyzed timeframes. Chi-squared values that are statistically significant at a 0.05 significance level are bold.

Table 3-2. Chi-squared values for comparison of 2018 monthly distribution of MDA8 O_3 concentrations at 55 ppb or above to 2017, 2016 and 2010-2015

Month	Chi-Squared Value for 2010-2015 Comparison	Chi-Squared Value for 2016 Comparison	Chi-Squared Value for 2017 Comparison
January	n/a	n/a	n/a
February	0.207595	2.510204	1.490909
March	3.231438	0.125436	**8.259202**
April	**38.705475**	0.382280	**4.172506**
May	**5.795616**	18.578800	1.837731
June	2.984122	**4.027875**	**4.131319**
July	**6.048511**	**31.861125**	**13.637250**
August	1.688809	**11.958686**	0.019956
September	**7.473418**	**5.020408**	**7.454545**
October	**6.850633**	**5.857143**	3.727273
November	0.415190	n/a	n/a
December	n/a	n/a	n/a
TOTAL	**73.400806**	**80.321951**	**44.730606**

As the table below shows, the distribution of MDA8 O_3 values >70 ppb were once again statistically significantly different from all previously analyzed timeframes. Chi-squared values that are statistically significant at a 0.05 significance level are bold. MDA8 >70 ppb in 2016 was not evaluated for differences since there was only one day in 2016 with MDA8 >70 ppb.

Table 3-3 Chi-squared values for comparison of 2018 monthly distribution of MDA8 O_3 concentrations >70 ppb to 2017 and 2010-2015

Month	Chi-Squared Value for 2010-2015 Comparison	Chi-Squared Value for 2017 Comparison
January	n/a	n/a
February	n/a	n/a
March	0.147059	n/a
April	1.694118	n/a
May	0.235829	0.128571
June	1.323529	2.857143
July	**47.107843**	n/a
August	0.047059	1.728571

Month	Chi-Squared Value for 2010-2015 Comparison	Chi-Squared Value for 2017 Comparison
September	2.352941	**4.285714**
October	1.176471	n/a
November	n/a	n/a
December	n/a	n/a
TOTAL	**54.084848**	**9.000000**

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 shows 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

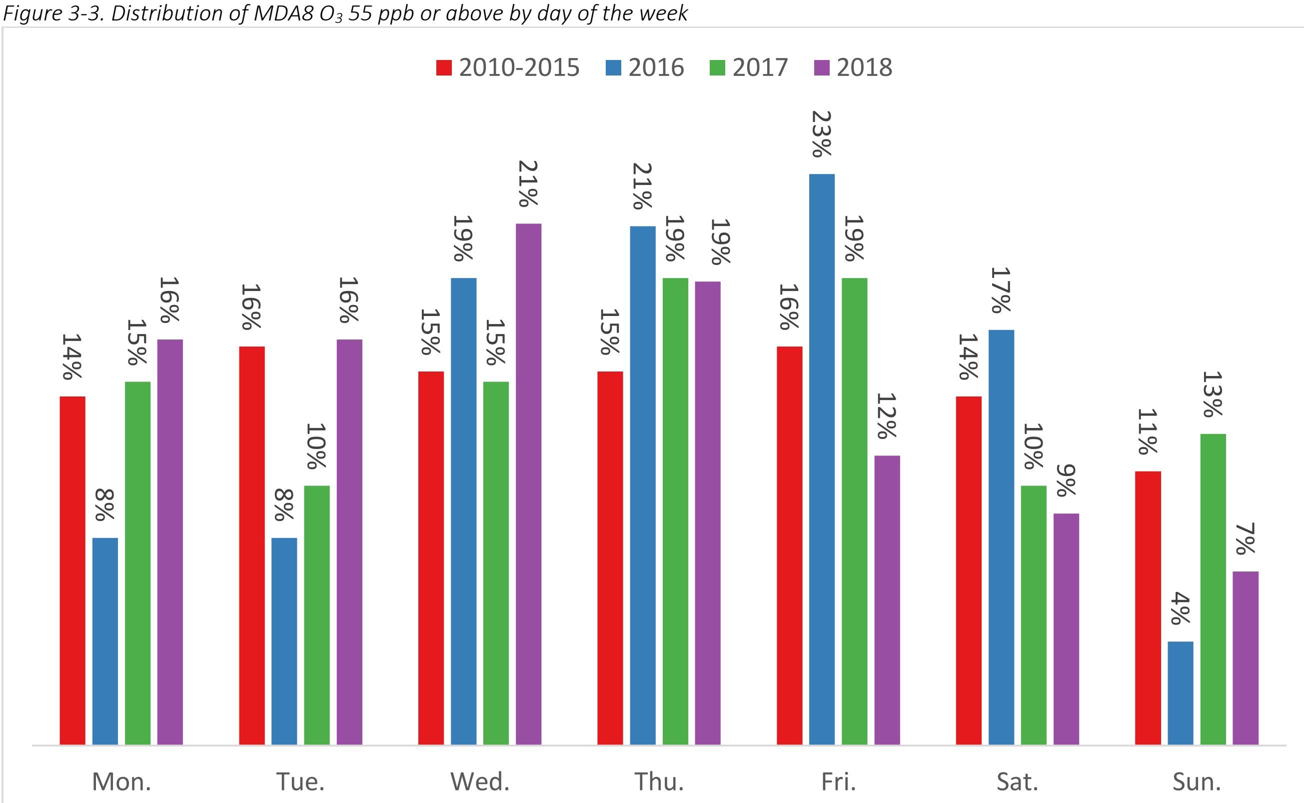
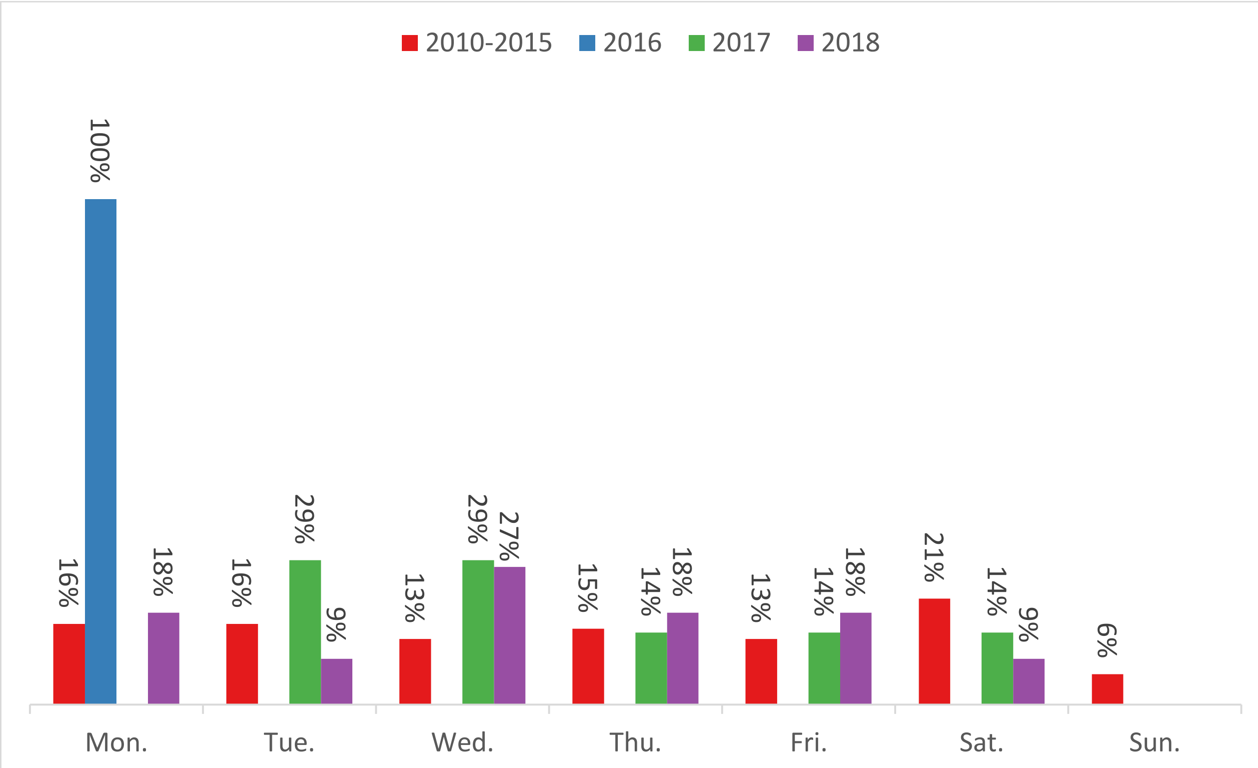


Figure 3-4. Distribution of MDA8 O_3 above 70 by day of the week



CAPCOG performed statistical analyses based on days with MDA8 O_3 ≥55 ppb and >70 ppb, comparing 2010-2015, 2016, and 2017 data to 2018 data. The tables below show Chi-squared values comparing the 2018 distribution to the previous time frames. There were no statistically significant differences at a 0.05 significance level between 2018 and any previously analyzed timeframe. MDA8 >70 ppb in 2016 was not evaluated for differences since there was only one day in 2016 with MDA8 >70 ppb.

Table 3-4. Chi-squared values for comparison of 2018 daily distribution of MDA8 O_3 concentrations at 55 ppb and above to 2017, 2016 and 2010-2015

Month	Chi-Squared Value for 2010-2015 Comparison	Chi-Squared Value for 2016 Comparison	Chi-Squared Value for 2017 Comparison
Monday	0.1595	3.2618	0.0848
Tuesday	0.0021	3.2618	1.4187
Wednesday	1.0081	0.1090	1.1878
Thursday	0.3725	0.1022	0.0005
Friday	0.5137	2.3922	1.1633
Saturday	0.6778	1.4002	0.0513
Sunday	0.6327	0.8123	1.0494
TOTAL	**3.3665**	**11.3396**	**4.9557**

Table 3-5 Chi-squared values for comparison of 2018 daily distribution of MDA8 O_3 concentrations above 70 ppb to 2010-2015

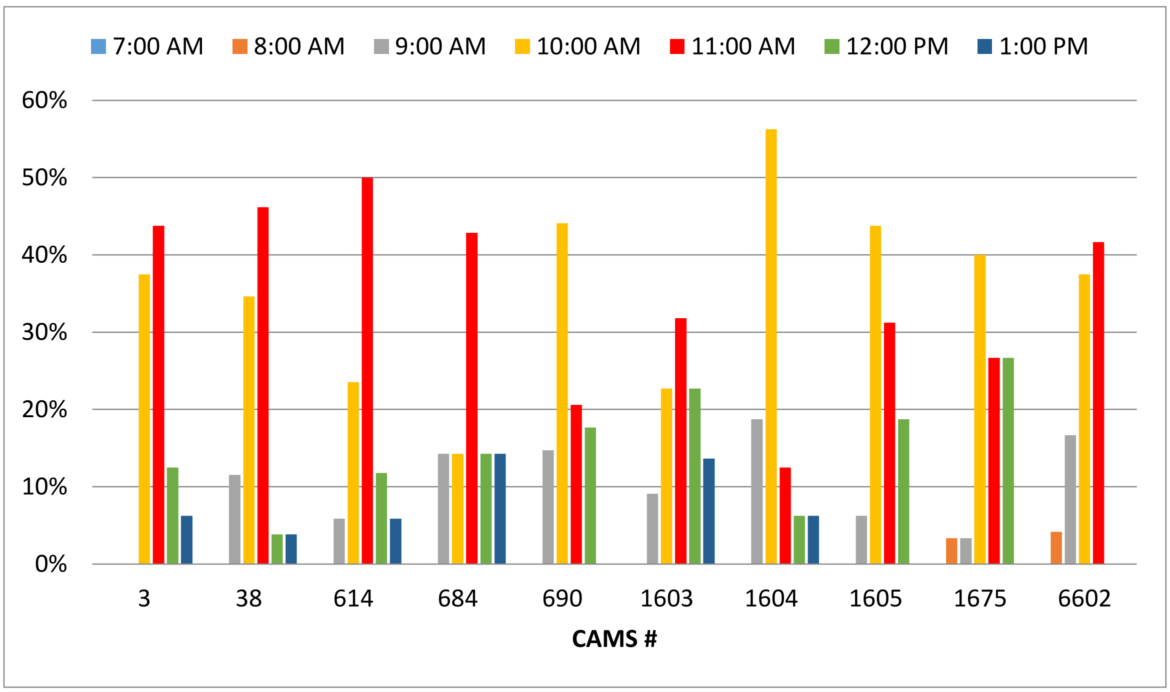
Month	Chi-Squared Value for 2010-2015 Comparison	Chi-Squared Value for 2017 Comparison
Monday	0.0327	n/a
Tuesday	0.3282	1.4610

Month	Chi-Squared Value for 2010-2015 Comparison	Chi-Squared Value for 2017 Comparison
Wednesday	1.7237	0.0065
Thursday	0.0742	0.1169
Friday	0.2272	0.1169
Saturday	0.7429	0.2078
Sunday	0.6600	n/a
TOTAL	**3.7890**	1.9091

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 2018. As the figure shows, 10 am and 11 am were the most common start hour for MDA8 O_3 values ≥ 55 ppb.

Figure 3-5. Distribution of start hour for MDA8 ≥ 55 ppb by monitoring station, 2018



In the figures below CAPCOG compared the distribution of start hours in 2018 to what was observed in 2010-2015, 2016, and 2017 for MDA8 O_3 ≥55.

Figure 3-6. Start hour for MDA8 O_3 ≥55 ppb at CAMS 3, 2010-2015, 2016, 2017, and 2018

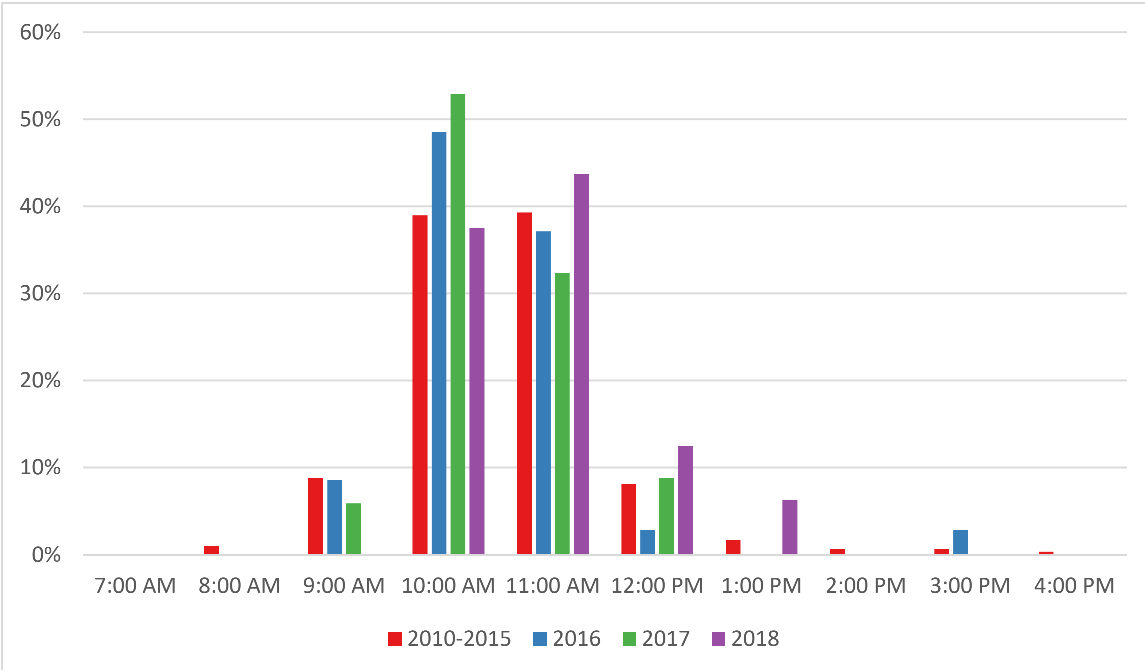
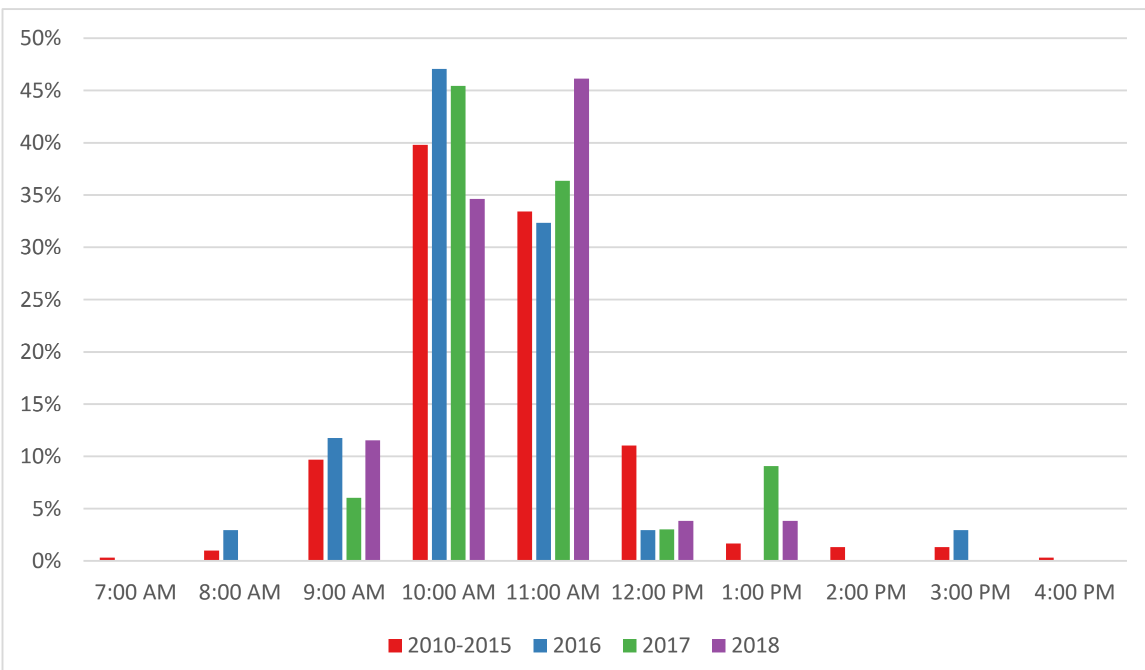


Figure 3-7. Start hour for MDA8 O_3 ≥55 ppb at CAMS 38, 2010-2015, 2016, 2017, and 2018



igure 3-8. Start hour for MDA8 O_3 ≥55 ppb at CAMS 614, 2010-2015, 2016, 2017, and 2018

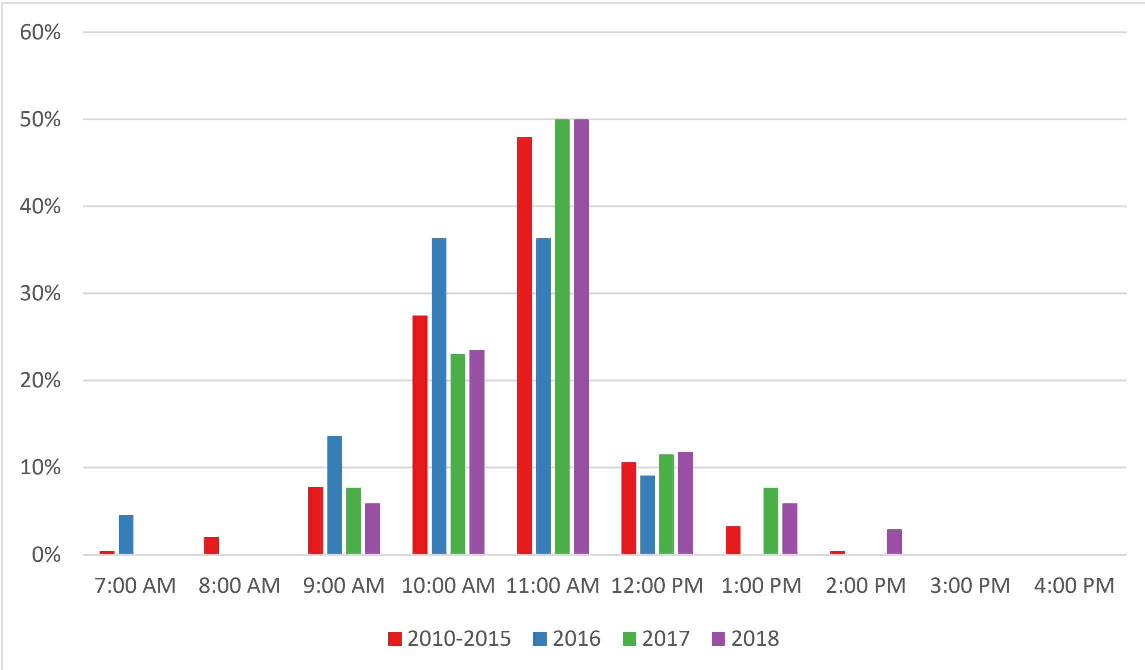


Figure 3-9. Start hour for MDA8 O_3 ≥55 ppb at CAMS 684, 2010-2015, 2016, 2017, and 2018

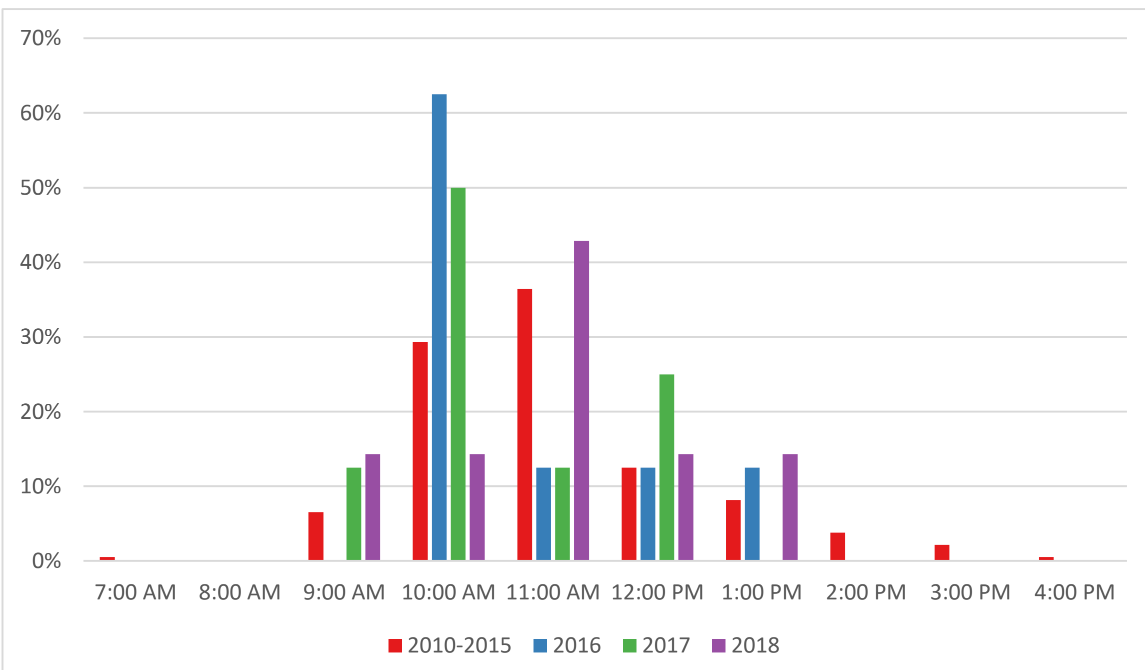


Figure 3-10. Start hour for MDA8 O_3 ≥55 ppb at CAMS 690, 2010-2015, 2016, 2017, and 2018

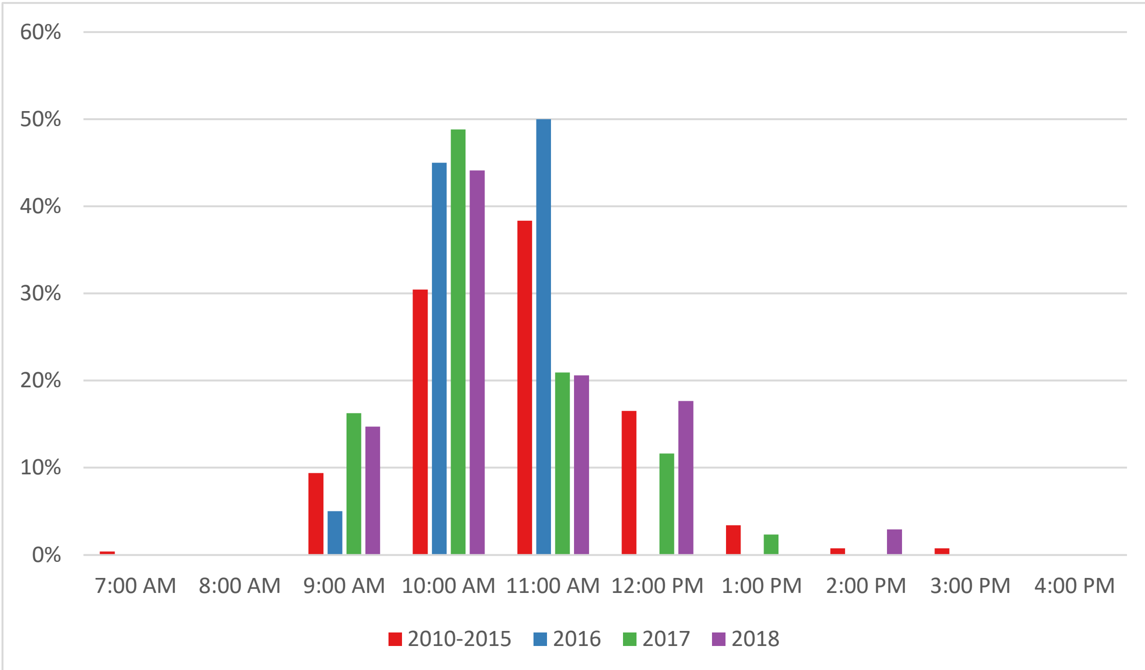


Figure 3-11. Start hour for MDA8 O_3 ≥55 ppb at CAMS 1603, 2010-2015, 2016, 2017, 2018

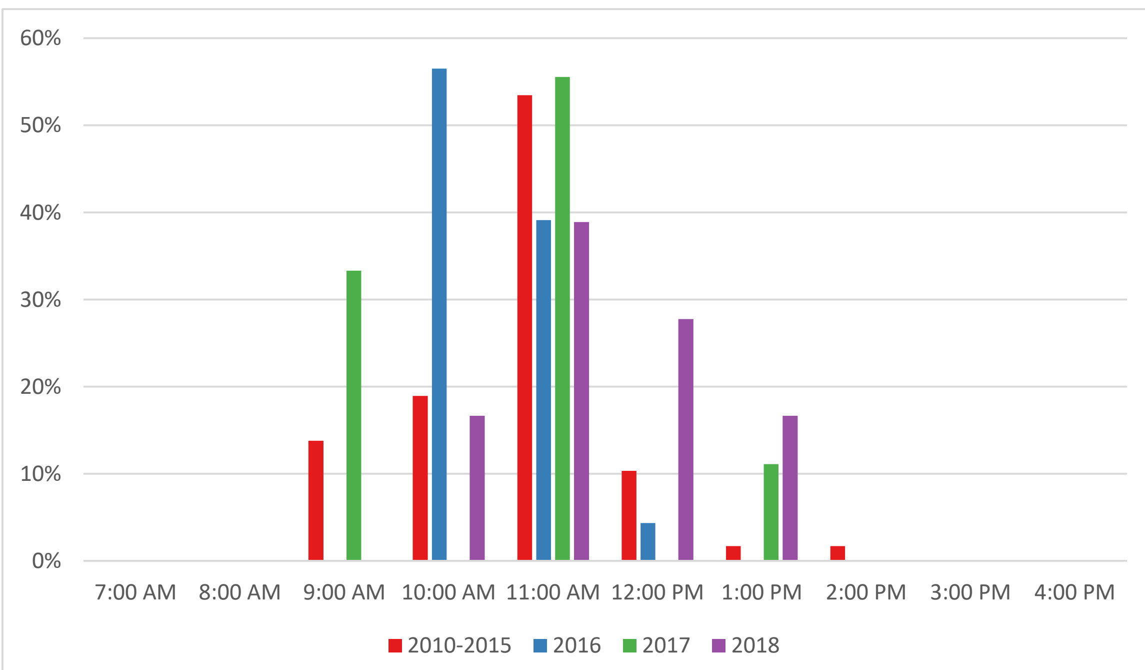


Figure 3-12. Start hour for MDA8 O_3 ≥55 ppb at CAMS 1604, 2010-2015, 2016, 2017, and 2018

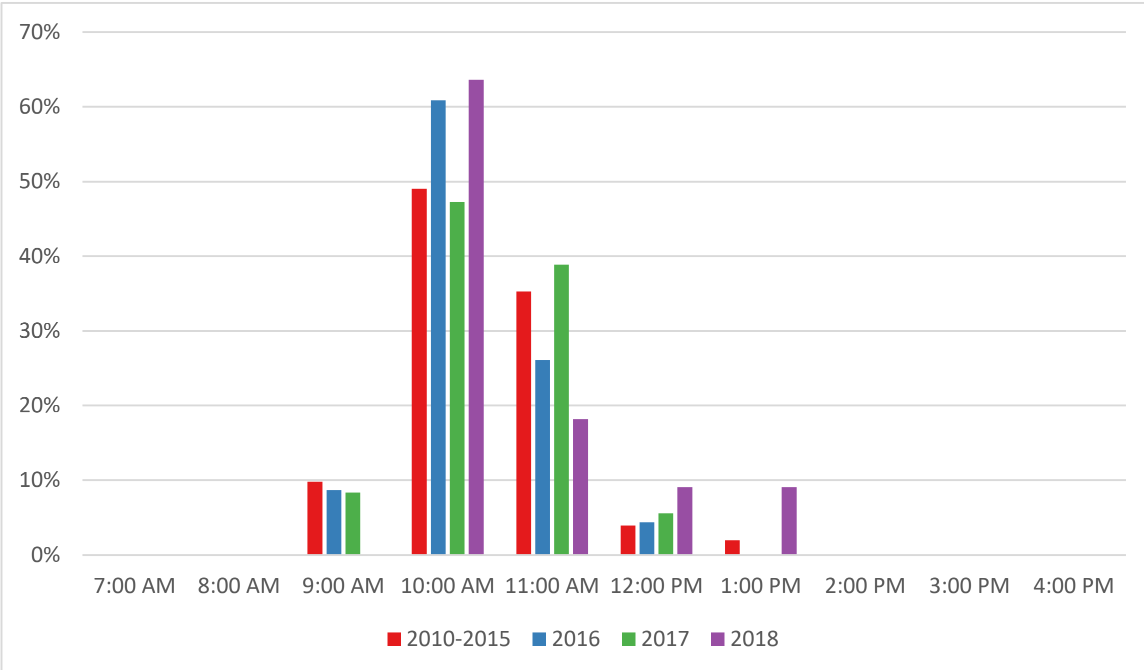


Figure 3-13. Start hour for MDA8 O_3 ≥55 ppb at CAMS 1675, 2010-2015, 2016, 2017, and 2018

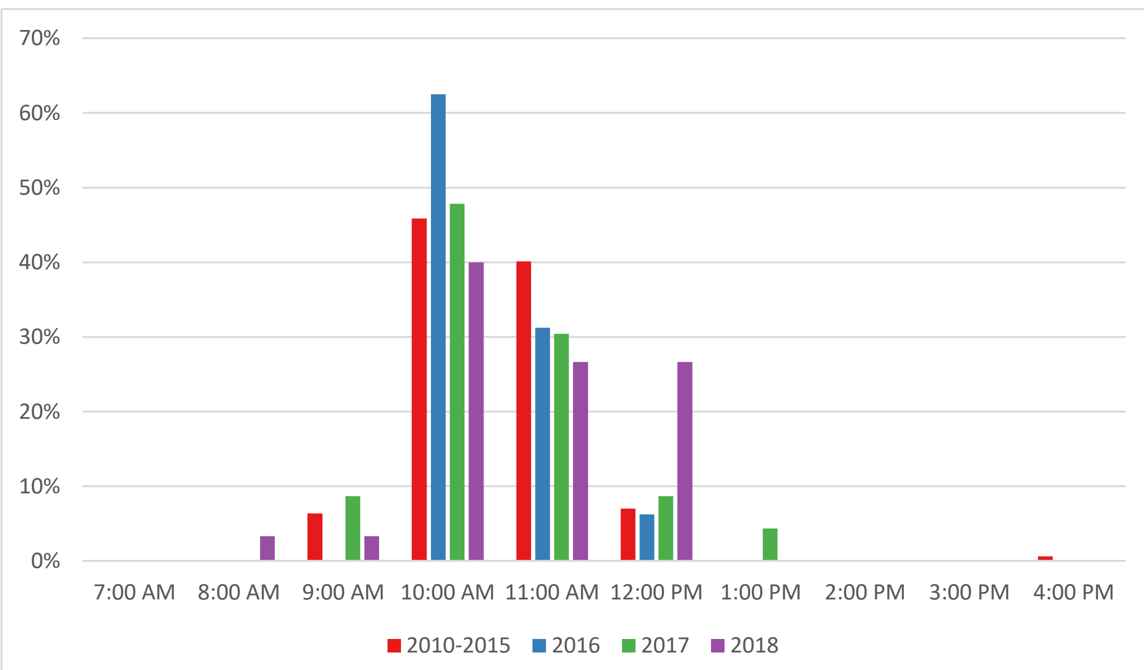
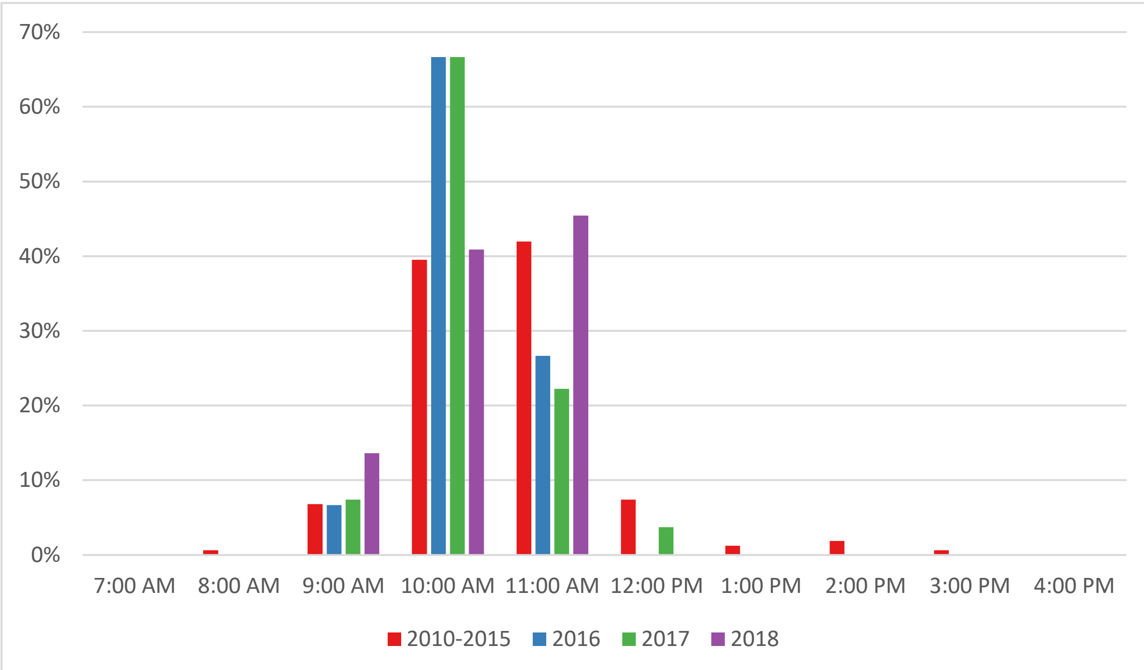


Figure 3-14. Start hour for MDA8 O_3 ≥55 ppb at CAMS 6602, 2010-2015, 2016, 2017, and 2018



4 Meteorological Factors

In the most recent conceptual model for the region, 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 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 and 2015. CAPCOG included the 8 am – 12 pm period for WD as well based on this time frame including all of the start hours for MDA8 values >70 ppb at CAMS 3 and CAMS 38 between 2010 and 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 χ^2- tests of independence in order to determine whether there were statistically significant differences between the actual distribution and the expected WD distribution given the data for all days.

For this report, 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 (this is the 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 statistically significant 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 statistically significant impacts of wind speed on MDA8 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 2018 wind speeds were statistically significantly different from wind speeds observed 2010-2017 or if the relationship between O_3 and wind speed was statistically significantly different than the relationship observed between 2010-2017.

4.1.1 Comparison of Relationship between Wind Speed and MDA8 O_3 in 2018 to 2010-2017

The figures below show the relationship between observed wind speeds and observed MDA8 O_3 values at CAMS 3. All trendlines are fairly similar showing that there is not a strong negative or positive relationship, though 2010-2015 did show a slightly negative relationship while all subsequent years have had a slightly positive 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

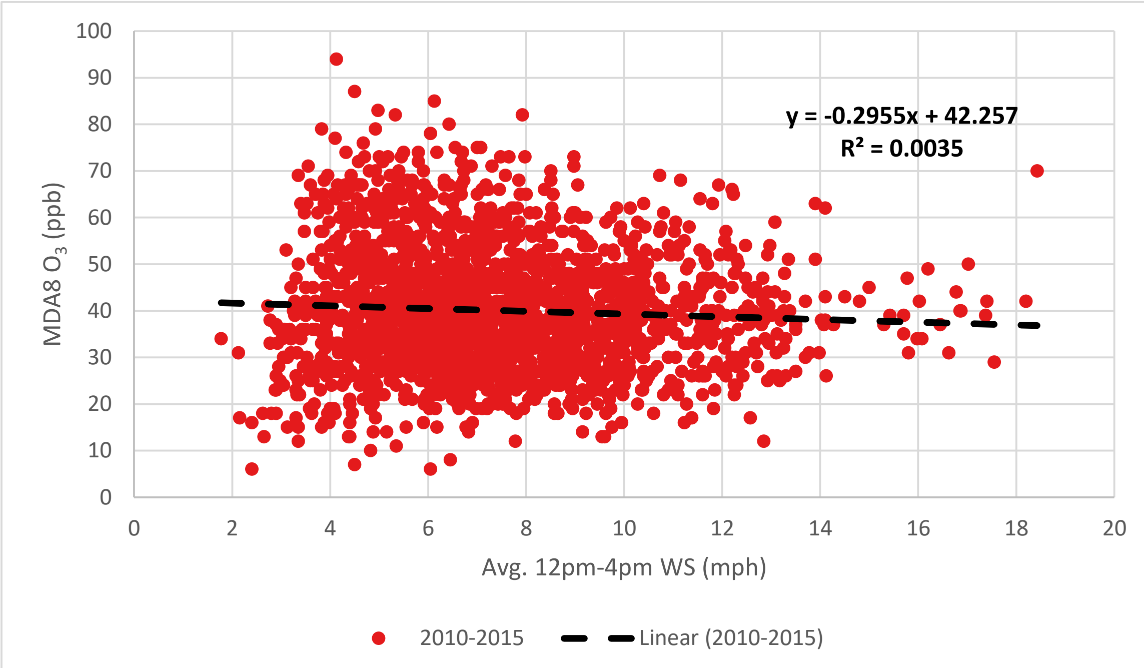


Figure 4-2. Scatter Plot of 12 pm – 4 pm Wind Speed at CAMS 3 v. MDA8 O_3 at CAMS 3, 2016

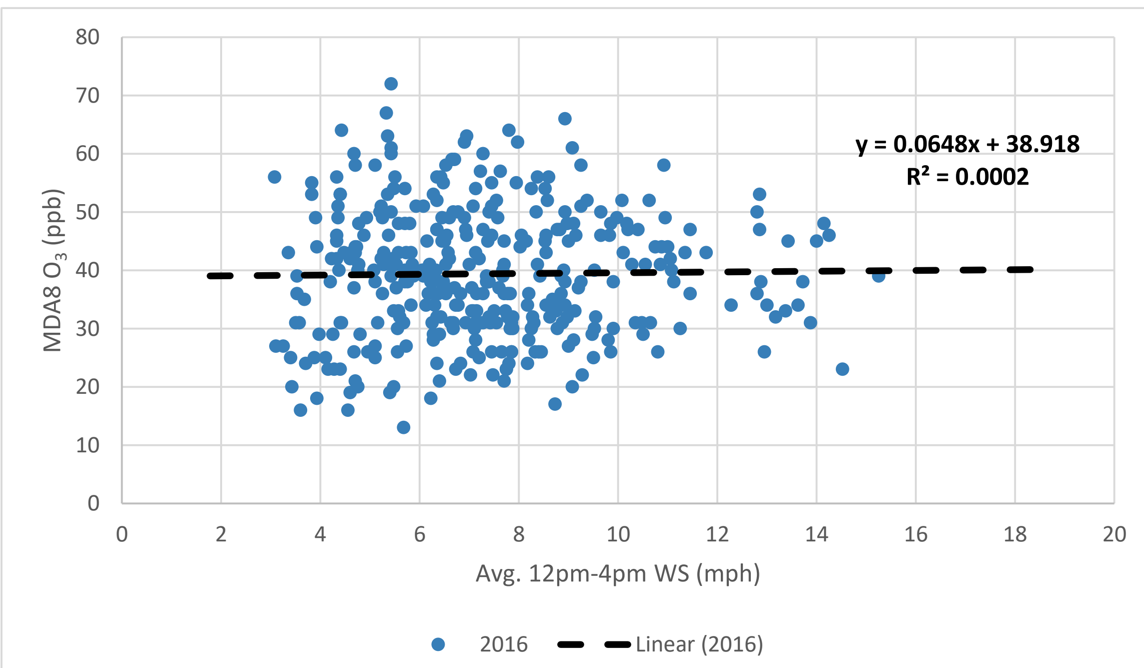


Figure 4-3. Scatter Plot of 12 pm – 4 pm Wind Speed at CAMS 3 v. MDA8 O_3 at CAMS 3, 2017

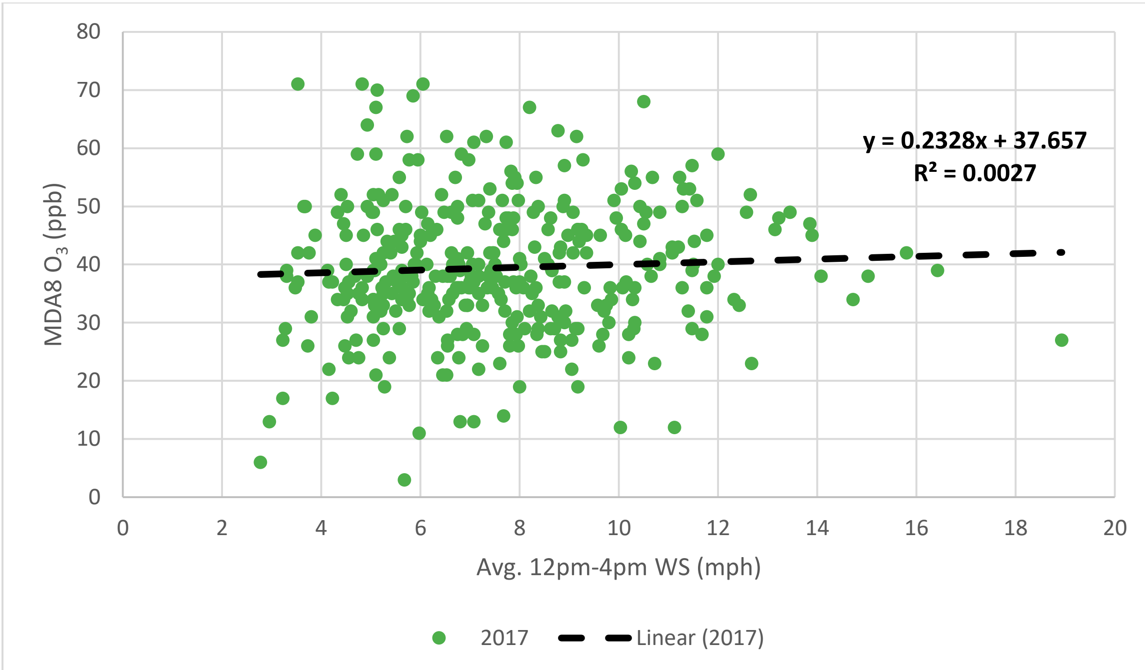
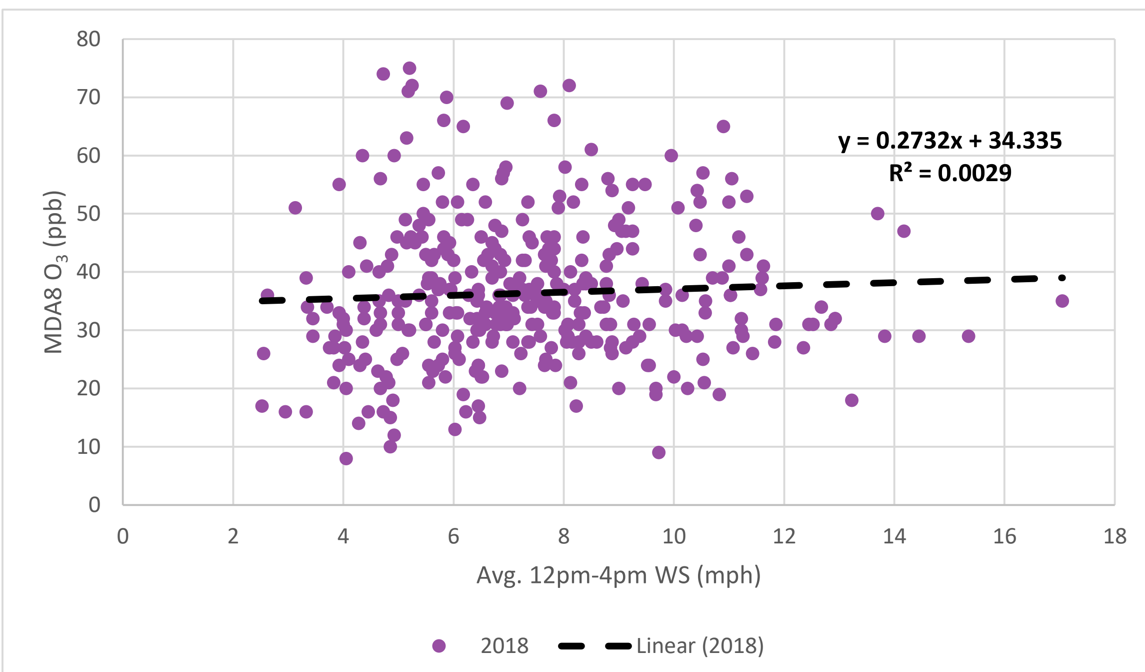
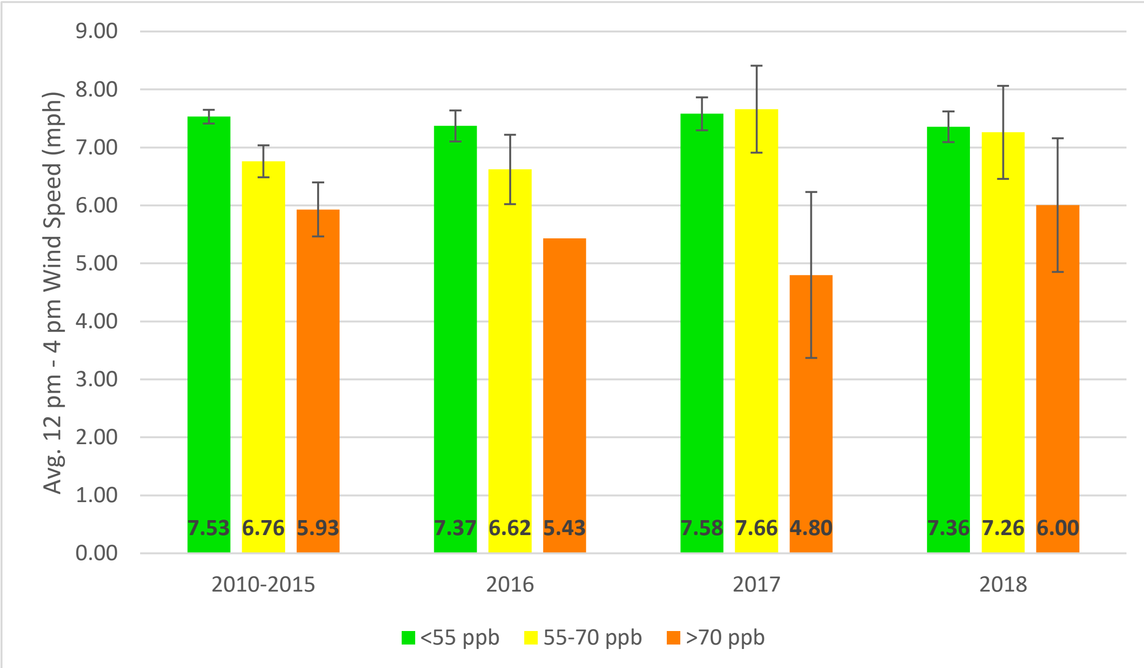


Figure 4-4 Scatter Plot of 12 pm – 4 pm Wind Speed at CAMS 3 v. MDA8 O_3 at CAMS 3, 2018



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 2018 compared to previous timeframes.

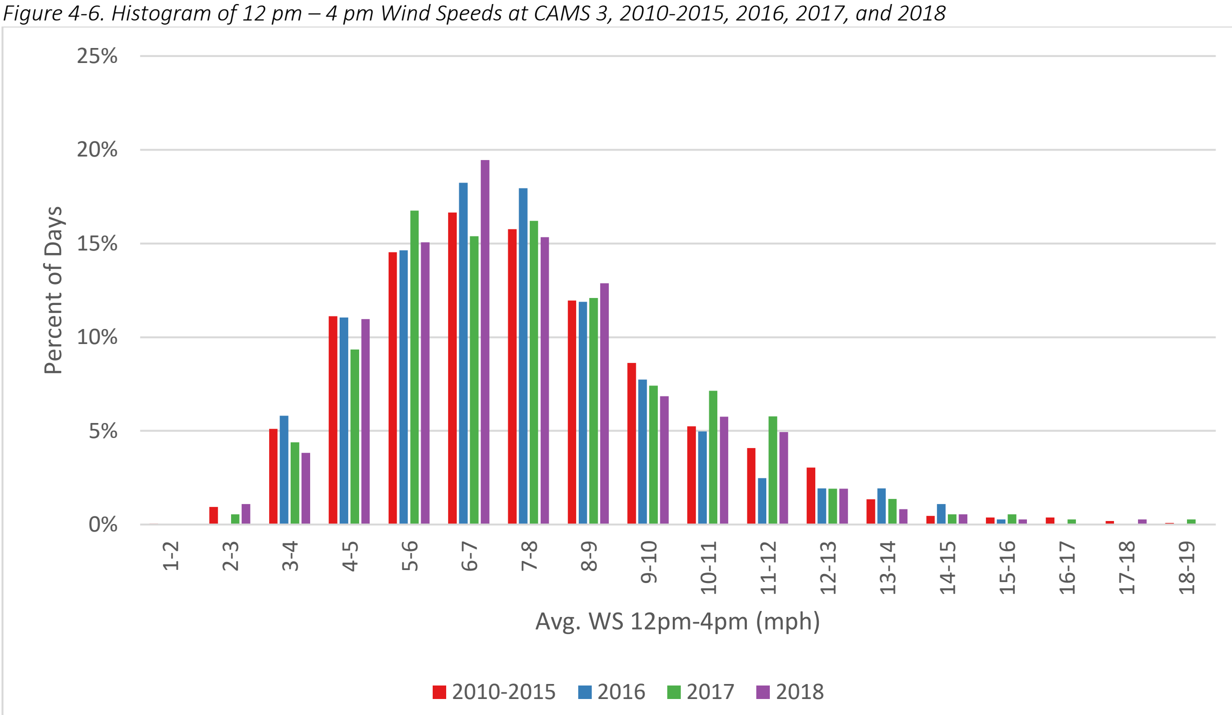
Figure 4-5. Typical Wind Speed 12 pm – 4pm at CAMS 3 on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 3, 2010-2015, 2016, 2017, and 2018



4.1.2 Comparison of 2018 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.

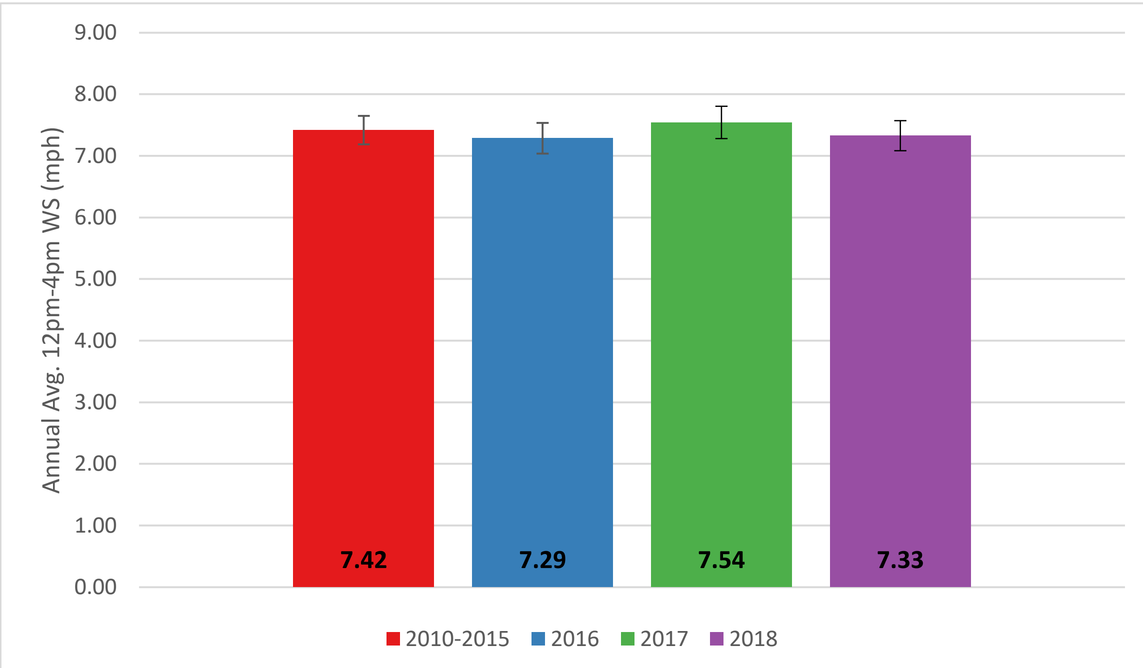
Figure 4-6. Histogram of 12 pm – 4 pm Wind Speeds at CAMS 3, 2010-2015, 2016, 2017, and 2018



CAPCOG performed a chi-squared test of independence on the data in the figure above to determine if the distributions were statistically significantly different. CAPCOG found that there was not a statistically significant difference in the distribution using this test at a 0.05 or 0.10 significance level in 2018 comparted to any previous timeframe.

CAPCOG also tested whether there was a statistically significant difference in the annual average of these daily 12 pm -4 pm wind speed averages. The following figure shows the average for 2010-2015, 2016, 2017 and 2018, along with the 95% confidence intervals.

Figure 4-7. Annual Avg. 12 pm-4 pm Wind Speed at CAMS 3, 2010-2015, 2016, 2017 and 2018



4.2 Temperature

CAPCOG's most recent O_3 conceptual model showed that average temperatures between 12 pm - 4 pm had a statistically significant positive correlation with MDA8 O_3. In CAPCOG's 2010-2015 Conceptual Model, CAPCOG analyzed the data for 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 statistically significant impacts of temperature on MDA8 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 2018 temperatures were statistically significantly different from temperatures observed 2010-2017 or if the relationship between O_3 and temperature was statistically significantly different than the relationship observed 2010-2017.

4.2.1 Comparison of Relationship between Temperature and MDA8 O_3 in 2018 to 2010-2017

The figures below show a scatter plot with MDA8 values and average temperatures for 12 pm – 4 pm at CAMS 3 for 2018, 2017, 2016, and 2010 – 2015. As the figures show, the 2018 data was consistent in showing a positive correlation between these two factors.

Figure 4-8. Scatter Plot of 12 pm – 4 pm Temperature at CAMS 3 v. MDA8 O_3 at CAMS 3, 2010-2015

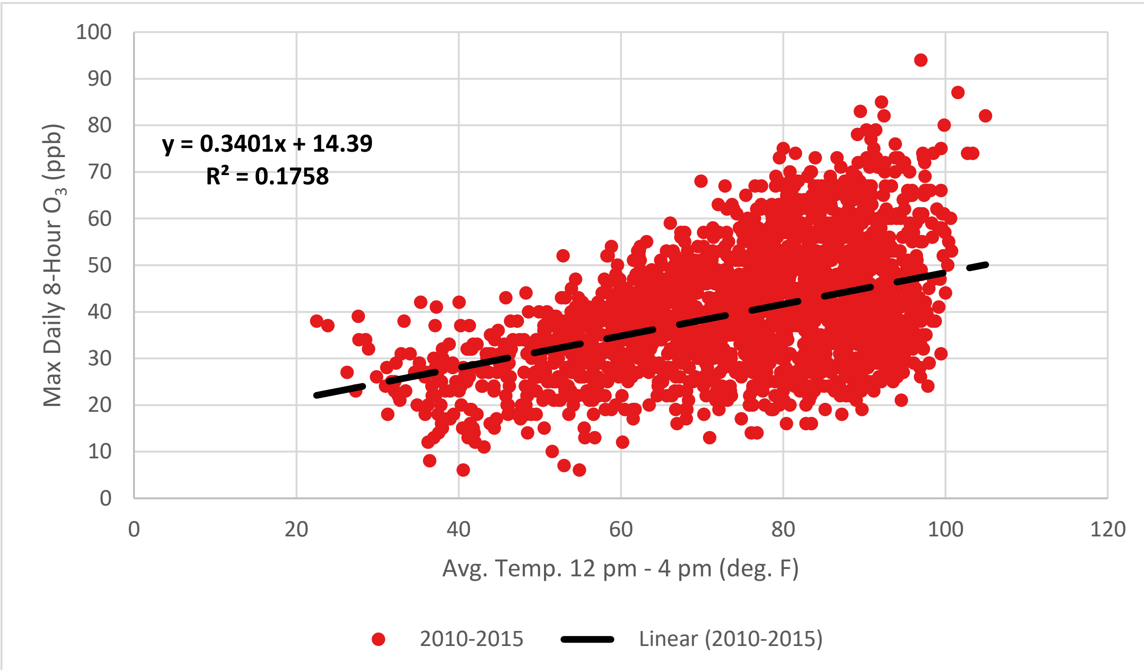


Figure 4-9. Scatter Plot of 12 pm – 4 pm Temperature at CAMS 3 v. MDA8 O_3 at CAMS 3, 2016

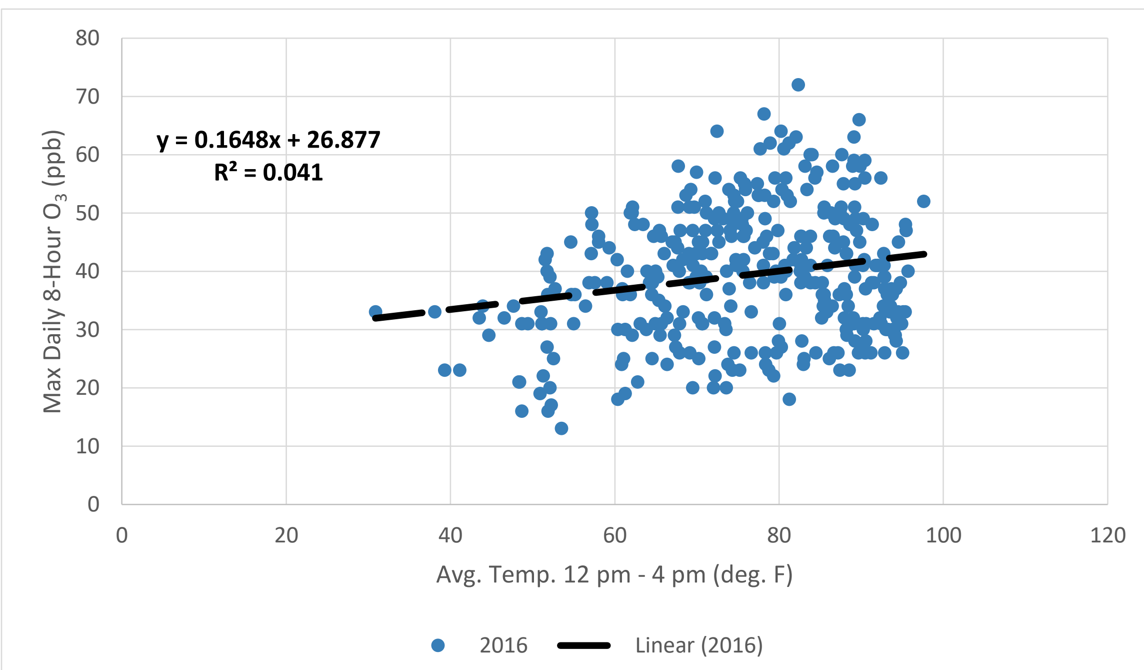


Figure 4-10. Scatter Plot of 12 pm – 4 pm Temperature at CAMS 3 v. MDA8 O_3 at CAMS 3, 2017

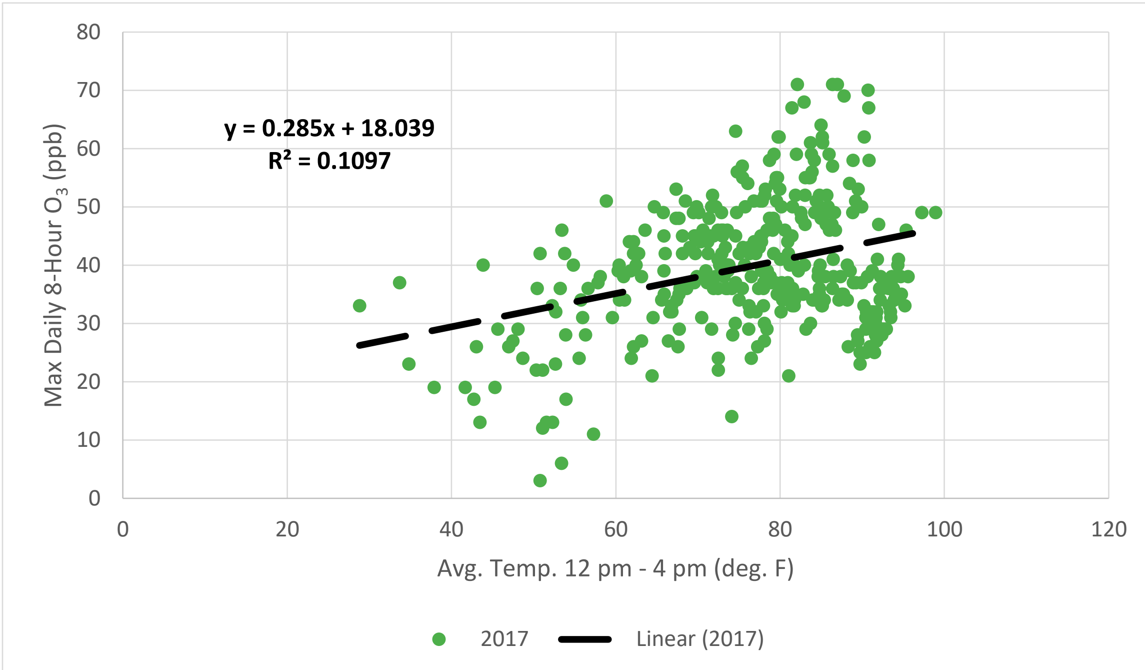
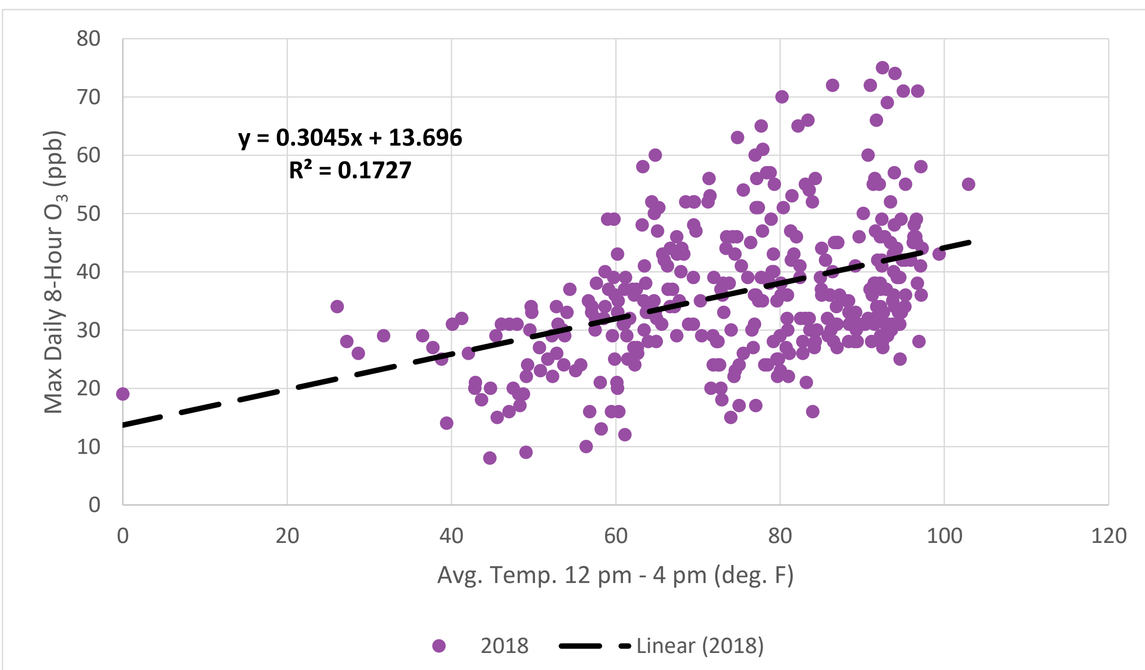
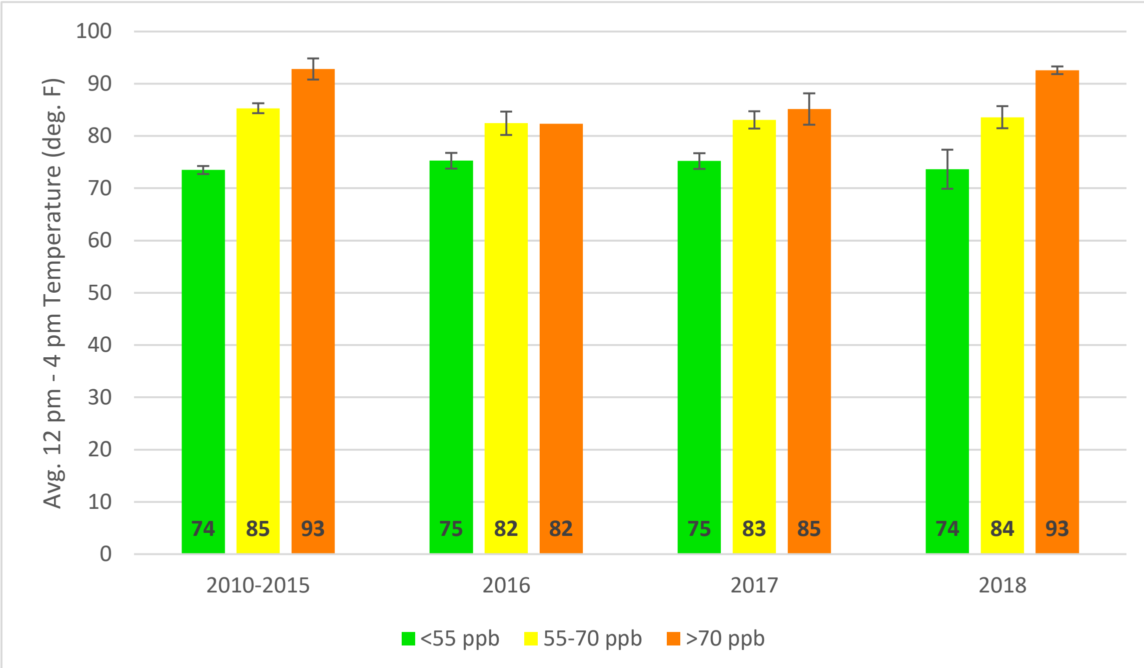


Figure 4-. Scatter Plot of 12 pm – 4 pm Temperature at CAMS 3 v. MDA8 O_3 at CAMS 3, 2018



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 2018 compared to previous timeframes. 2018 data was within the 0.05 confidence range for 2010-2015 MDA8 O_3 <55 ppb and >70 ppb, however it was lower between 55-70 ppb.

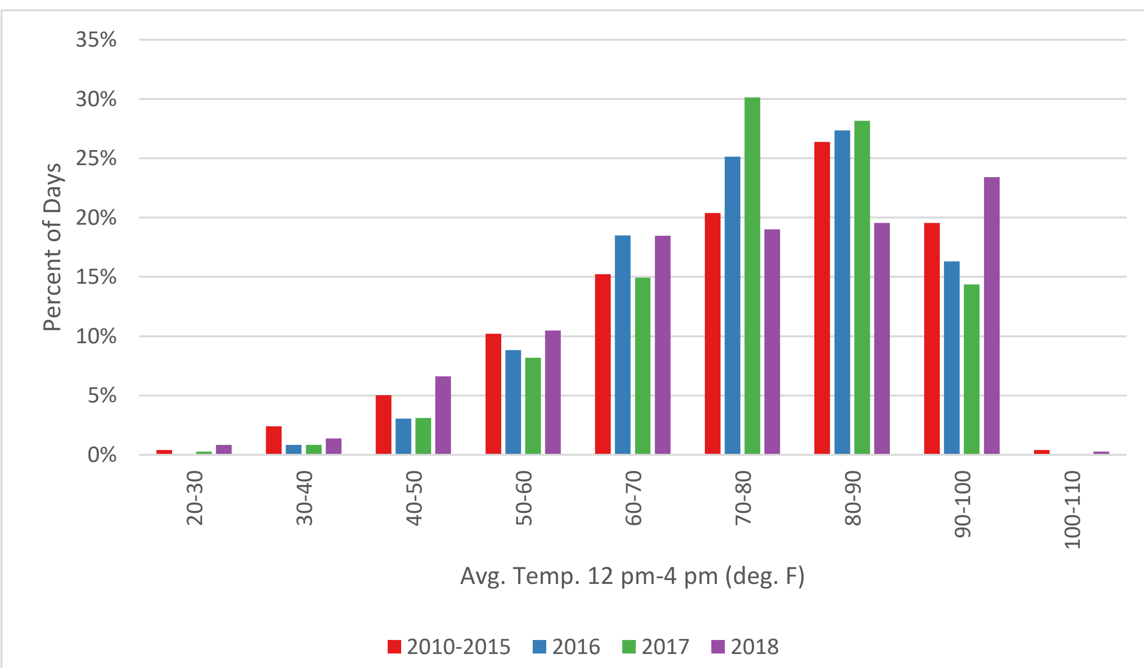
Figure 4-11. Typical Temperature 12 pm – 4pm at CAMS 3 on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 3, 2010-2015, 2016, 2017, and 2018



4.2.2 Comparison of 2018 Temperatures to 2010-2015 Temperatures

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

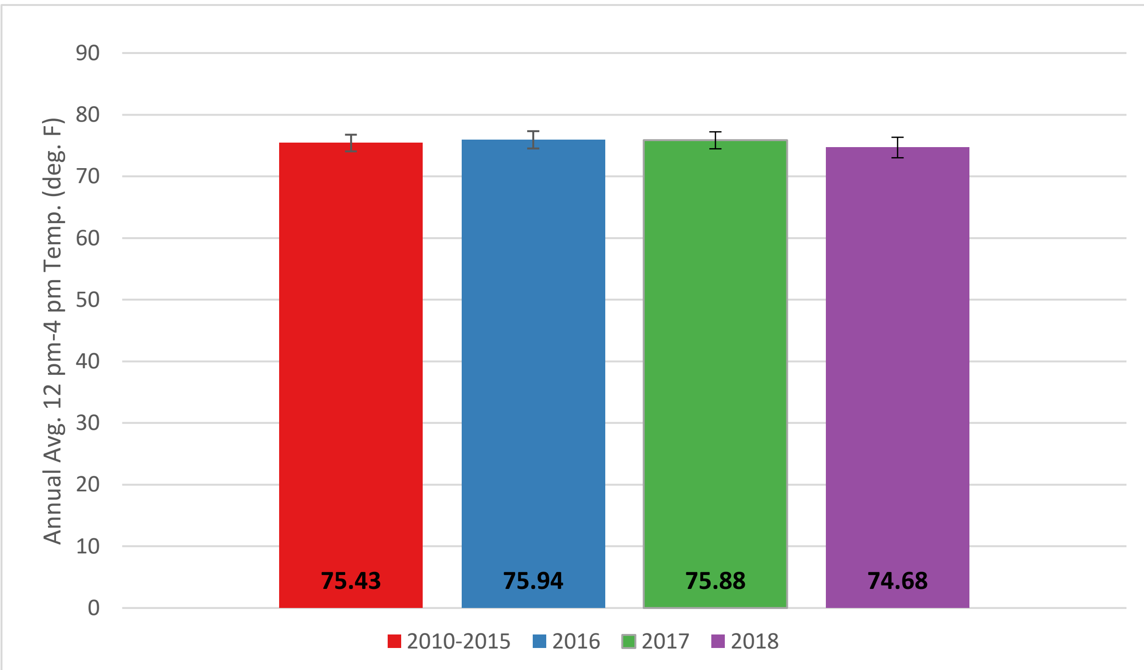
Figure 4-12. Histogram of 12 pm – 4 pm Temperatures at CAMS 3, 2010-2015, 2016, 2017, and 2018



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 significantly statistically different from the distribution in 2010-2015, 2016, or 2017. There was a significant statistical difference in the distribution using this test at a 0.05 significance level between 2018 and all previous timeframes.

CAPCOG also tested whether there was a significant statistical difference in the annual average of these daily 12 pm - 4 pm wind speed averages. The following figure shows the average from 2010-2015, 2016, and 2017 along with the 95% confidence intervals.

Figure 4-13. Annual Avg. 12 pm-4 pm Temperature at CAMS 3, 2010-2015, 2016, 2017, and 2018



4.3 Diurnal Temperature Change

CAPCOG's most recent O_3 conceptual model showed that diurnal temperature change had a statistically 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 statistically significant impacts of diurnal temperature changes on MDA8 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 2018 diurnal temperature changes were statistically significantly different from temperature changes observed 2010-2017 or if the relationship between O_3 and temperature change was statistically significantly different than the relationship observed 2010-2017.

4.3.1 Comparison of Relationship between Diurnal Temperature Change and MDA8 O_3 in 2018 to 2010-2017

The figures below show scatter plots with MDA8 values and diurnal temperature changes at CAMS 3 for 2018, 2017, 2016, and 2010 – 2015. As the figures show, the 2018 data was consistent in showing a positive correlation between these two factors.

Figure 4-14. Scatter Plot of Diurnal Temperature Change at CAMS 3 v. MDA8 O_3 at CAMS 3, 2010-2015

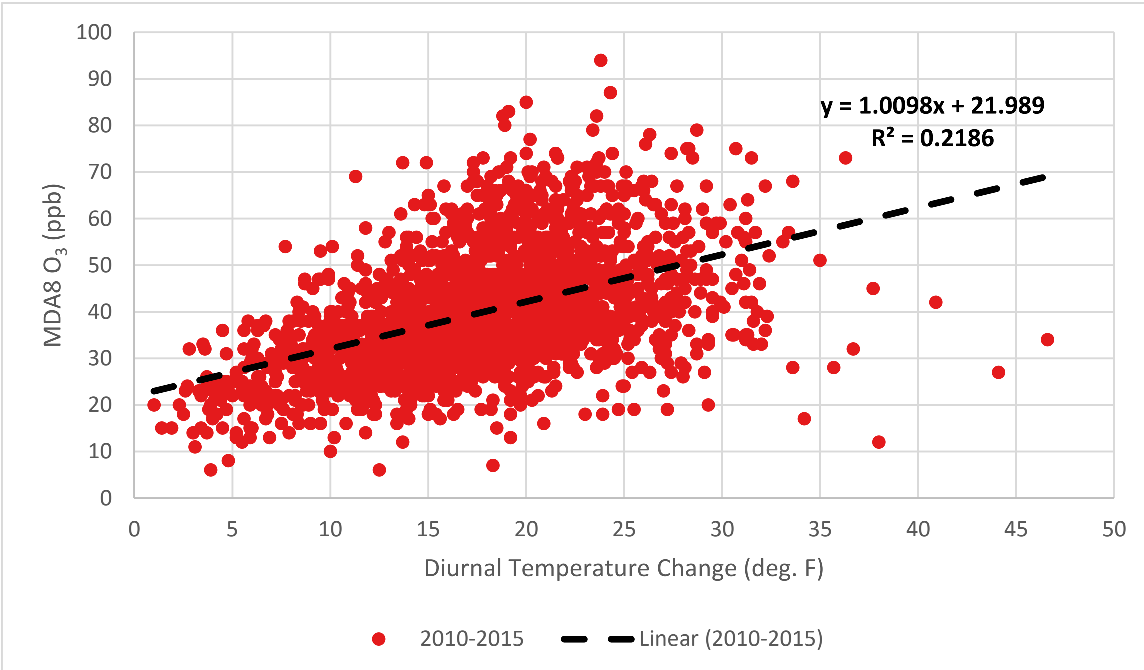


Figure 4-15. Scatter Plot of Diurnal Temperature Change at CAMS 3 v. MDA8 O_3 at CAMS 3, 2016

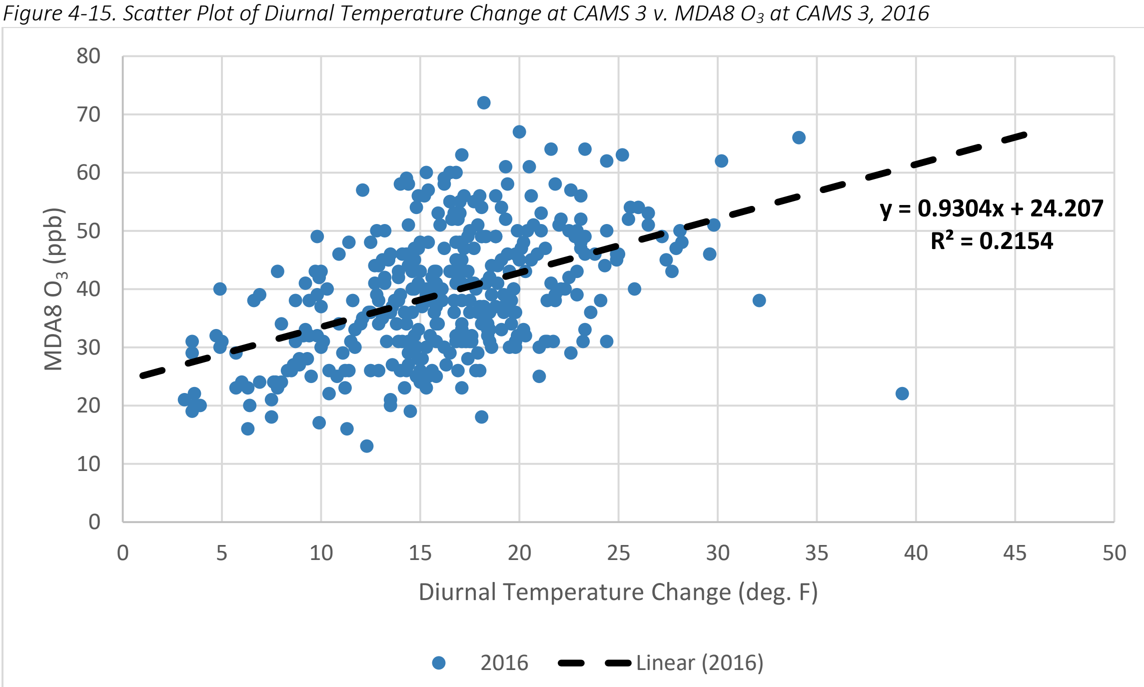


Figure 4-16. Scatter Plot of Diurnal Temperature Change at CAMS 3 v. MDA8 O_3 at CAMS 3, 2017

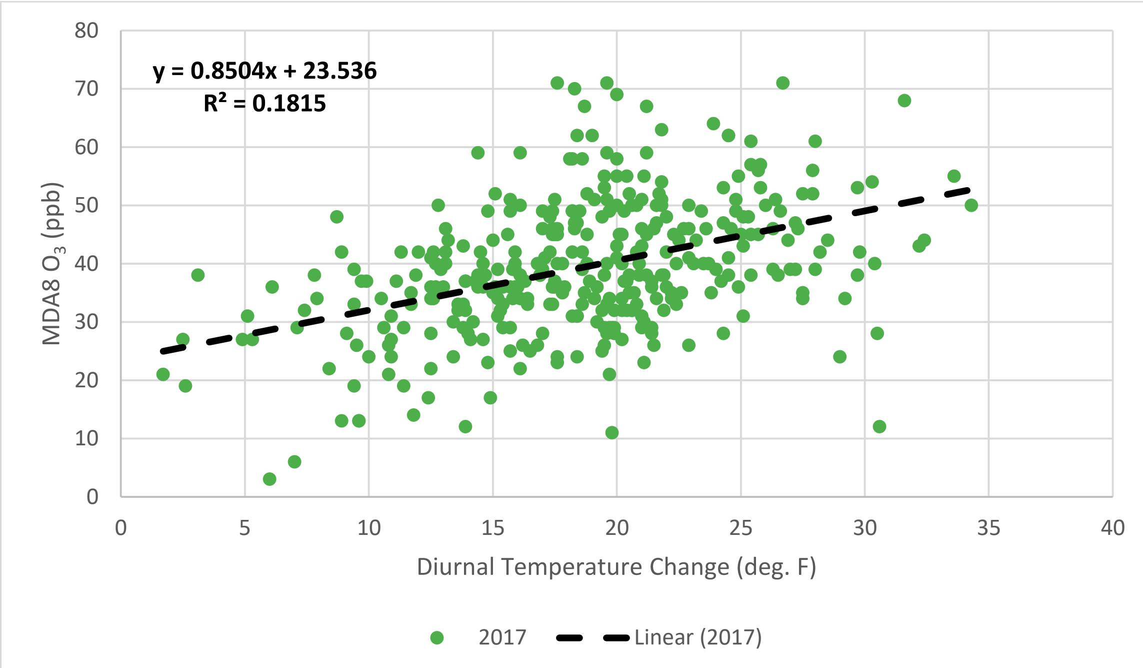
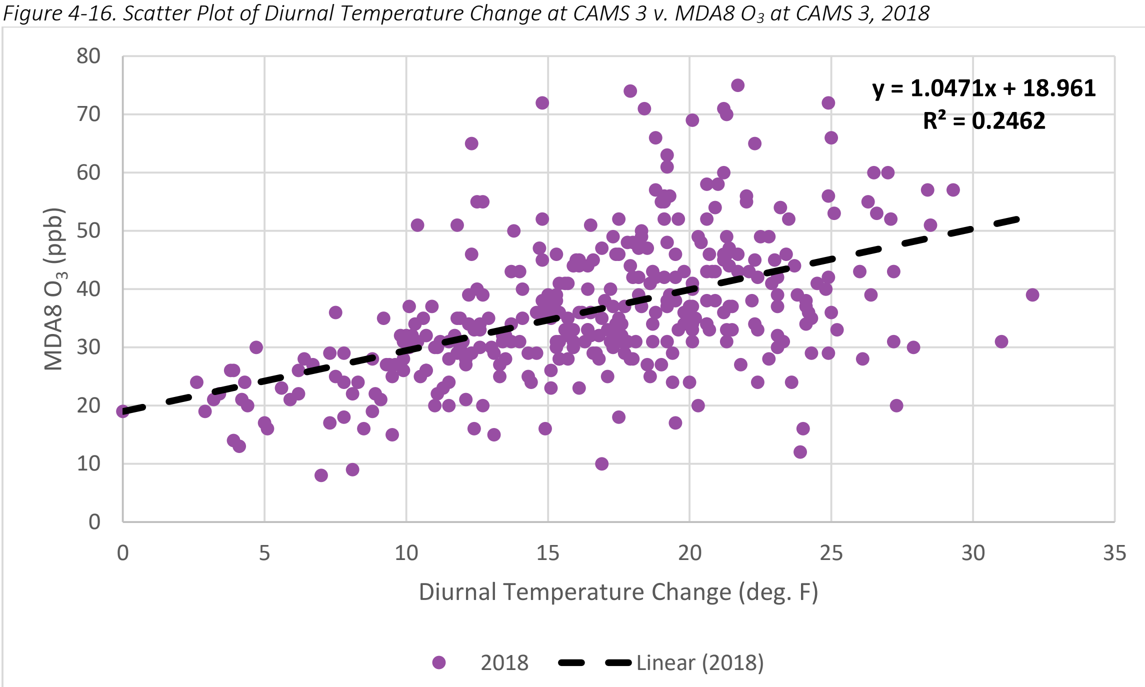
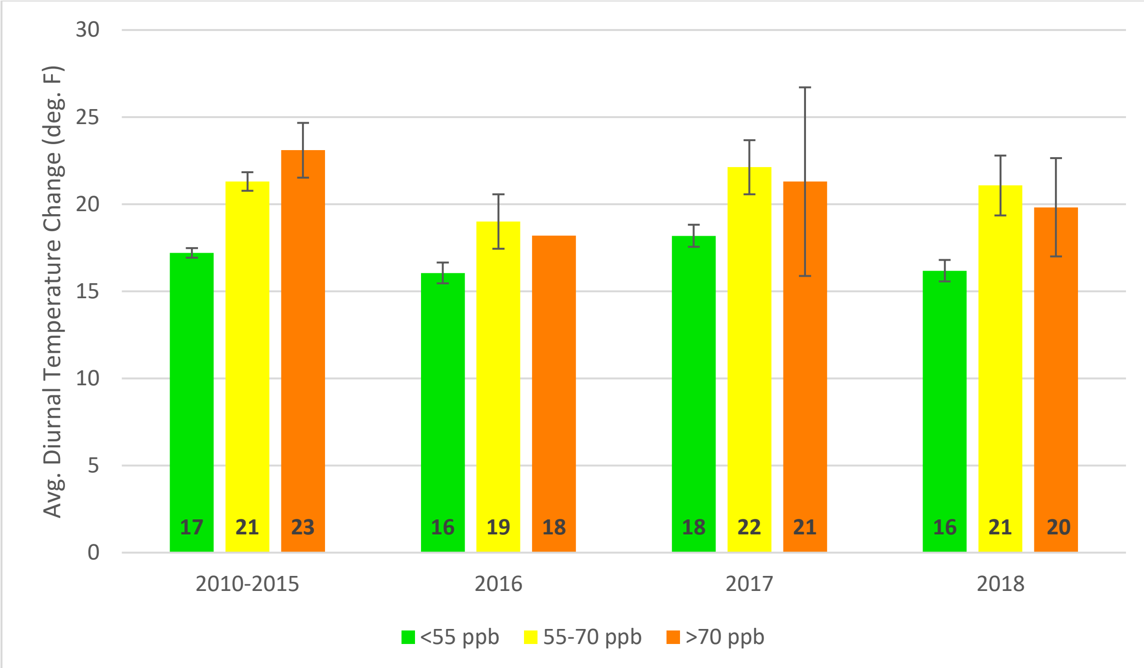


Figure 4-16. Scatter Plot of Diurnal Temperature Change at CAMS 3 v. MDA8 O_3 at CAMS 3, 2018



The figure below shows a comparison of the typical diurnal temperature changes on days <55 ppb, 55-70 ppb, and >70 ppb in 2018 relative to 2010-2015, 2016, and 2017.

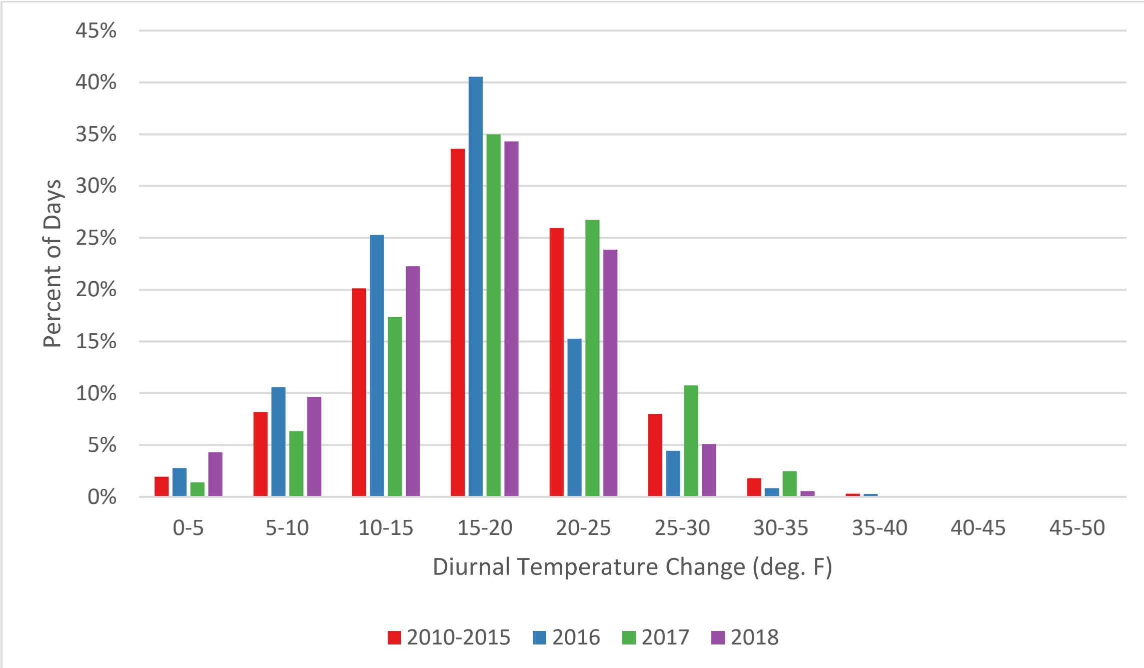
Figure 4-17. Typical Diurnal Temperature Change at CAMS 3 on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 3, 2010-2015, 2016, 2017, and 2018



4.3.2 Comparison of 2018 Diurnal Temperature Changes to 2010-2017 Diurnal Temperature Changes

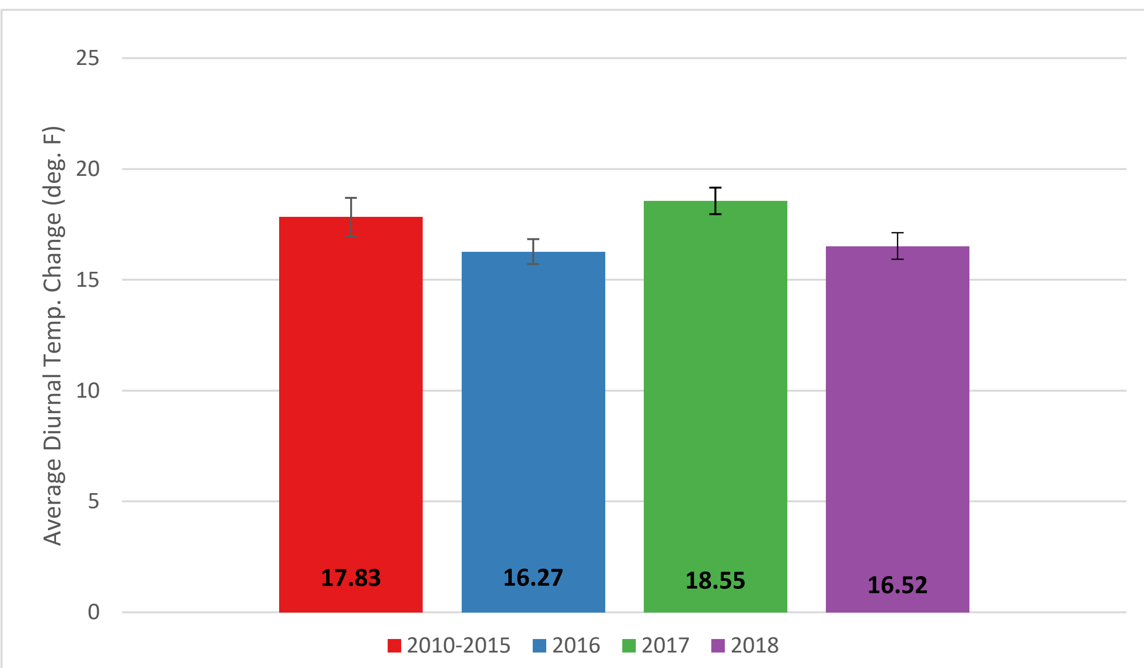
Based on a review of the meteorological data in 2010-2015, 2016, 2017, and 2018, CAPCOG determined that there were statistically significant differences in the diurnal temperature change in 2018 compared to all previous observed timeframes. The distribution of days into 5-degree bins in the histogram below shows that 2018 had substantially more days with high temperature changes that are associated with high MDA8 O_3.

Figure 4-18. Histogram of Diurnal Temperature Changes at CAMS 3, 2010-2015, 2016, 2017, and 2018



CAPCOG also performed a confidence interval analysis of the average annual daily diurnal temperature change. The average 16.52°F diurnal change in 2018 was lower than the confidence interval for the 2010-2015 average.

Figure 4-19. Annual Avg. Diurnal Temperature Change at CAMS 3, 2010-2015, 2016, 2017, and 2018



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 significantly negative correlation with MDA8 O_3. Regression analyses that CAPCOG conducted for that report showed similar statistically significant impacts of relative humidity on MDA8 values: -0.28 ppb at CAMS 3/% RH at CAMS 5001 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 2018 12 pm – 4 pm relative humidity measurements were statistically significantly different from the relative humidity measurements in 2010-2017 or if the relationship between O_3 and relative humidity was statistically significantly different from the relationship observed 2010-2017.

4.4.1 Comparison of Relationship between Relative Humidity and MDA8 O_3 in 2018 to 2010-2017

The figures below show scatter plots with MDA8 values at CAMS 3 and 12 pm – 4 pm relative humidity data at CAMS 5002 (Camp Mabry) for 2017, 2016, and 2010-2015. As the figures show, the 2018 data was consistent in showing a negative correlation between these two factors.

Figure 4-20. Scatter Plot of 12 pm – 4 pm Relative Humidity at Camp Mabry v. MDA8 O_3 at CAMS 3, 2010-2015

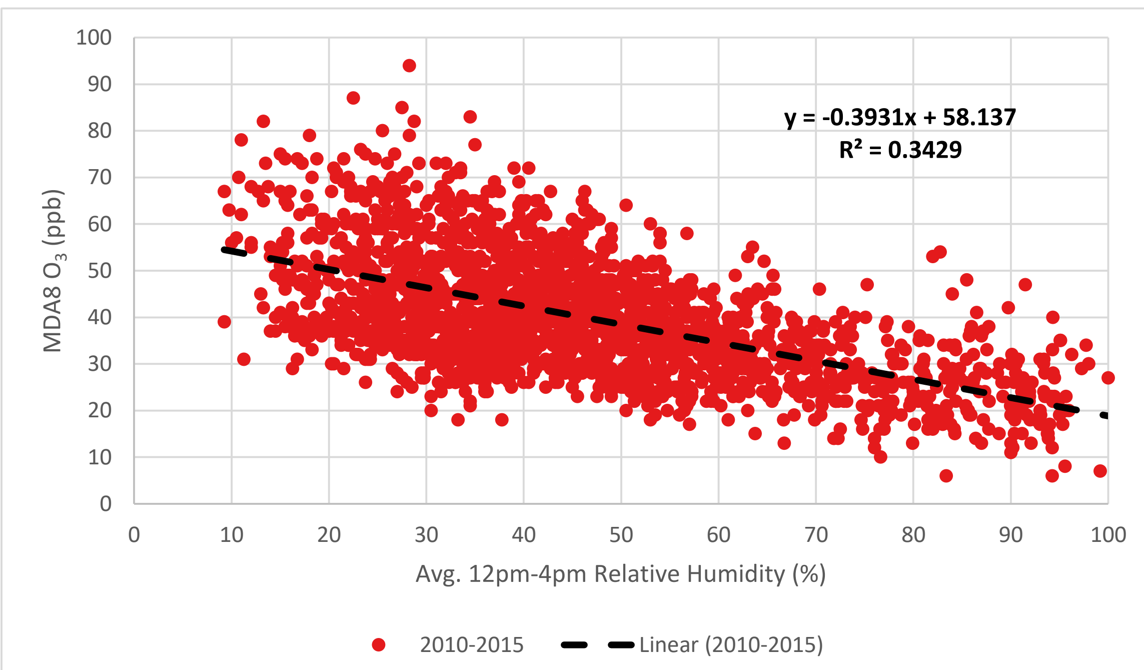


Figure 4-21. Scatter Plot of 12 pm – 4 pm Relative Humidity at Camp Mabry v. MDA8 O_3 at CAMS 3, 2016

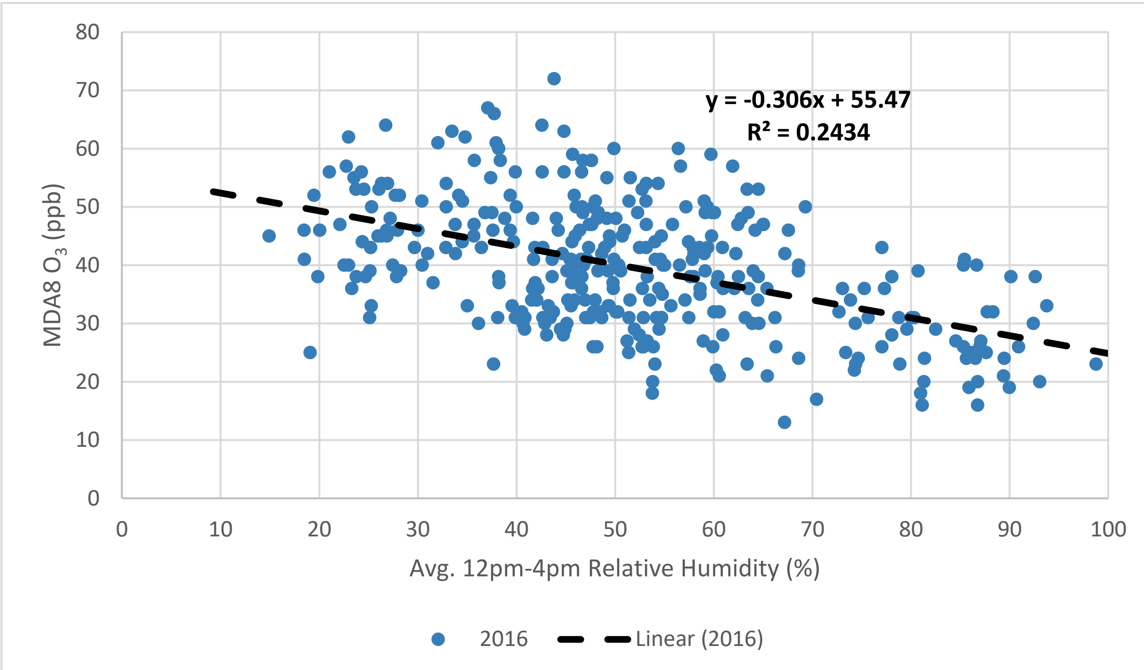


Figure 4-18. Scatter Plot of 12 pm – 4 pm Relative Humidity at Camp Mabry v. MDA8 O_3 at CAMS 3, 2017

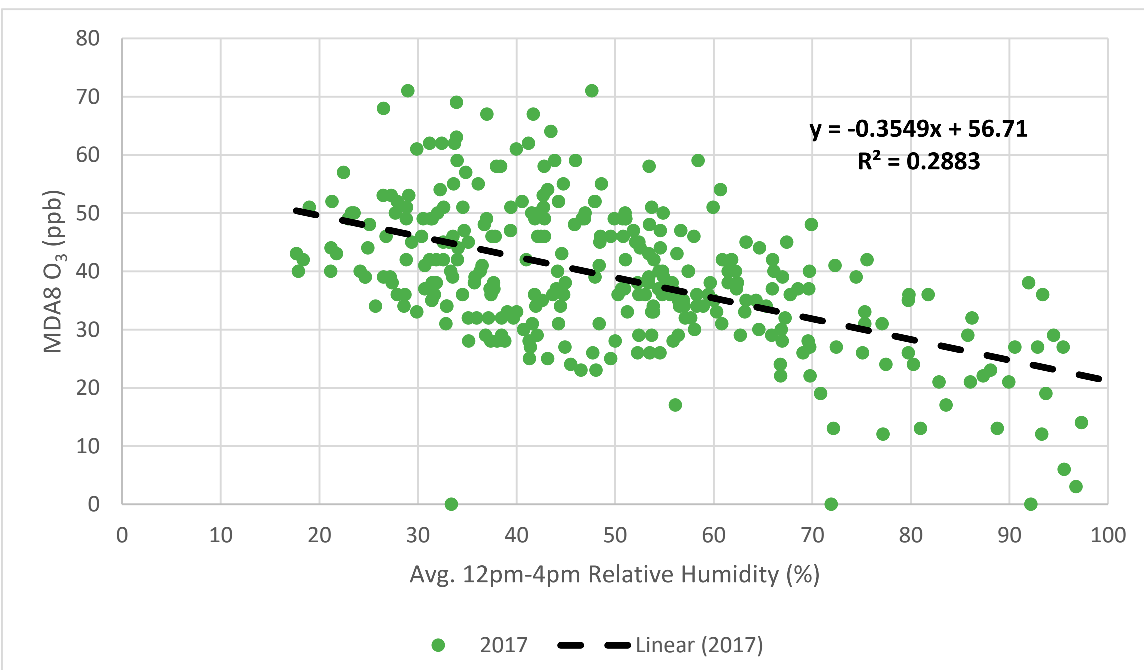
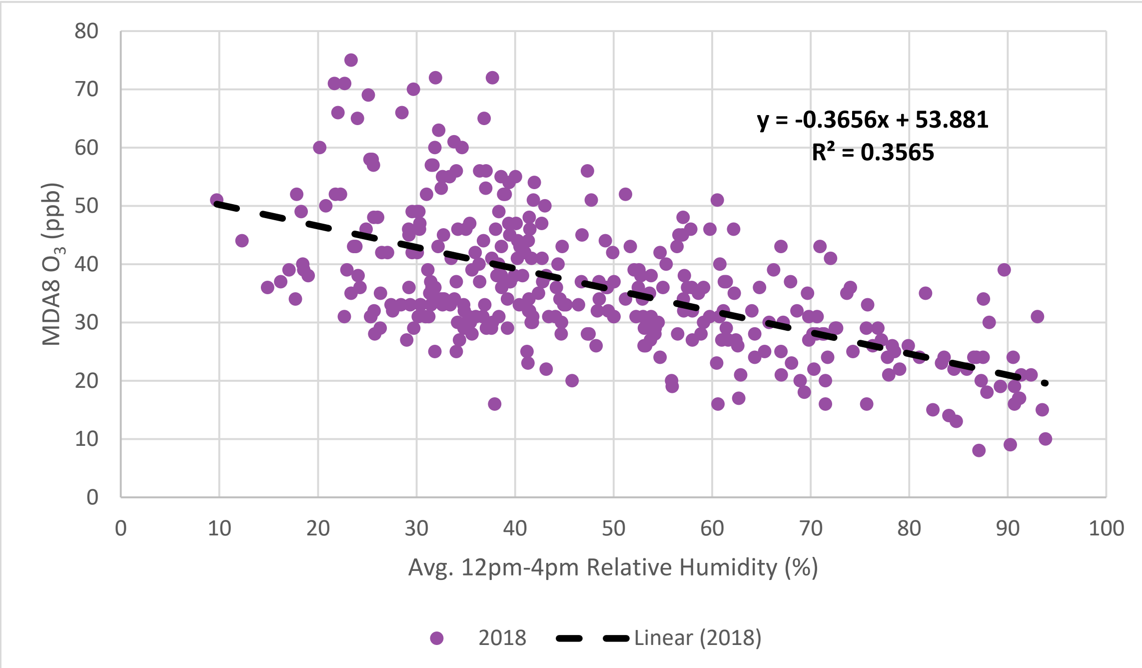
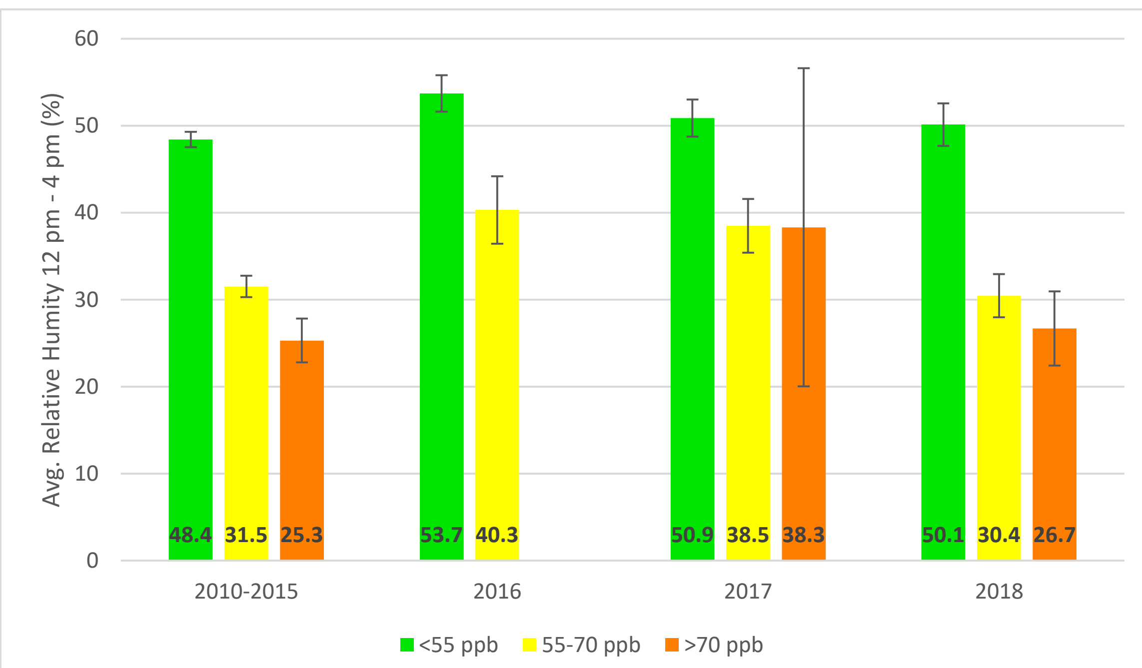


Figure 4-23. Scatter Plot of 12 pm – 4 pm Relative Humidity at Camp Mabry v. MDA8 O_3 at CAMS 3, 2018



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 2018 relative to 2017, 2016, and 2010-2015.

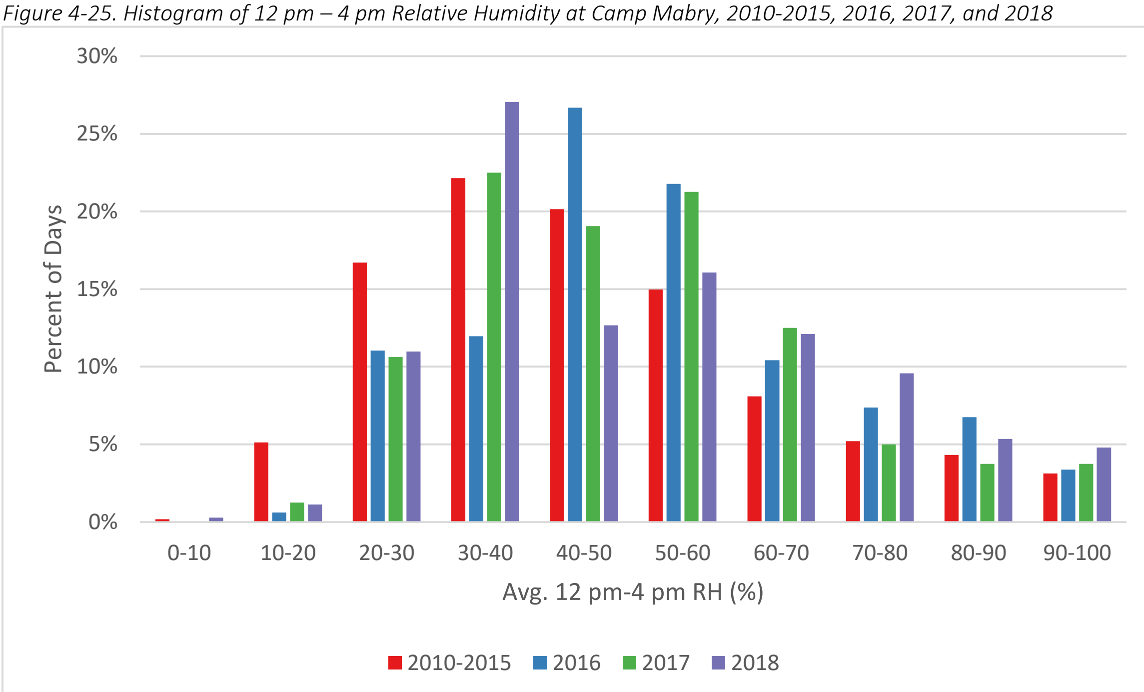
Figure 4-24. Typical Relative Humidity 12 pm – 4pm at Camp Mabry on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 3, 2010-2015, 2016, 2017, and 2018



4.4.2 Comparison of 2018 Relative Humidity to 2010-2017 Relative Humidity

The figure below shows the distribution of RH into ten bins and compares observed data in 2018 to previous studied timeframes. Overall this data suggests that 2018 had more days with RH above 70% which would suggest that there were fewer chances for the formation of high levels of O_3, however, 2018 also had the highest percentage of days in the 30-40% bin which may explain the frequency of high O_3 days in 2018.

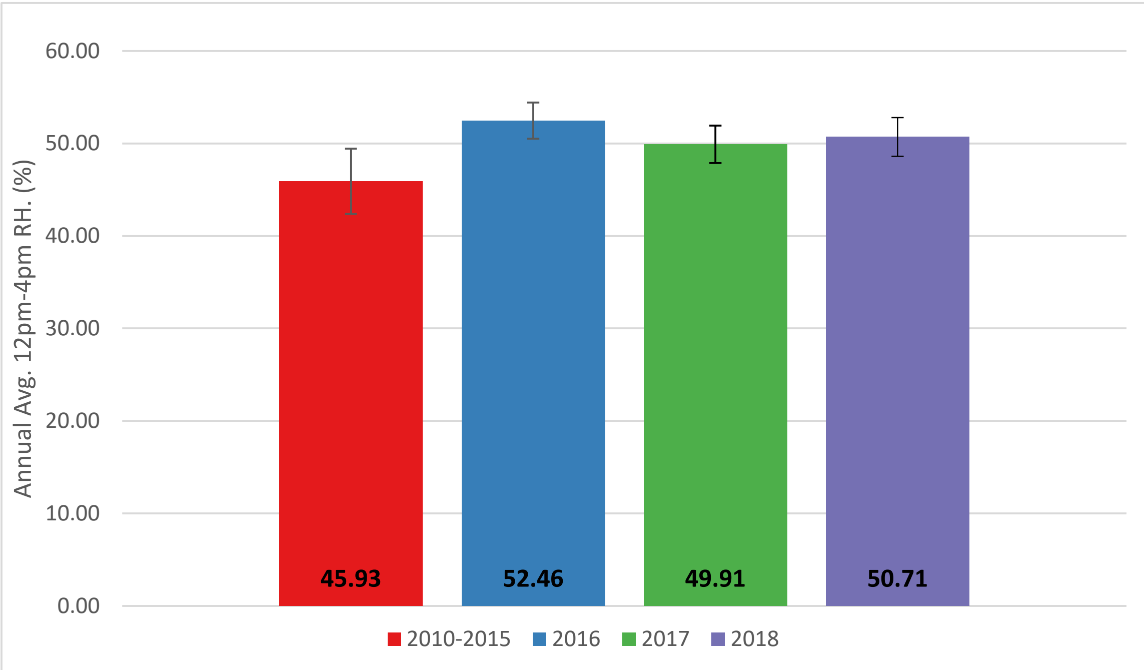
Figure 4-25. Histogram of 12 pm – 4 pm Relative Humidity at Camp Mabry, 2010-2015, 2016, 2017, and 2018



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 significantly different from the 2010-2015, 2016, and 2017 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 50.11% 12 pm – 4 pm relative humidity in 2018 was above the upper bound of the confidence interval for the 2010-2015 average.

Figure 4-26. Annual Avg. 12 pm-4 pm Relative Humidity at Camp Mabry, 2010-2015, 2016, 2017, and 2018



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

4.5.1 Comparison of Relationship between Solar Radiation and MDA8 O_3 in 2018 to 2010-2017

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 2017, 2016, and 2010-2015. As the figures show, the 2018 data was consistent in showing a positive correlation between these two factors.

Figure 4-27. Scatter Plot of 12 pm – 4 pm Solar Radiation at CAMS 38 v. MDA8 O_3 at CAMS 38, 2010-2015

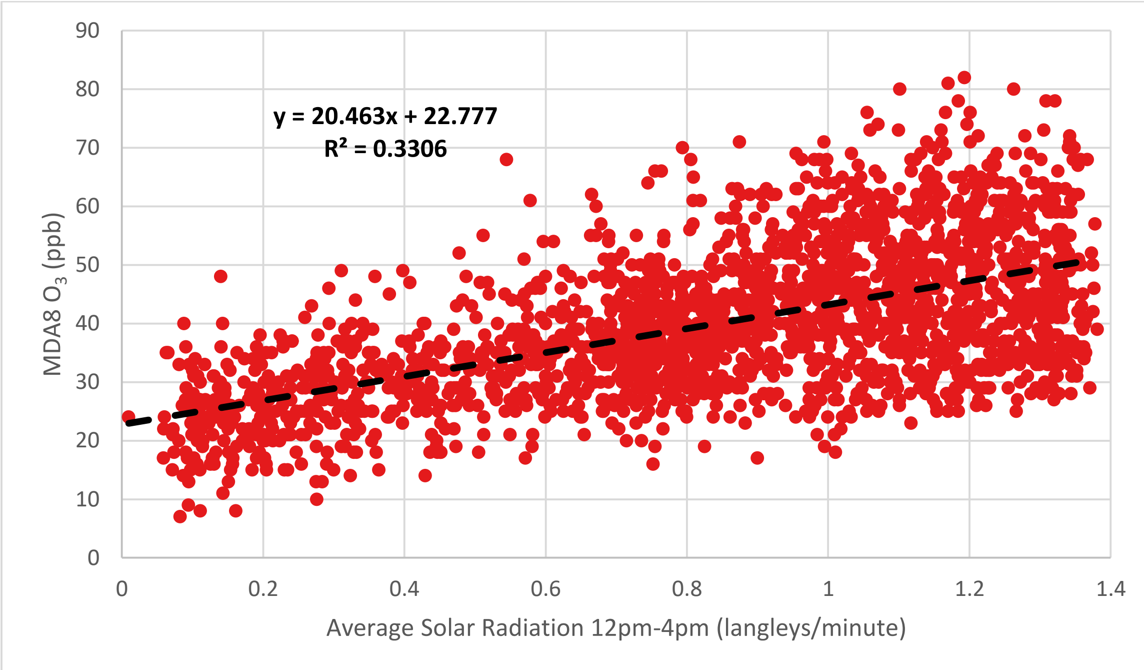


Figure 4-28. Scatter Plot of 12 pm – 4 pm Solar Radiation at CAMS 38 v. MDA8 O_3 at CAMS 38, 2016

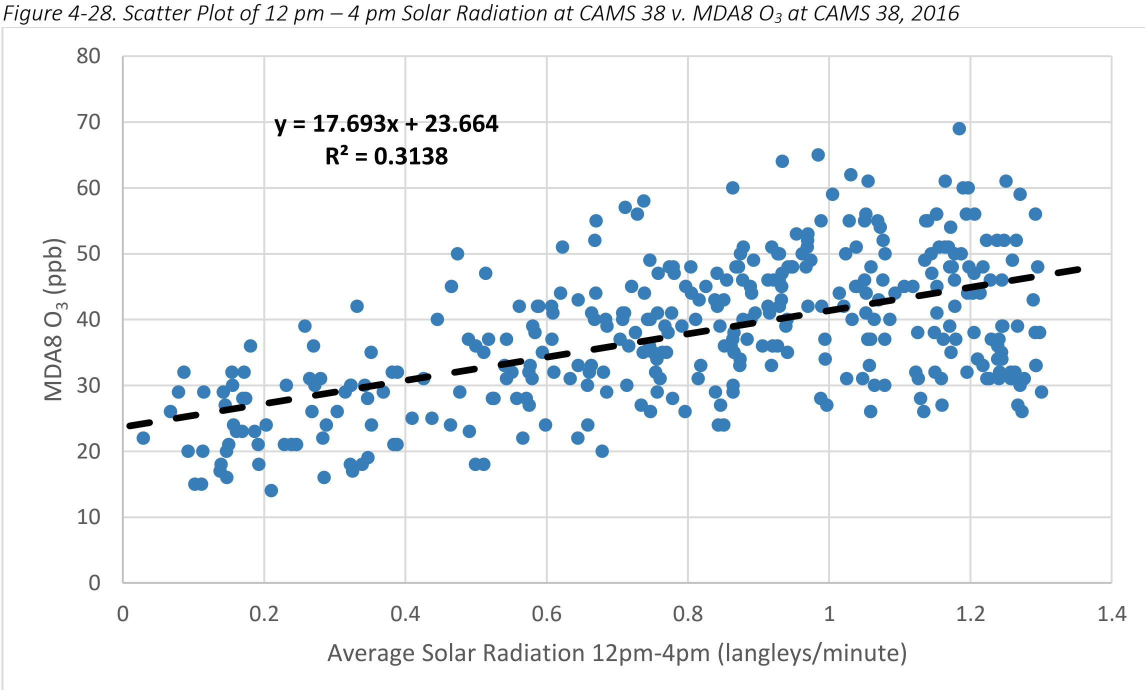


Figure 4-19. Scatter Plot of 12 pm – 4 pm Solar Radiation at CAMS 38 v. MDA8 O_3 at CAMS 38, 2017

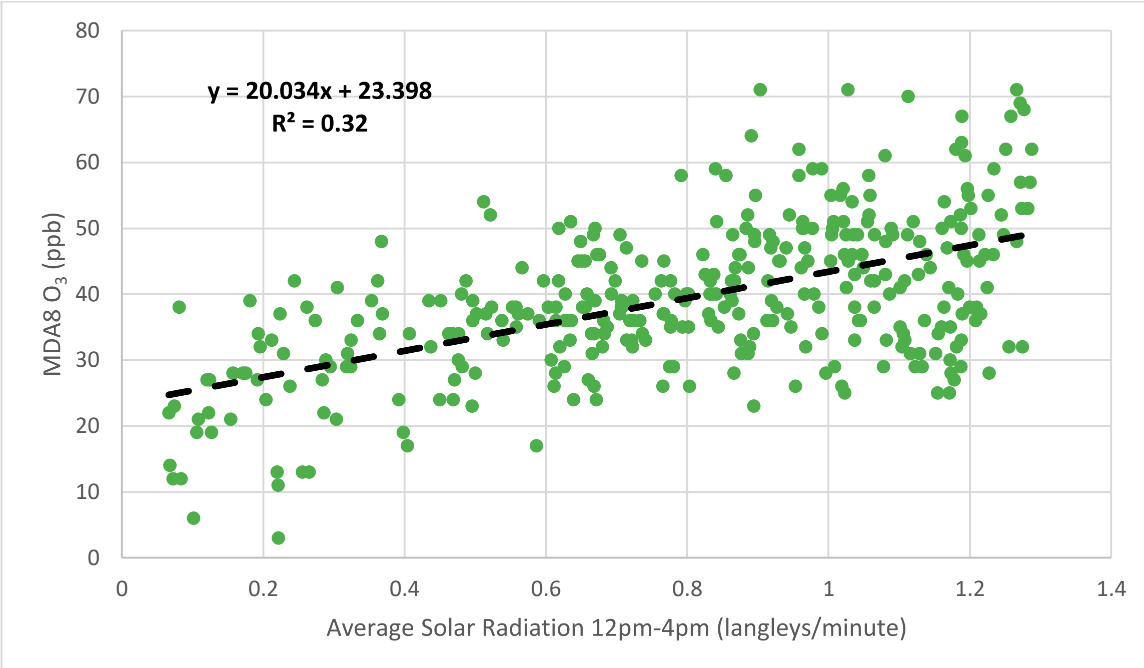
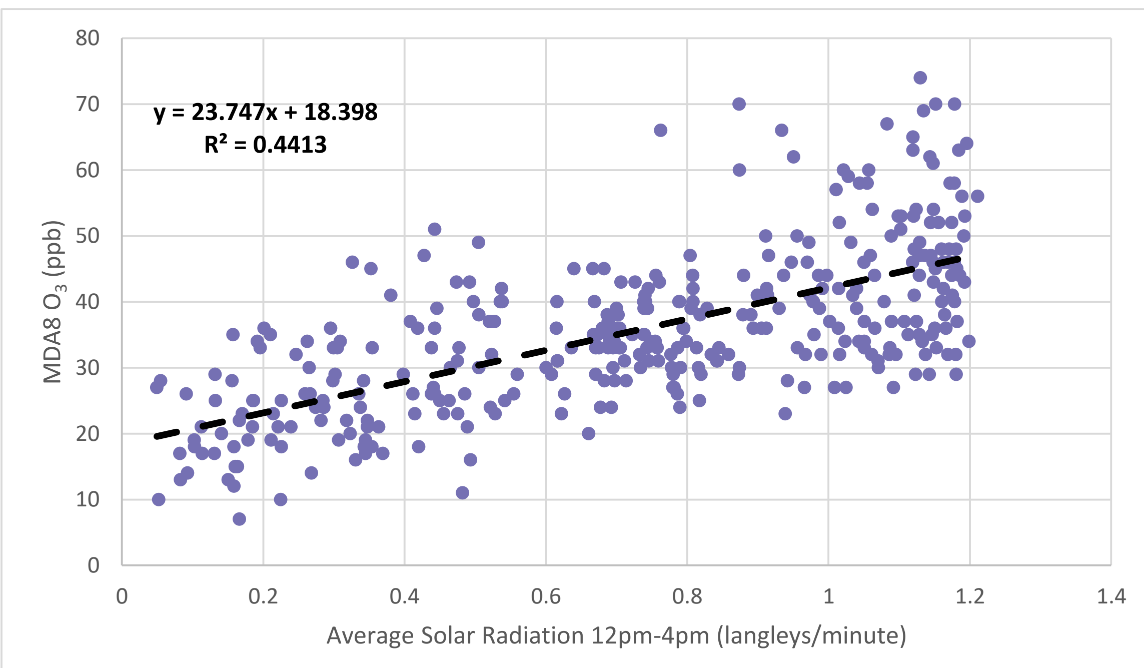
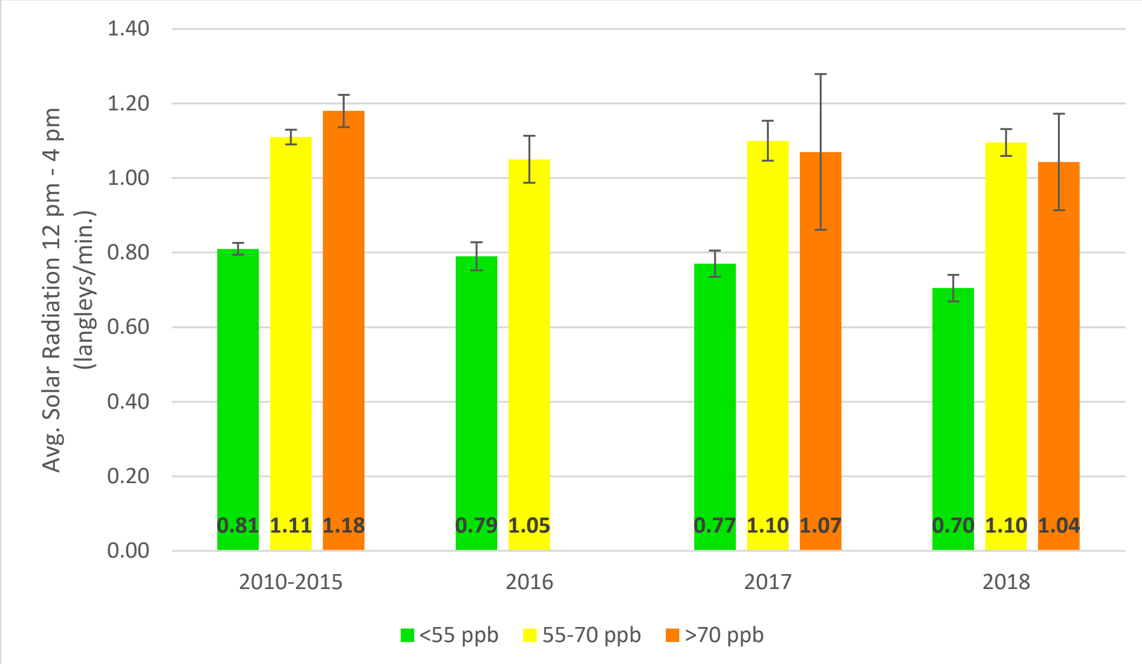


Figure 4-30- Scatter Plot of 12 pm – 4 pm Solar Radiation at CAMS 38 v. MDA8 O_3 at CAMS 38, 2018



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 2018 relative to 2017, 2016, and 2010-2015.

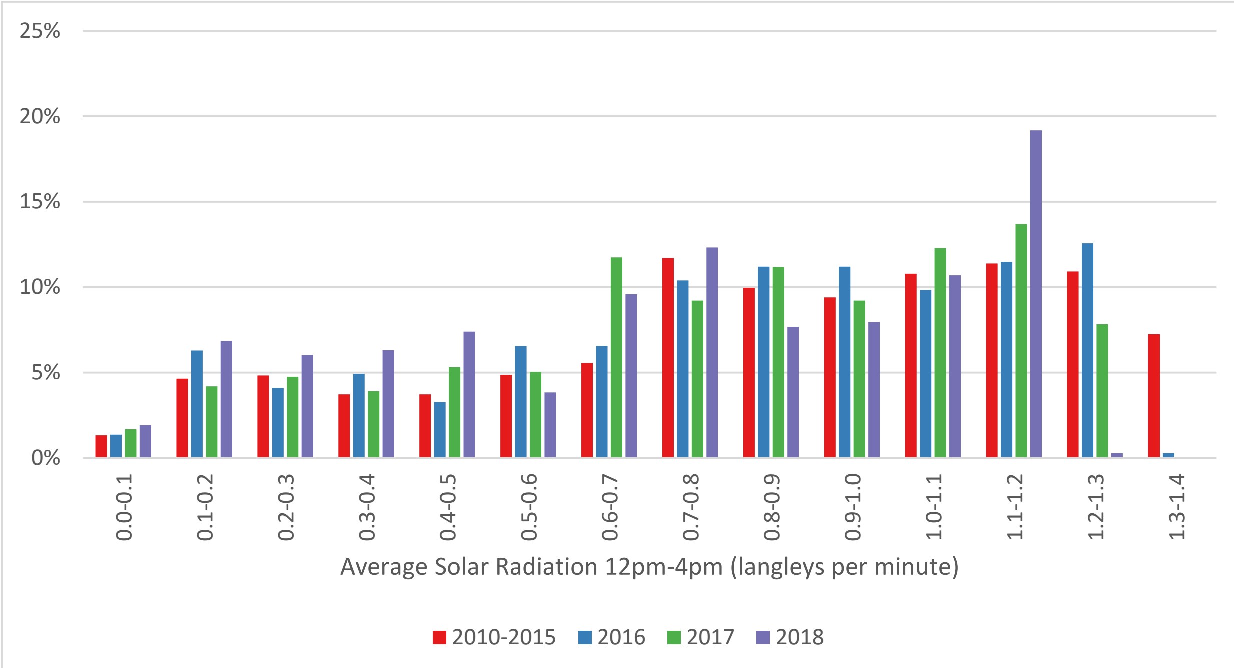
Figure 4-20. Typical Solar Radiation 12 pm – 4pm at CAMS 38 on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 38, 2010-2015, 2016, 2017, and 2018



4.5.2 Comparison of 2018 Solar Radiation to 2010-2017 Radiation

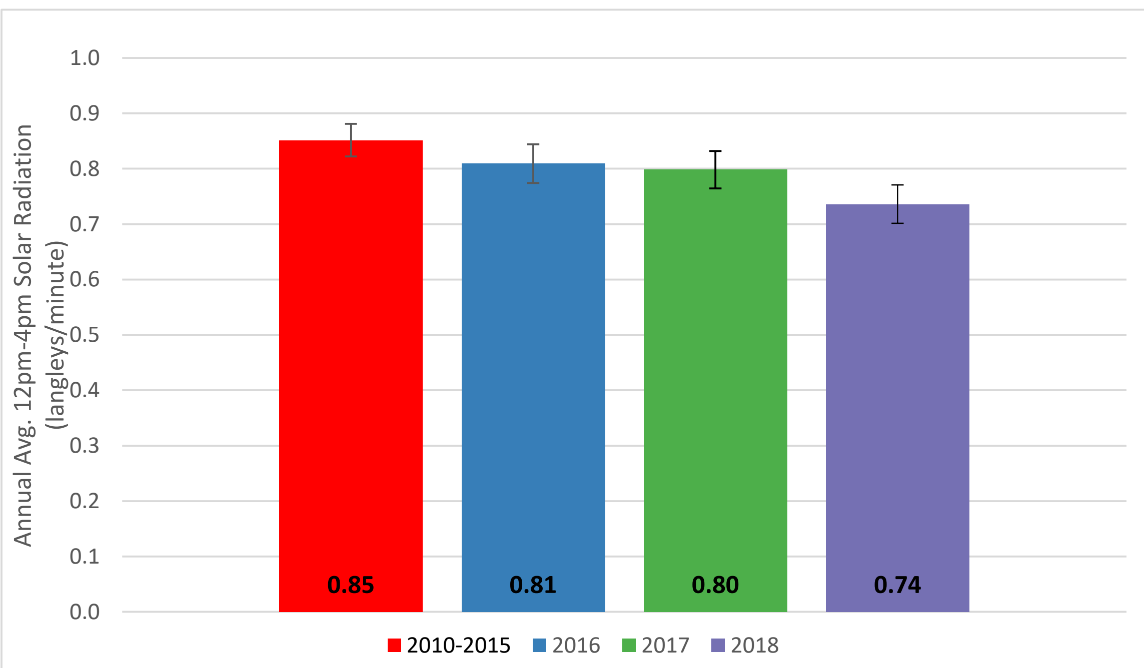
Based on a review of the meteorological data in 2010-2015, 2016, 2017, and 2018, CAPCOG was able to determine that there were statistically significant differences in the 12 pm – 4 pm solar radiation at CAMS 38 in 2018 compared to 2010-2015, 2016, and 2017. The distribution of days into 0.1 langley/minute bins in the histogram below shows that 2018 had substantially more days with the highest level of solar radiation at or below 0.5 langleys/minute and in the 1.1 – 1.2 langleys/minute range than what was observed in previous timeframes.

Figure 4-32. Histogram of 12 pm – 4 pm Solar Radiation at CAMS 38, 2010-2015, 2016, 2017, and 2018



CAPCOG also performed a confidence interval analysis of the average annual 12 pm – 4 pm solar radiation. The average 0.74 langley/minute average for 2018 was below the lower limit of the 95% confidence interval for the average annual solar radiation values for 2010-2015.

Figure 4-33. Annual Avg. 12 pm-4 pm Solar Radiation at CAMS 38, 2010-2015, 2016, 2017, and 2018



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 2018. In CAPCOG's 2010-2015 Conceptual Model, CAPCOG developed HYSPLIT[2] 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 2018 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) in the MDA8
- 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 ten total days in 2018 when a CAPCOG region monitor recorded ground level O_3 >70 ppb.

Table 4-1. MDA8 O_3 >70 ppb, 2018

Date	MDA8 Level (ppb)	Location	Start Hour for Peak 1-hr. Avg.
April 28, 2018	73	CAMS 690	10:00 AM
May 7, 2018	72	CAMS 3	10:00 AM
	71	CAMS 614	11:00 AM
	77	CAMS 690	10:00 AM
	71	CAMS 1603	11:00 AM
	71	CAMS 6602	10:00 AM
July 23, 2018	72	CAMS 1675	11:00 AM
July 25, 2018	74	CAMS 3	11:00 AM
	71	CAMS 614	11:00 AM
	74	CAMS 1603	9:00 AM
July 26, 2018	71	CAMS 3	10:00 AM
	72	CAMS 1603	11:00 AM
	74	CAMS 1675	10:00 AM
July 27, 2018	71	CAMS 3	10:00 AM
July 31, 2018	72	CAMS 3	12:00 PM
	80	CAMS 1603	1:00 PM
	76	CAMS 1675	11:00 AM
August 1, 2018	73	CAMS 1603	10:00 AM
	84	CAMS 1675	11:00 AM
August 2, 2018	75	CAMS 3	10:00 AM
	74	CAMS 38	9:00 AM
	77	CAMS 614	11:00 AM
	73	CAMS 690	10:00 AM
	82	CAMS 1603	12:00 PM
	82	CAMS 1675	10:00 AM
August 3, 2018	72	CAMS 1603	10:00 AM
	72	CAMS 1675	10:00 AM

[2] Hybrid Single-Particle Lagrangian Integrated Trajectory

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

Figure 4-21 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 elevations – 100 m, 500 m, and 1,000 m. In 2018, upwind counties were most often to the southwest of the region. This is in line with trends from previous years where days with MDA8 O_3 >70 ppb typically have back trajectories from southwest of the MSA. CAMS 684, 1604, and 1605 are not shown in the figure below since these monitoring stations didn't record any MDA8 O_3 values >70 ppb in 2018.

Figure 4-21. Number of Days Upwind in 2018 per County on Days with MDA8 O3 days >70 ppb at a CAPCOG region monitor at elevations of 100m, 500m, and 1,000m

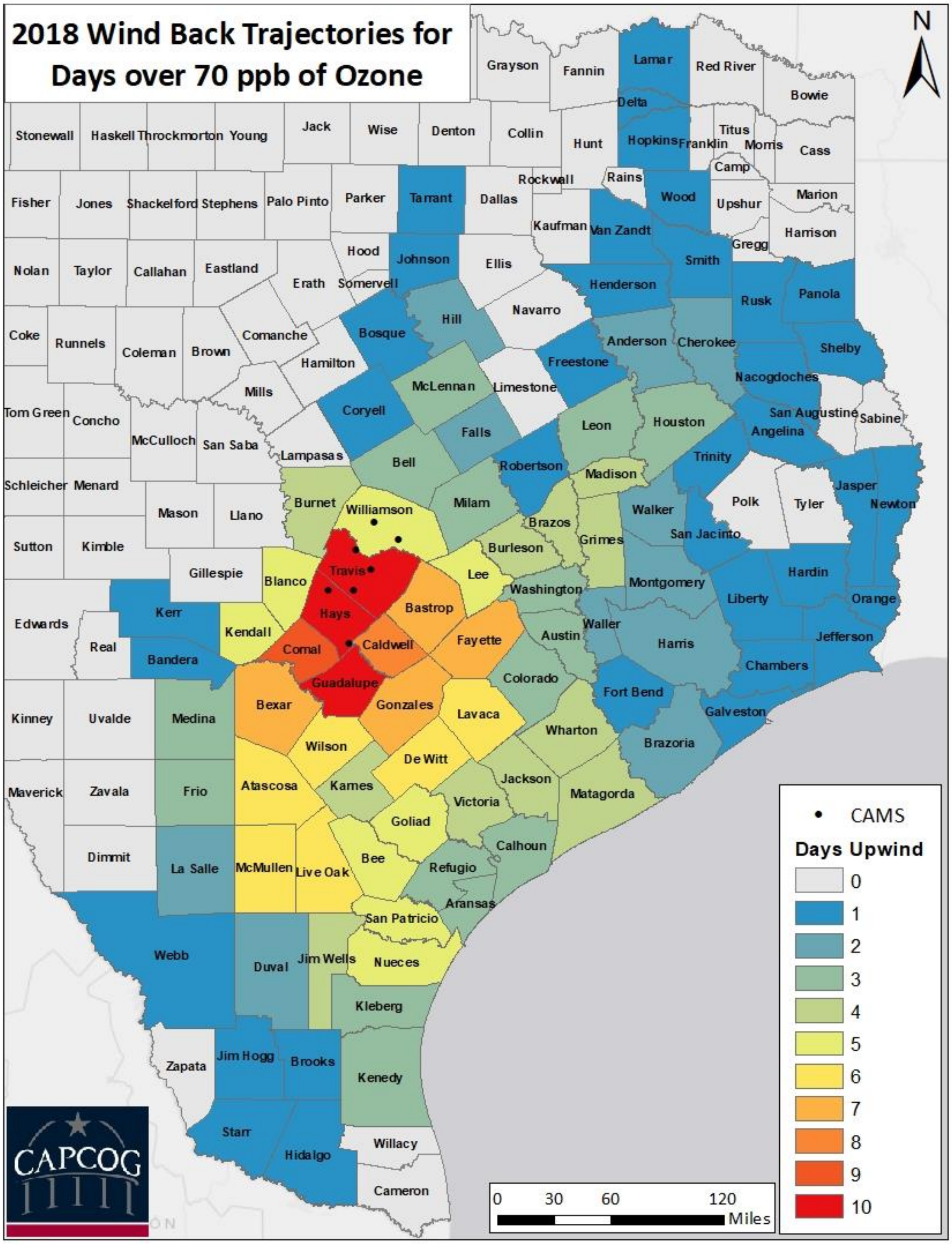
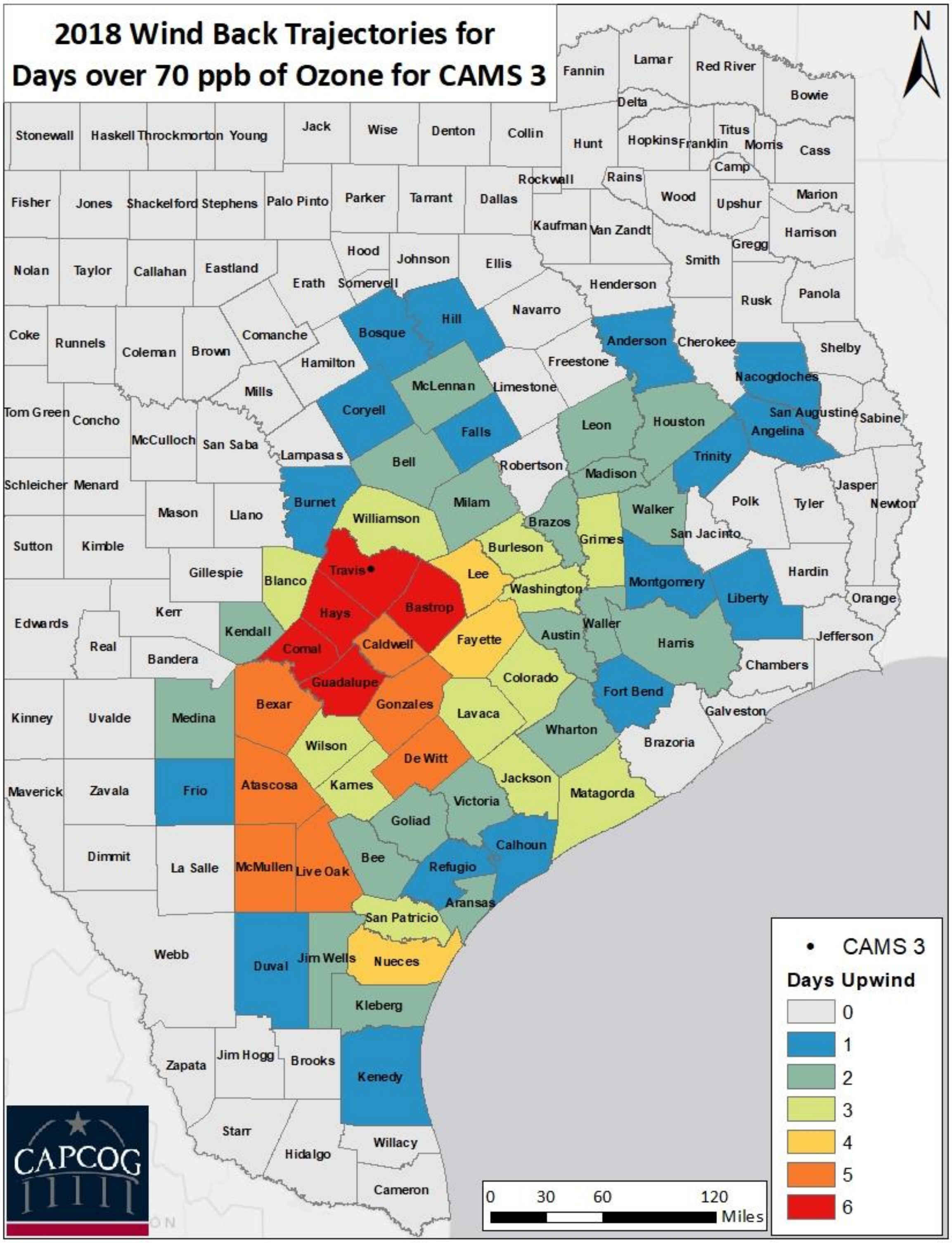


Figure 4-22 displays the same data for just CAMS 3 due to its importance for regulatory compliance. Six days >70 ppb were recorded at CAMS 3 in 2018.

Figure 4-22. Number of Days Upwind in 2018 per County on Days with MDA8 O3 days >70 ppb at CAMS 3 at elevations of 100 m, 500 m, and 1,000 m



As evident in the figure above, the majority of the upwind counties were south and southwest from CAMS 3. This indicates that O_3 could be transported from the San Antonio metro area and the Eagle Ford Shale oil and gas production area.

4.6.2 Wind Direction on days with MDA8 O_3 at 80 ppb or above

In 2018, the region experienced three days with MDA8 O_3 at 80 ppb or above, July 31, August 1, and August 2. This was the first time the region experienced MDA8 O_3 levels that high since August 28, 2015, when CAMS 3 and CAMS 38 reached 85 ppb and 82 ppb respectively. Those CAMS were also at or above 80 ppb on August 27th and 29th in 2015. The monitors that reached this threshold in 2018 were CAMS 1603 and CAMS 1675, which are both in the southern parts of the region. The below figures are the wind back-trajectories on those days, that generally show that the winds on those days were from the southwest with the exception of August 1st, when the back-trajectories at different elevations did not follow a consistent trend.

Figure 4-23. Wind Back-Trajectories on July 31, 2018, for Monitors over 80 ppb.

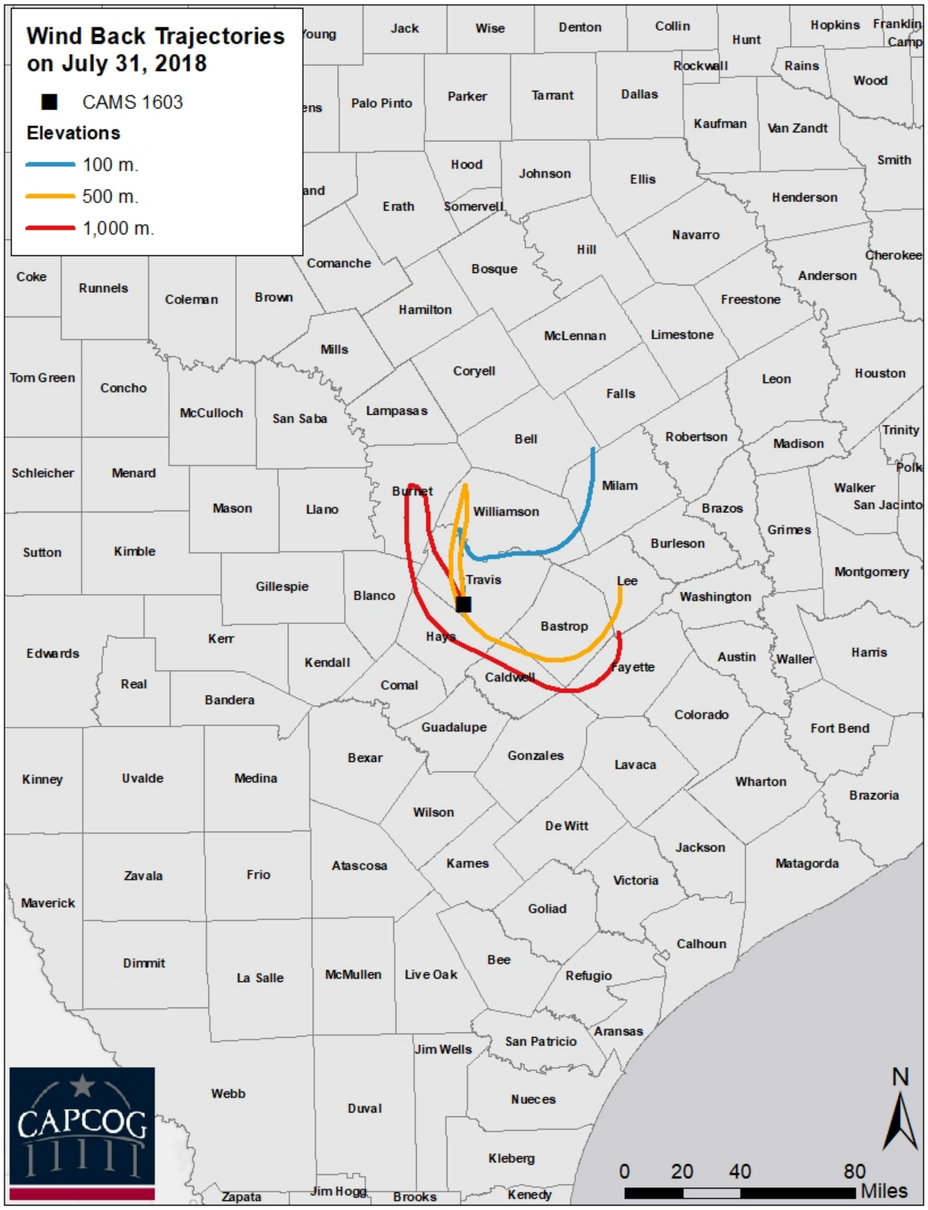


Figure 4-24. Wind Back-Trajectories on August 1, 2018, for Monitors over 80 ppb.

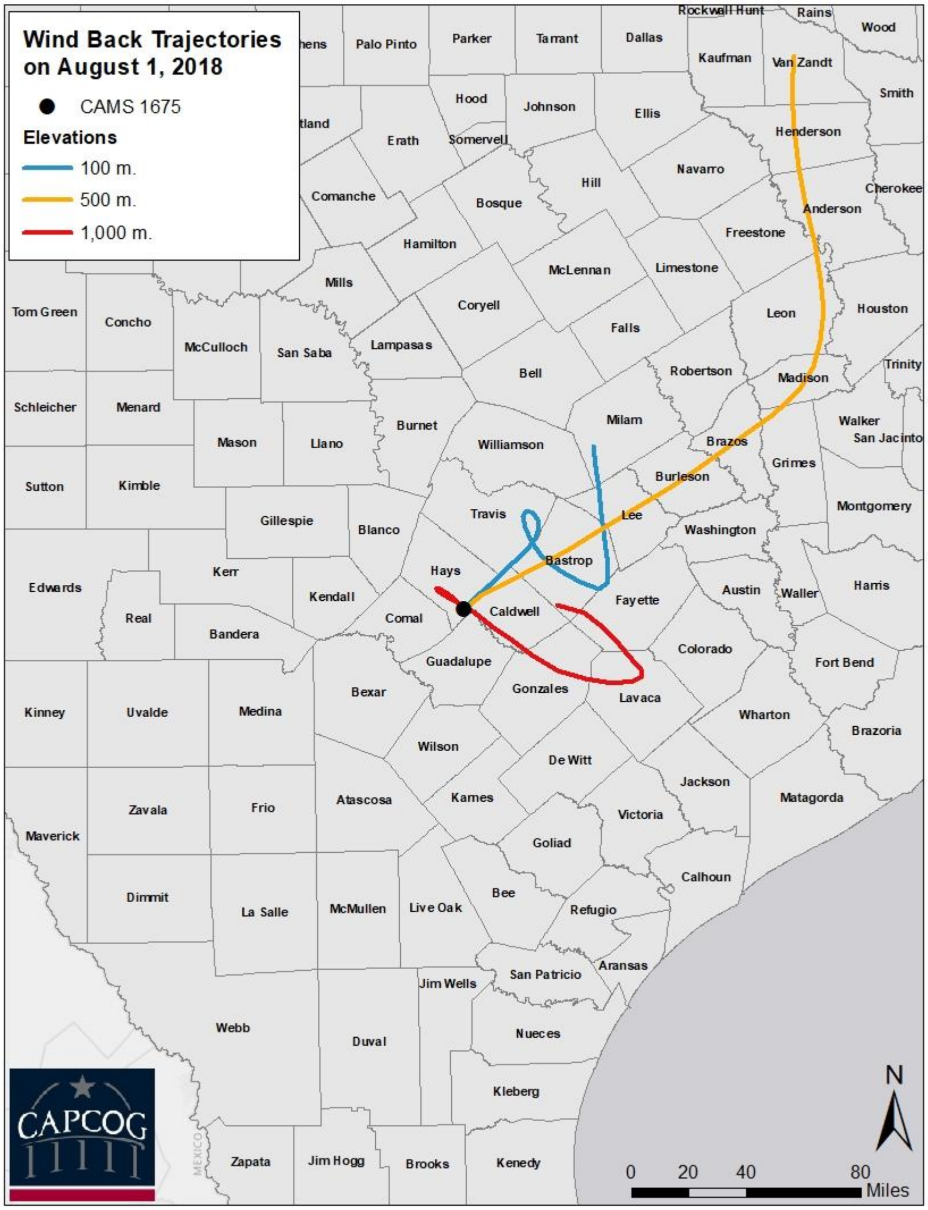
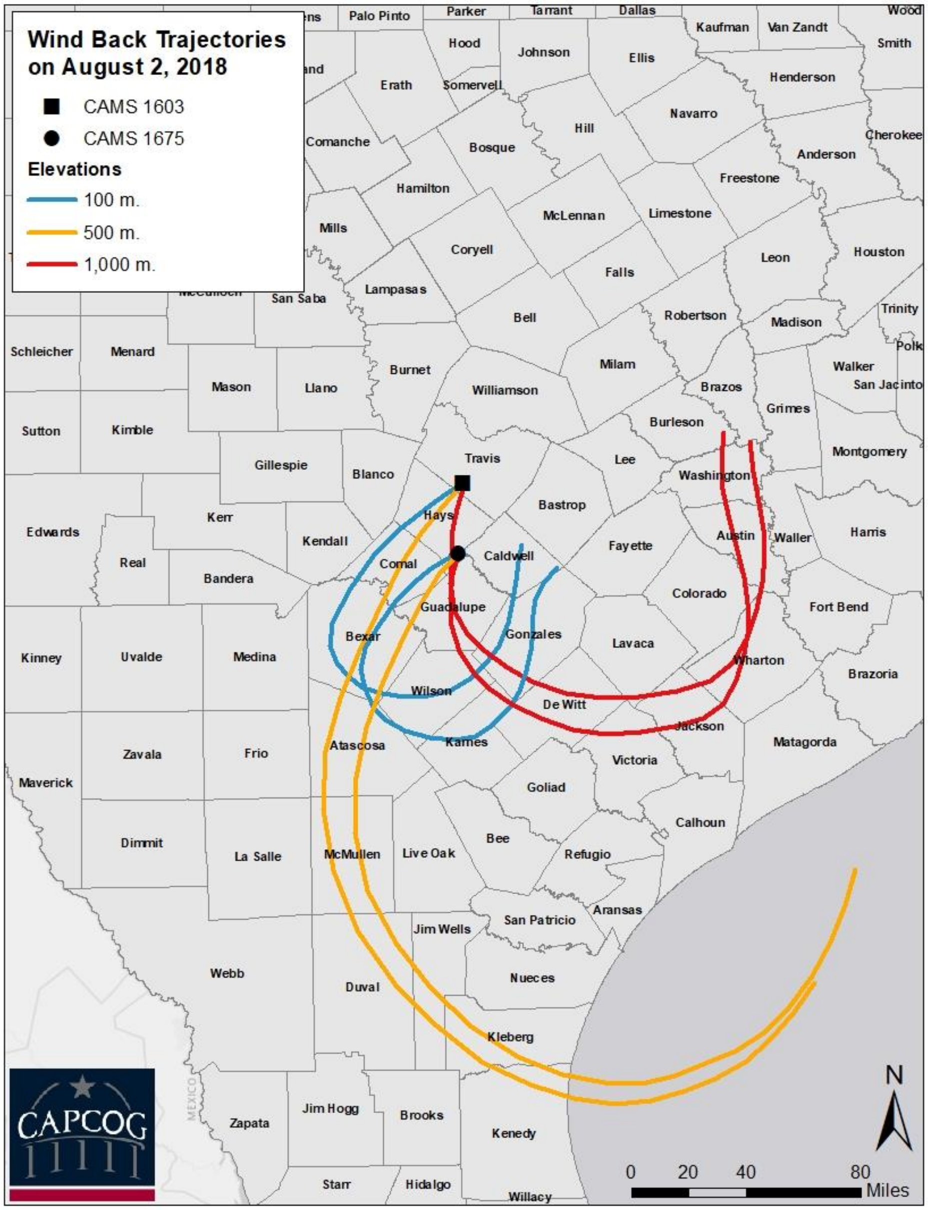


Figure 4-25. Wind Back-Trajectories on August 2, 2018, for Monitors over 80 ppb.



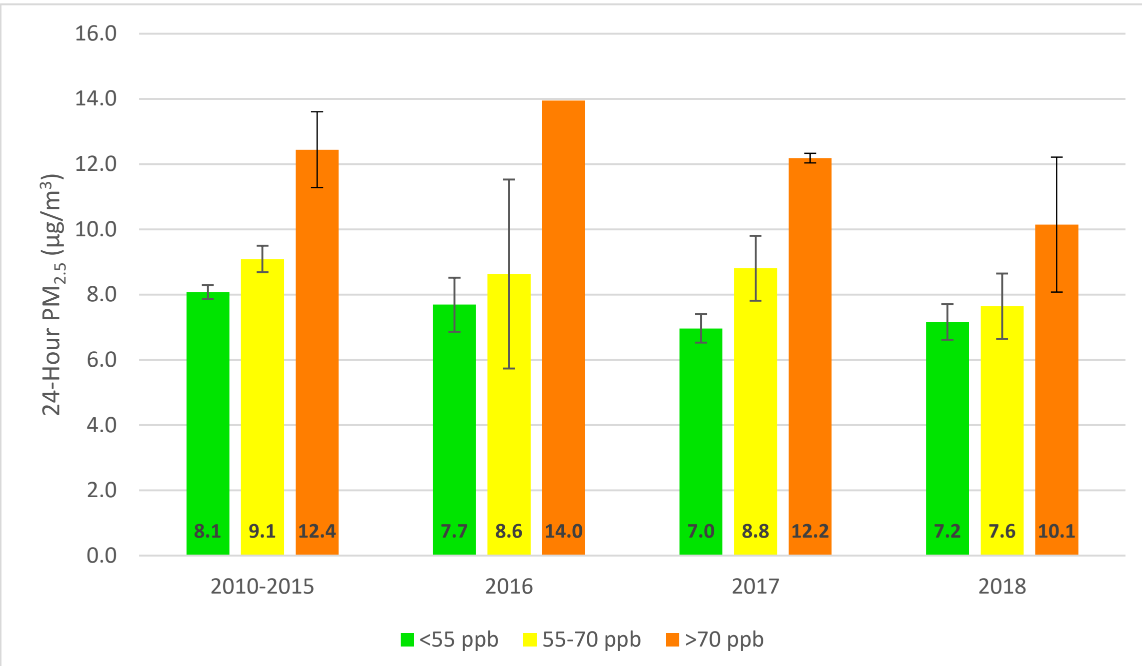
5 Correlation between MDA8 and Other Criteria Pollutants

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 2018 data compared to 2010-2015, 2016, and 2017. 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 O_3 MDA8 values at CAMS 3 were >70 ppb, 55-70 ppb, and <55 ppb. The following figure shows a comparison of these data.

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, 2010-2015, 2016, 2017, and 2018

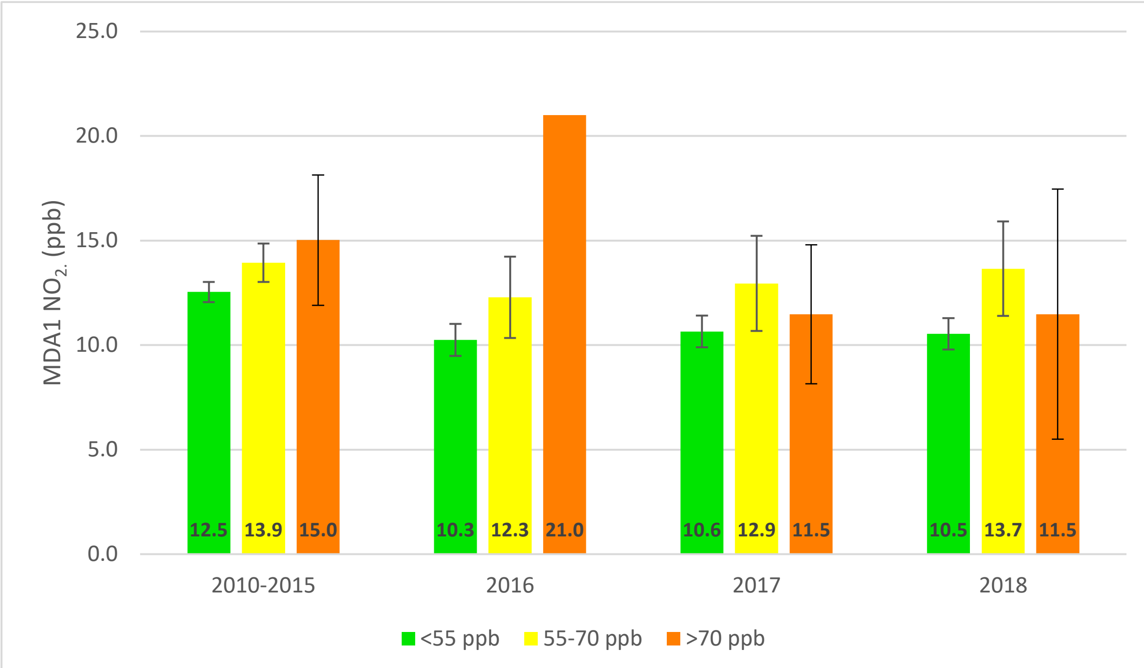


$PM_{2.5}$ concentrations in 2018 continued a similar trend from previous timeframes in which days with lower $PM_{2.5}$ concentrations also had lower MDA8 O_3, and vice-versa. However, 2018 is notable for having a lower average $PM_{2.5}$ concentration on days when MDA8 O_3 was observed >70 ppb than the averages for 2010-2015, 2016, and 2017.

5.2 NO_2

CAPCOG calculated the average maximum daily 1-hour (MDA1) NO_2 concentrations when the O_3 MDA8 values at CAMS 3 were >70 ppb, 55-70 ppb, and <55 ppb. The following figure shows a comparison of these data.

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, 2010-2015, 2016, 2017, and 2018

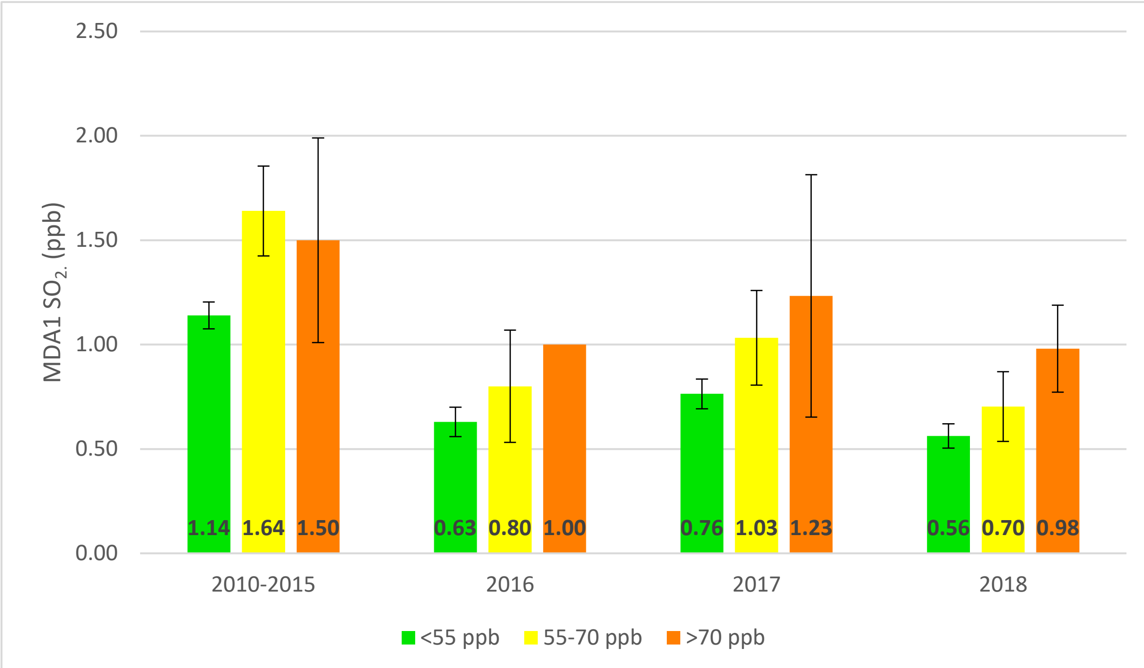


MDA1 NO_2 concentrations in 2018 continued a trend from 2017 where the relationship with MDA8 O_3 is not consistent or strong enough to show that high MDA1 NO_2 concentrations are significantly correlated with high MDA8 O_3 concentrations in the region.

5.3 SO_2

CAPCOG calculated the average MDA1 SO_2 concentrations when the O_3 MDA8 values at CAMS 3 were >70 ppb, 55-70 ppb, and <55 ppb. The following figure shows a comparison of these data.

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, 2010-2015, 2016, 2017, and 2018

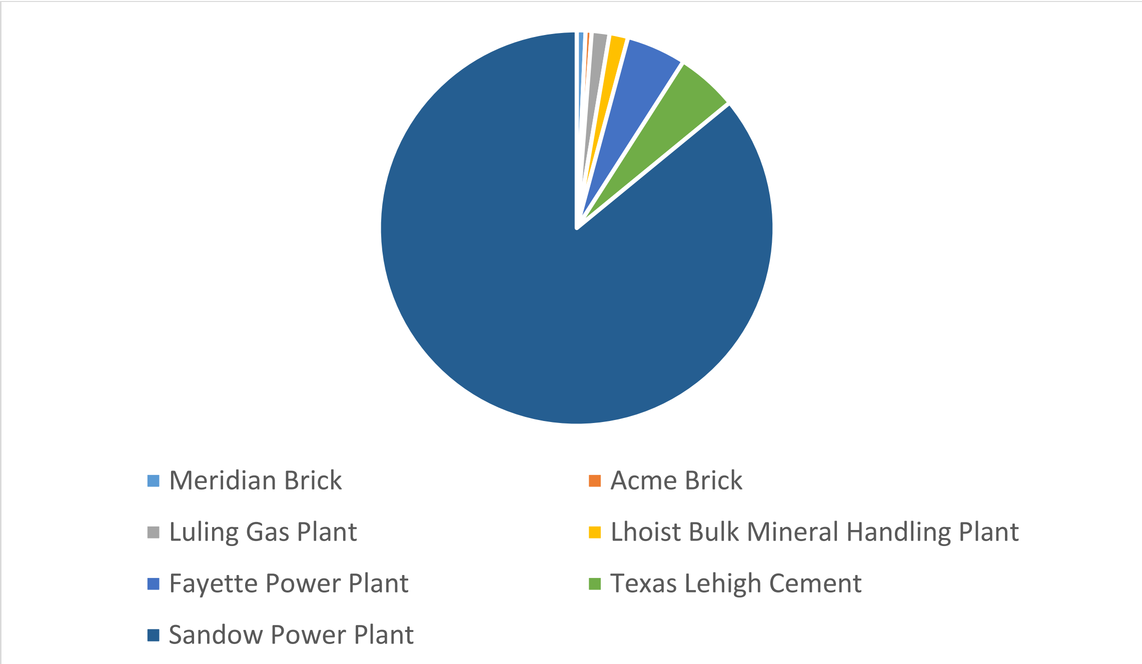


2018 MDA1 SO_2 concentrations and the relationship with MDA8 O_3 levels continue to show a similar trend from 2016 and 2017 with higher MDA1 SO_2 concentrations at higher MDA8 O_3 levels. MDA1 SO_2 concentrations were significantly different in 2018 when MDA8 O_3 levels were >70 ppb compared to days when MDA8 O_3 levels were <55, and 55-70 ppb.

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 (Bell, Blanco, Burnet, Comal, Guadalupe, Gonzales, Fayette, Lee, and Milam) from TCEQ's point source emissions inventory summary for 2017 (the most recent year for which a comprehensive point source emissions inventory is available for all facilities).[3] As the figure shows, the Sandow plant in Milam County accounted for by far the largest amount of point-source SO_2 emissions within the vicinity in 2017. However, Luminant shut down this plant prior to the 2018 O_3 season along with two other large coal-fired power plants in the eastern half of the state, which may help explain the significantly lower average MDA1 SO_2 concentrations on days with MDA8 O_3 >70 ppb than was observed in 2017. Based on the back-trajectories observed on high O3 days in 2017 and 2018, however, when high O_3 more often came out of the southwest, it is unlikely that the closure of these plants would explain the decrease in average peak SO_2 concentrations when MDA8 O3 was >70 ppb. However, it could have played a role in the lower SO2 levels observed in the "good" and "moderate" O3 ranges between 2017 and 2018.

[3] https://www.tceq.texas.gov/assets/public/implementation/air/ie/pseisums/2016statesum.xlsx

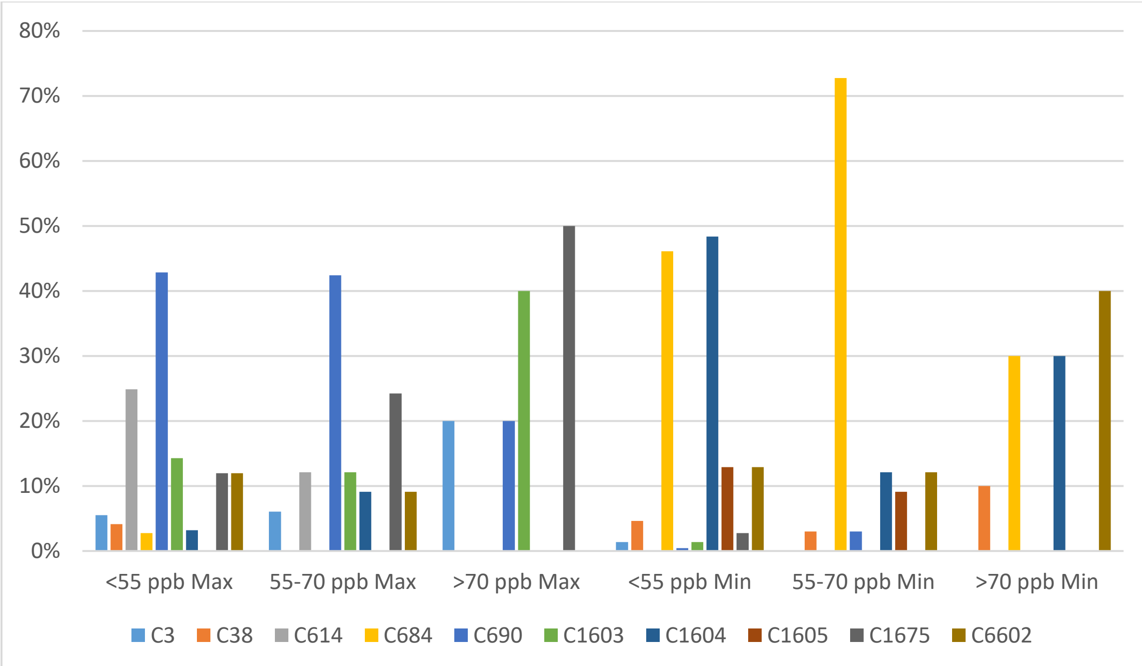
Figure 5-4. 2017 SO_2 Emissions from Major Point Sources in Austin-Round Rock-Georgetown MSA and Adjacent Counties



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 days when at least three monitors recorded data. CAPCOG performed this same analysis on the data collected in the region in 2018. 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 2010-2015, 2016, 2017, and 2018.

The following figures show the % 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, 2018 – November 15, 2018. This was the timeframe in which CAPCOG's non-regulatory monitors were operating.



A few significant notes about this figure:

- CAPCOG's CAMS 1675 most frequently recorded the region-wide maximum MDA8 O_3 when it reached at least 71 ppb, followed by CAPCOG's CAMS 1603, with TCEQ's CAMS 3 and CAPCOG's 690 tied for third, with no other monitoring stations in the region recording the region-wide high on days >70 ppb.
- For days when MDA8 O_3 was 55-70 ppb and <55 ppb, CAPCOG's CAMS 690 was most frequently recording the region-wide max.
- Notably, TCEQ's CAMS 38 did not record the region-wide maximum for any days when MDA8 O_3 was ≥55 ppb.
- St. Edwards University's CAMS 1605 didn't record the region-wide max on any day.
- Similarly, CAMS 684 and 1605 – both of which CAPCOG has concerns about the representativeness of the data for 2018 – never recorded the region-wide max.

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.

Figure 6-1. 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, 2010-2015, 2016, 2017, and 2018

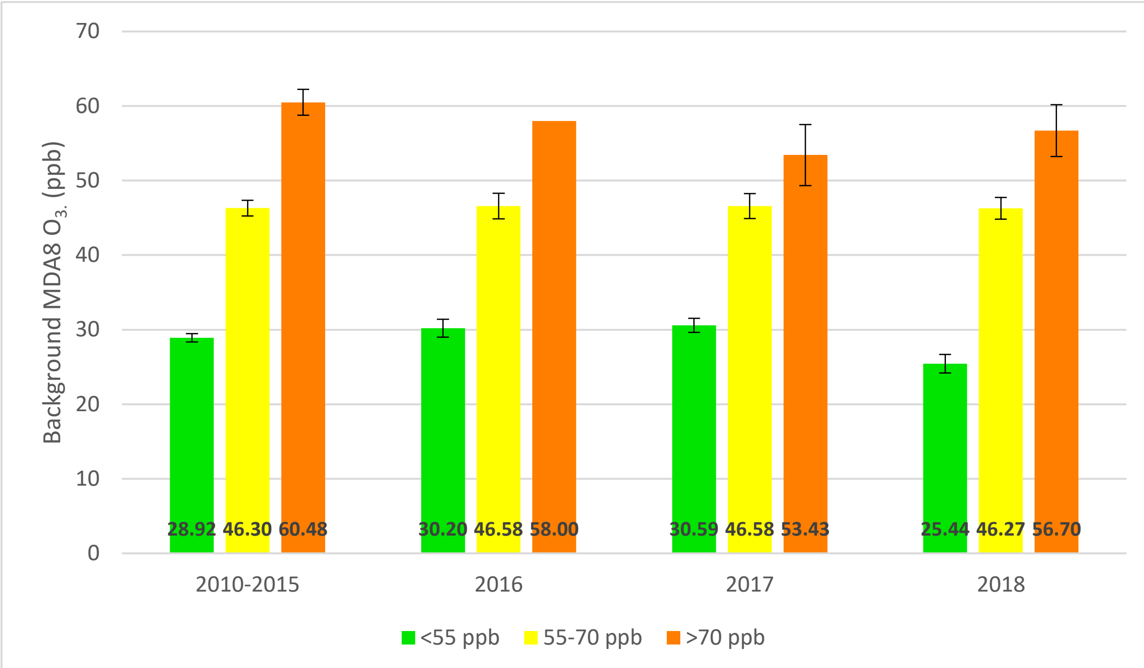
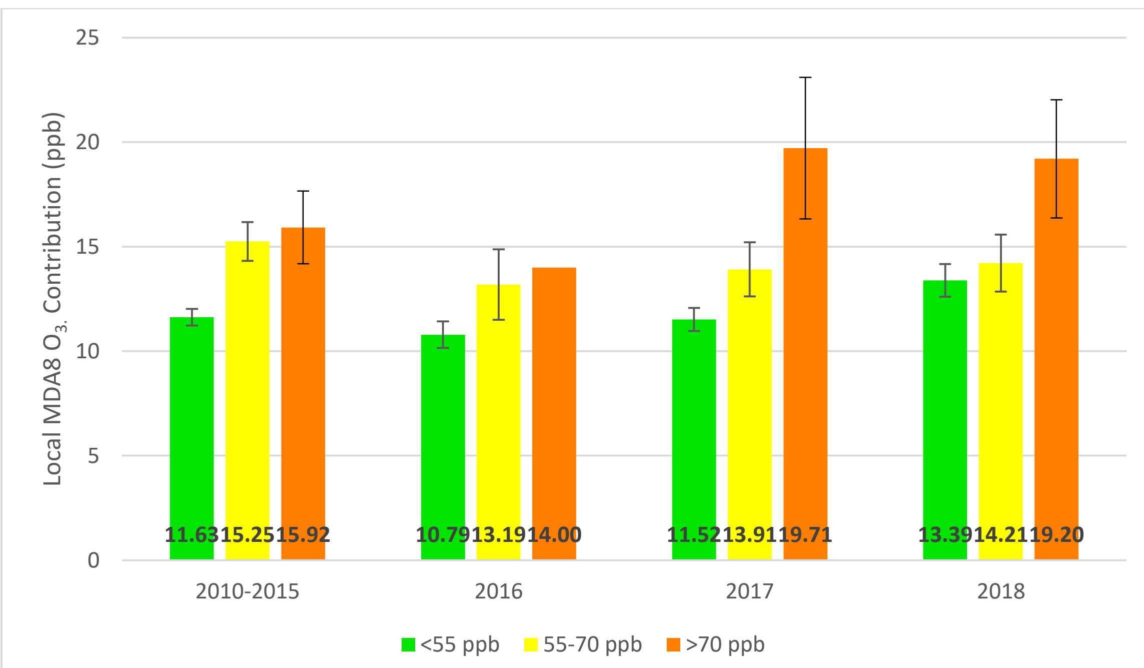


Figure 6-2. Comparison of Local Contribution to MDA8 O3 on Days with MDA8 O3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 3, 2010-2015, 2016, 2017, and 2018



The graphs show that "background" levels in 2018 were lower than 2010-2015 MDA8 O_3 levels on days with <55 ppb and days with >70 ppb, while days MDA8 O_3 levels between 55-70 ppb were within the

95% confidence range. Local contributions were higher in 2018 compared to 2010-2015 when MDA8 O_3 levels were in the <55 ppb and >70 ppb ranges but lower in the 55-70 ppb range.

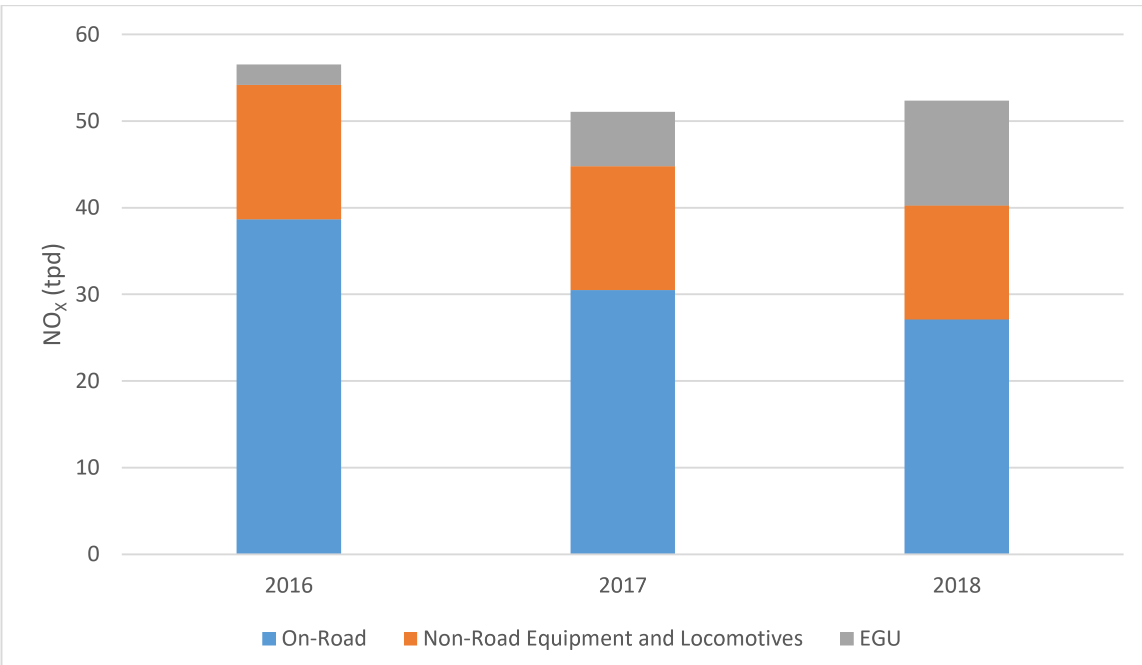
While CAPCOG believes that the O3 measurements at CAMS 684 may have been biased low in recent years due to encroachment of vegetation to the area where the monitoring equipment was located, which could explain why the local contribution estimated using this analysis could have been much higher in 2017 and 2018 than what was typical from 2010-2015. However, there were also fewer O3 monitors in the CAPCOG region for most of 2010-2015 and many of them changed locations, so it is also possible that the 2010-2015 data may not have captured enough of the local contribution due to the positioning of the monitors. There are a number of reasons that CAPCOG decided to leave CAMS 684 in this analysis despite our concerns:

- CAPCOG monitors were both recording the highest and lowest MDA8 O_3 measurements in the region a majority of the days when 8-hour O3 in the region reached >70 ppb.
- CAMS 6602 rather than CAMS 684 was actually most frequently the lowest in the region on days when MDA8 O_3 was >70 ppb.
- When CAPCOG conducted a sensitivity analysis of the data in Figures 6-1 and 6-2, the average local contribution for days when peak MDA8 O3 in the region was 55-70 ppb was actually lower than the local contribution estimated for “good” days when peak MDA8 O3 was <55 ppb, contrary to expectations.

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, and in 2018, the increase in NOX from power plants actually appears to have been enough to push overall regional NO_X emissions higher on high O3 days. Between on-road vehicles, non-road equipment and locomotives, and power plants, NO_X emissions were slightly (just over 1 tpd) higher in 2018 than they were in 2017. Power plant NO_X emissions were much higher in 2018 to 2017, which could partially explain some of the increase in O_3 from 2017 and 2018 due to the higher concentration of emissions from point sources compared to mobile sources..

Figure 7-1. Summary of On-Road, Non-Road, and EGU Point Source NOX Emissions 2016-2018



7.1 EGU Point Sources

2018 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.[4]

[4] 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.

Figure 7-2. Average Daily May – September NO_X Emissions from EGU Point Sources in Austin-Round Rock-Georgetown MSA and Surrounding Counties, 2010-2018

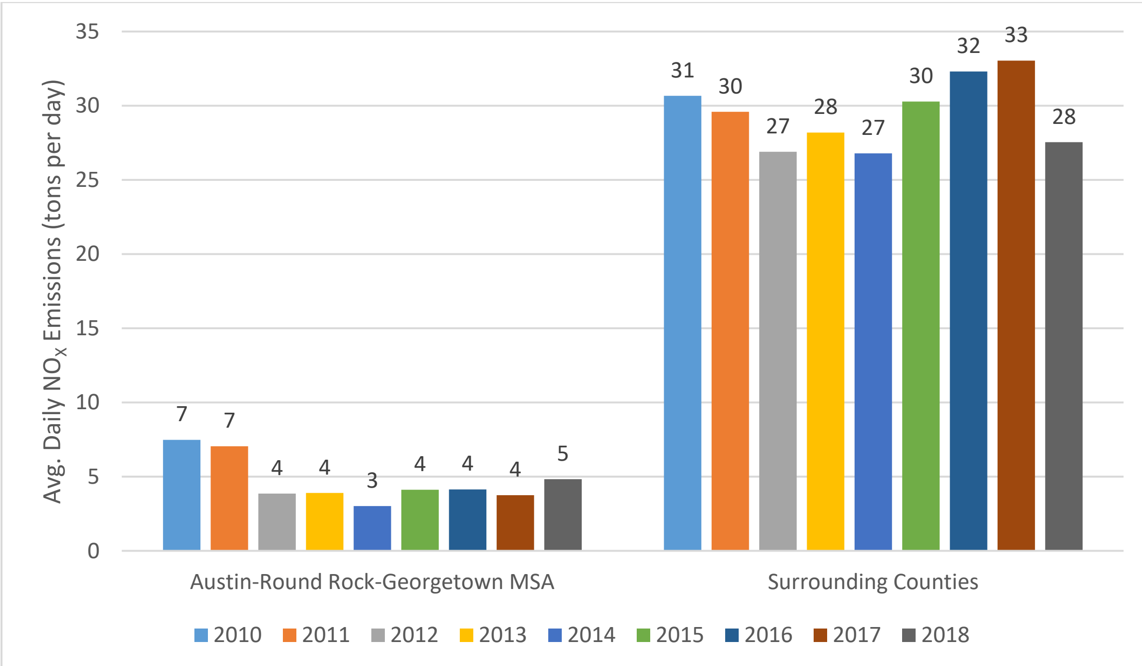
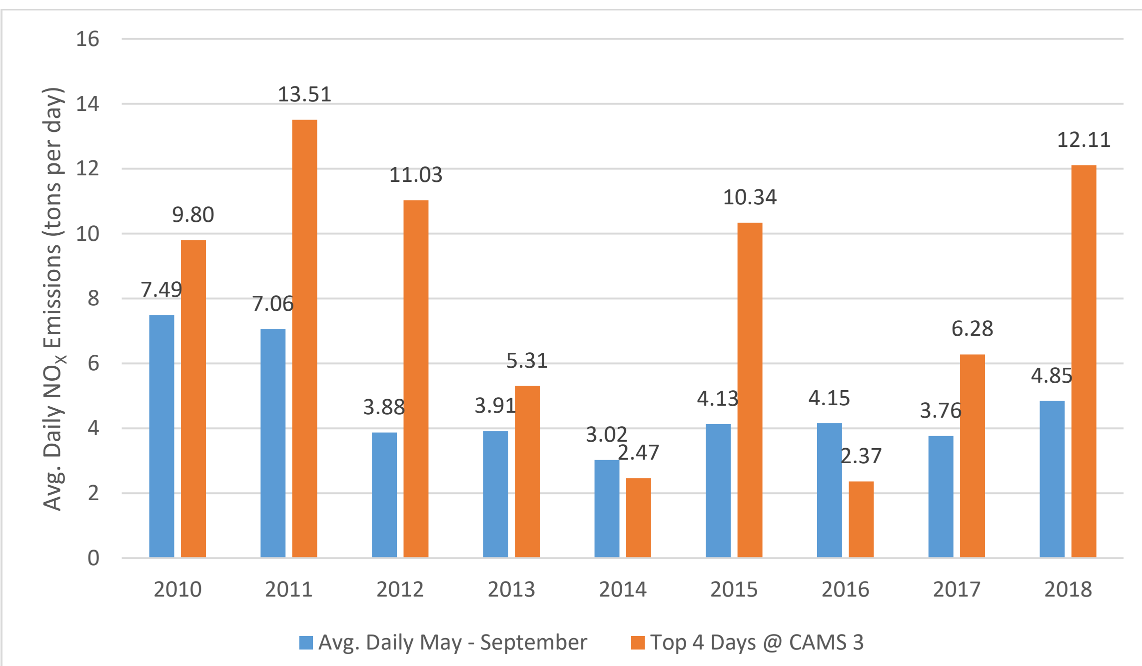


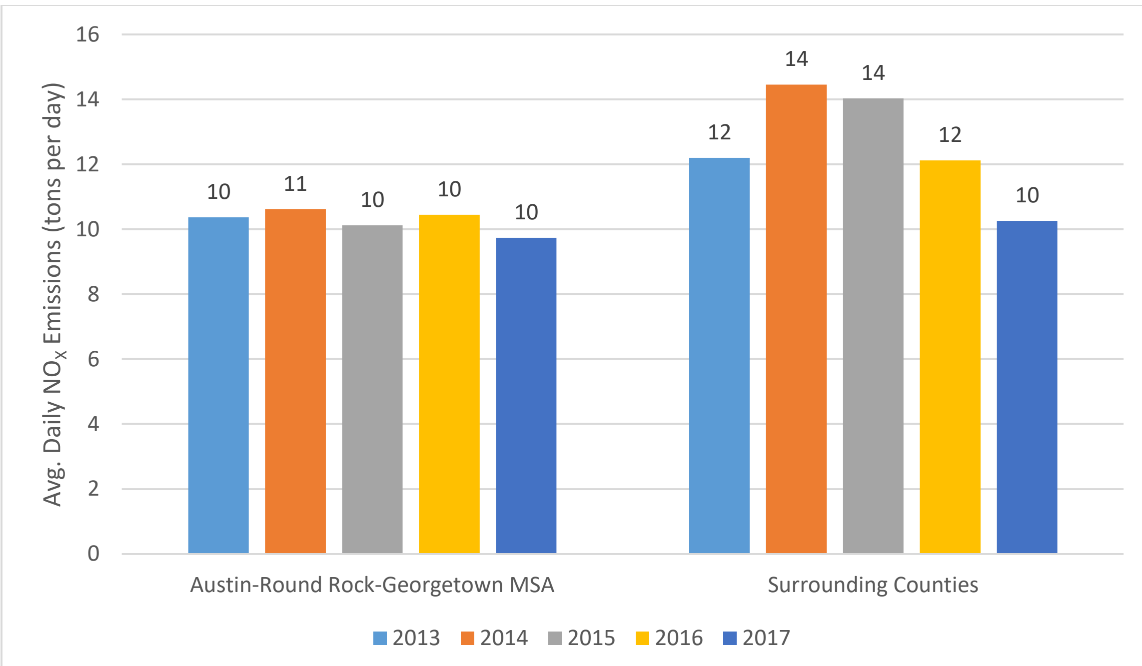
Figure 7-3. O_3 Season Daily EGU Point Source NO_X Emissions Averages May – September and Top 4 Days at CAMS 3 2010-2018



7.2 Non-EGU Point Sources

2018 non-EGU point source emissions data has not yet been posted online by TCEQ – that will likely happen in January 2020. The following figure shows the average daily NO_X emissions for 2013 – 2017 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 2018 emissions are likely comparable. NO_X emissions from non-EGU point sources in adjacent counties has seen more substantial changes within this time frame, but has decreased substantially each year since 2014.

Figure 7-4. Average Daily NO_X Emissions from Non-EGU Point Sources in Austin-Round Rock-Georgetown MSA and Surrounding Counties, 2013-2017

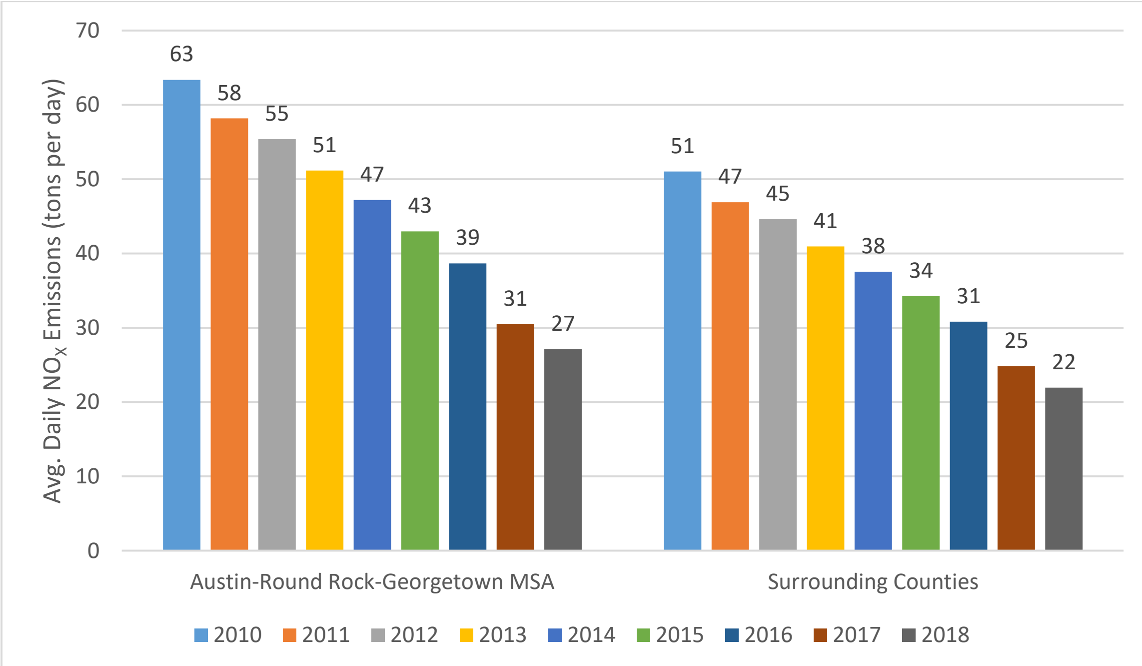


Based on these trends, it is unlikely that non-EGU point source NO_X emissions would account for any increase in regional O_3 levels in 2018 compared to 2017.

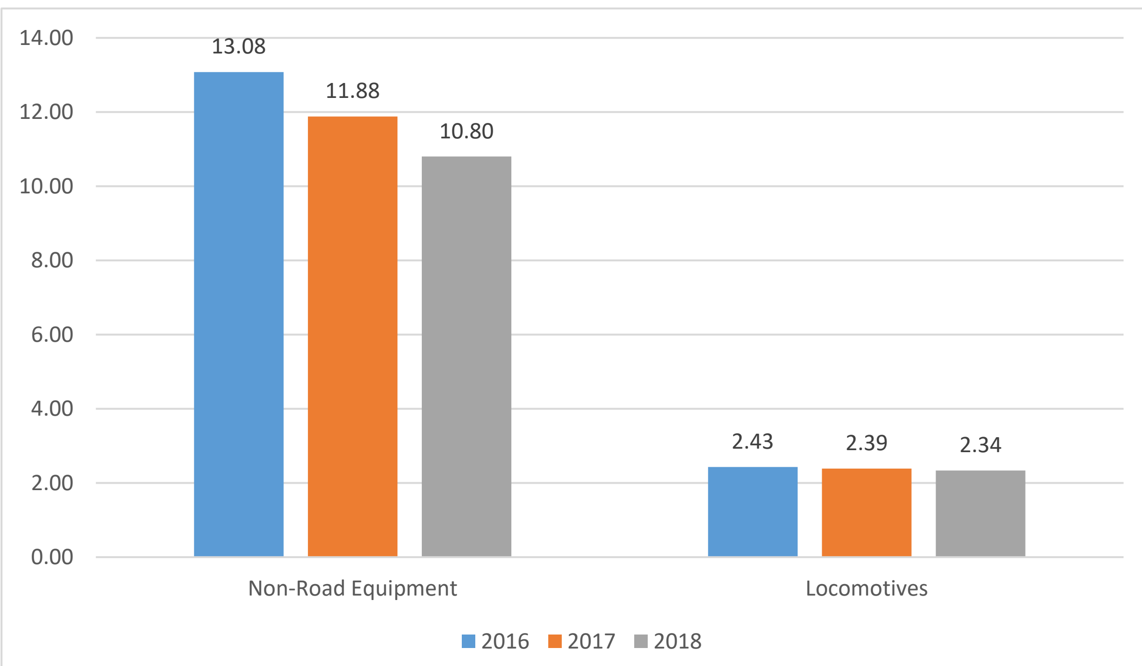
7.3 On-Road Mobile Sources

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 – 2018 NO_X emissions for the MSA and adjacent counties. As the figure shows, NO_X emissions decreased in each area by 3 tpd (approximately 11-12% from 2017-2018).

Figure 7-5. Average Summer Weekday NO_X Emissions from On-Road Sources in Austin-Round Rock-Georgetown MSA and Surrounding Counties, 2013-2017



7.4 Non-Road Mobile Sources



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:

- While there were fewer number of days when MDA8 O_3 levels were ≥ 54 ppb than usual, there were significantly more days when MDA8 O_3 >70 ppb than in 2017 or 2016.
- The 4th-highest MDA8 O_3 level at TCEQ's CAMS 3 (72 ppb) was high enough to put the region at substantial risk of violating the region's 2017-2019 O_3 design value violating the 70 ppb 2015 O_3 NAAQS.
- The monthly distribution of high O_3 was unusual due to a very large number of high O_3 days in July and no days when MDA8 O_3 even reached "moderate" levels after August.
- While the 2018 levels were substantially higher than in 2017 or 2016, they would not be considered "outliers" based on year-to-year variation across the 2016 – 2018 period.
- Two local meteorological factors stand out as potential explanations for the higher O_3 observed in the MSA in 2018 compared to 2017 and 2016: more days high temperatures (>90 deg. F) and more days with lower RH (<40%).
- There were several other meteorological factors that the region's Conceptual Model has previously shown were associated with high O_3 that were actually *less* prevalent in 2018, including low wind speed, high diurnal temperature changes, and high solar radiation.
- The "transport" analysis suggests that the local contribution on high O_3 days (>70 ppb) continued to be about 20 ppb.
- Aside from counties within the Austin-Round Rock-Georgetown MSA, Bexar, Comal, Gonzales, and Guadalupe Counties were the most common "upwind" counties of CAMS 3 when MDA8 O_3 levels were >70 ppb.
- Williamson County was actually upwind of CAMS 3 on high O_3 days less frequently than Bexar, Comal, Gonzales, and Guadalupe Counties.
- Despite continued long-term trends in NO_X emissions from mobile sources from 2017-2018, overall NO_X emissions from within the MSA may have increased slightly due to increases in power plant emissions, which were especially high on the four key "design value days."
- Overall, 2018 meteorological data trends were consistent with the relationship between MDA8 O_3 and weather conditions observed in 2010-2015.
- The general relationships between meteorology and high MDA8 O_3 in 2018 were broadly consistent with what the relationships observed 2010-2015, 2016, and 2017.
- Observed wind speeds were consistent with observations in 2010-2017.
- Diurnal temperature changes were smaller in 2018 than observed in 2010-2015 and 2017, but similar to 2016.
- Solar radiation was lower in 2018 than all previous timeframes.
- As in 2016 and 2017, relative humidity continued to be higher in 2018 than in the 2010-2015 timeframe.
- 2018 MDA8 O_3 data at 55 ppb or above was significantly statistically different from what was typically observed in September and October of previously analyzed timeframes, with 2018 having no days with MDA8 O_3 data at 55 ppb or above after August 2018.
- Background concentrations and local contributions to MDA8 O_3 levels on days with MDA8 O_3 at 55 ppb or above in 2018 were extremely similar to what was observed in 2017.

9 Appendix

Additional data collected for this analysis can be reviewed in this appendix including CAMS calibration data, monitor-by-monitor meteorological statistics, and a full list of counties whose wind back trajectory intercepts a CAPCOG region O_3 monitor on MDA8 O_3 days >70 ppb.

9.1 Accuracy of O_3 Monitors in the CAPCOG Region O_3 Monitors

In comparing the data for CAPCOG's stations to TCEQ's stations, it is also important to note that CAPCOG uses significantly different data-handling procedures for its O_3 data than TCEQ uses in terms of how O_3 instrument calibration results are handled:

- TCEQ uses automated calibration systems that perform weekly three-point precision ("span") checks and five-point calibrations every two weeks, and TCEQ's data system applies slope corrections following each five-point calibration and intercept corrections after every three-point check in order to have the data report out O_3 concentrations that are "corrected" based on the calibration results. TCEQ's automated calibration systems also perform daily "SpanZ" checks that check a 0 ppb and 400 ppb level in order to ensure that the values are within acceptable ranges.
- CAPCOG uses manual calibrations for its own monitors each month and simply accepts data as long as the instrument is within the acceptable ranges of deviation.
- In 2017, CAPCOG paid for periodic manual calibrations of CAMS 1605 at St. Edwards University using the same data acceptance principles as it used for CAPCOG's own stations.

The following table summarizes the statistics for TCEQ's precision checks at CAMS 3 and CAMS 38 for 2018.

Table 9-1. Summary of CAMS 3 and 38 Precision Calibration Checks, 2018

Statistic	CAMS 3	CAMS 38
Number of Precision Checks, Including Five-Point Calibrations	58.00	54.00
Number of Five-Point Calibrations	19.00	13.00
Avg. Bias (ppb)	3.02	5.57
St. Deviation Bias (ppb)	1.13	1.62
Min. Bias Value (ppb)	-23.00	-21.95
Max. Bias Value (ppb)	-15.50	-12.80
Avg. Error (ppb)	3.12	5.63
St. Deviation Error (ppb)	1.13	1.62
Min. Error Value (ppb)	-3.00	-1.95
Max. Error Value (ppb)	4.50	7.20

All of CAPCOG's calibration check values were within acceptable limits. The following table shows the statistics for the 70 ppb calibration checks at each of CAPCOG's 8 CAMS and the one St. Edward's University CAMS.

Table 9-2. Summary of Deviations from 70 ppb Calibration Checks at CAPCOG and St. Edwards CAMS in 2018 (ppb)

Month	CAMS 614	CAMS 684	CAMS 690	CAMS 1603	CAMS 1604	CAMS 1605	CAMS 1675	CAMS 6602
Feb.	1.00	0.50	2.30	0.80	0.80	n/a	0.10	1.20
Mar.	0.10	0.20	0.40	0.80	0.90	0.80	1.40	1.20
Apr.	0.50	0.80	0.80	0.30	0.90	n/a	0.00	0.70
May	-0.10	0.10	0.20	0.70	0.30	n/a	0.60	-0.30
Jun.	-0.10	0.10	0.30	0.70	0.30	n/a	0.60	0.00
Jul.	0.10	-0.10	0.40	0.00	0.70	n/a	0.40	-0.20
Aug.	-0.40	0.30	0.80	-0.10	1.00	n/a	-0.90	1.00
Sep.	-0.10	-0.10	1.50	-0.20	0.70	n/a	-0.10	-0.30
Oct.	-0.50	0.00	0.30	0.00	0.20	n/a	0.00	0.10
Nov.	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Avg.	0.06	0.20	0.78	0.33	0.64	0.80	0.23	0.38
St. Dev.	0.46	0.30	0.70	0.42	0.30	n/a	0.63	0.64
Min.	-0.50	-0.10	0.20	-0.20	0.20	0.80	-0.90	-0.30
Max.	1.00	0.80	2.30	0.80	1.00	0.80	1.40	1.2

9.2 Monitor-by-Monitor Wind Speed Statistics

Table 9-3. Avg. wind speed 12-4 pm statistics for CAMS 3

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. WS (mph)	2010-2015 Avg. WS St. Dev. (mph)	2018 Count	2018 Avg. WS. (mph)	2018 Avg. WS. St. Dev. (mph)
>70 ppb	36	5.93	1.42	6	6.05	1.44
55-70 ppb	260	6.76	2.26	26	7.26	2.09
<55 ppb	1801	7.53	2.60	327	7.36	2.44

Table 9-4. Avg. wind speed 12-4 pm statistics for CAMS 38

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. WS (mph)	2010-2015 Avg. WS St. Dev. (mph)	2018 Count	2018 Avg. WS. (mph)	2018 Avg. WS. St. Dev. (mph)
>70 ppb	25	5.22	1.06	1	5.95	n/a
55-70 ppb	276	6.41	2.03	25	7.11	1.86
<55 ppb	1802	7.00	2.27	327	7.04	2.20

Table 9-5. Avg. wind speed 12-4 pm statistics for CAMS 614

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. WS (mph)	2010-2015 Avg. WS St. Dev. (mph)	2018 Count	2018 Avg. WS. (mph)	2018 Avg. WS. St. Dev. (mph)
>70 ppb	17	6.72	1.72	3	6.14	.23
55-70 ppb	184	8.01	3.06	31	9.00	2.80
<55 ppb	1044	9.59	3.59	230	9.02	2.92

Table 9-6. Avg. wind speed 12-4 pm statistics for CAMS 690

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. WS (mph)	2010-2015 Avg. WS St. Dev. (mph)	2018 Count	2018 Avg. WS. (mph)	2018 Avg. WS. St. Dev. (mph)
>70 ppb	5	4.38	0.77	3	7.96	1.03
55-70 ppb	106	4.51	1.69	31	10.39	3.75
<55 ppb	858	5.02	1.96	230	9.55	3.32

Table 9-7. Avg. wind speed 12-4 pm statistics for CAMS 1603

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. WS (mph)	2010-2015 Avg. WS St. Dev. (mph)	2018 Count	2018 Avg. WS. (mph)	2018 Avg. WS. St. Dev. (mph)
>70 ppb	28	3.76	1.51	7	6.61	1.20
55-70 ppb	224	4.30	1.91	15	7.83	3.25
<55 ppb	887	6.35	3.39	220	8.74	3.13

Table 9-8. Avg. wind speed 12-4 pm statistics for CAMS 1604

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. WS (mph)	2010-2015 Avg. WS St. Dev. (mph)	2018 Count	2018 Avg. WS. (mph)	2018 Avg. WS. St. Dev. (mph)
>70 ppb	6	4.06	0.85	0	n/a	n/a
55-70 ppb	52	3.51	2.16	16	7.76	2.57
<55 ppb	358	6.01	3.10	257	9.34	3.62

Table 9-9. Avg. wind speed 12-4 pm statistics for CAMS 1605

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. WS (mph)	2010-2015 Avg. WS St. Dev. (mph)	2018 Count	2018 Avg. WS. (mph)	2018 Avg. WS. St. Dev. (mph)
>70 ppb	0	n/a	n/a	0	n/a	n/a
55-70 ppb	52	3.16	2.28	16	2.71	.81
<55 ppb	380	5.32	3.34	321	3.45	1.26

Table 9-10. Avg. wind speed 12-4 pm statistics for CAMS 1675

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. WS (mph)	2010-2015 Avg. WS St. Dev. (mph)	2018 Count	2018 Avg. WS. (mph)	2018 Avg. WS. St. Dev. (mph)
>70 ppb	14	3.35	1.43	6	8.46	1.46
55-70 ppb	142	3.16	2.21	24	10.11	3.74
<55 ppb	752	5.53	3.85	241	10.99	4.66

Table 9-11. Avg. wind speed 12-4 pm statistics for CAMS 6602

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. WS (mph)	2010-2015 Avg. WS St. Dev. (mph)	2018 Count	2018 Avg. WS. (mph)	2018 Avg. WS. St. Dev. (mph)
>70 ppb	18	2.31	1.48	1	5.03	n/a
55-70 ppb	142	2.52	1.73	23	6.85	1.88
<55 ppb	621	3.92	2.22	250	6.71	2.26

9.3 Monitor-by-Monitor Temperature Statistics

Table 9-12. Avg. temp. 12-4 pm statistics for CAMS 3

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. Temp. (deg. F)	2010-2015 St. Dev. Avg. Temp. (deg. F)	2018 Count	2018 Avg. Temp. (deg. F)	2018 St. Dev. Avg. Temp. (deg. F)
>70 ppb	36	92.8	6.2	6	92.59	3.63
55-70 ppb	260	85.3	7.7	26	83.59	9.68
<55 ppb	1810	73.5	16.2	325	73.66	16.26

Table 9-13. Avg. temp. 12-4 pm statistics for CAMS 38

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. Temp. (deg. F)	2010-2015 St. Dev. Avg. Temp. (deg. F)	2018 Count	2018 Avg. Temp. (deg. F)	2018 St. Dev. Avg. Temp. (deg. F)
>70 ppb	25	90.9	7.4	1	92.93	n/a
55-70 ppb	276	86.1	7.4	25	82.50	9.06
<55 ppb	1818	73.3	16.4	322	72.80	16.90

Table 9-14. Avg. temp. 12-4pm statistics for CAMS 614

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. Temp. (deg. F)	2010-2015 St. Dev. Avg. Temp. (deg. F)	2018 Count	2018 Avg. Temp. (deg. F)	2018 St. Dev. Avg. Temp. (deg. F)
>70 ppb	24	92.0	7.5	3	91.73	5.74
55-70 ppb	214	85.8	7.3	31	83.67	10.58
<55 ppb	967	83.9	9.6	242	77.73	13.48

Table A 13. Avg. temp. 12-4 pm statistics for CAMS 690

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. Temp. (deg. F)	2010-2015 St. Dev. Avg. Temp. (deg. F)	2018 Count	2018 Avg. Temp. (deg. F)	2018 St. Dev. Avg. Temp. (deg. F)
>70 ppb	28	90.0	8.4	3	87.53	7.13
55-70 ppb	232	87.2	8.4	31	85.99	10.19
<55 ppb	977	84.2	10.6	237	79.50	13.00

Table A 14. Avg. temp. 12-4 pm statistics for CAMS 1603

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. Temp. (deg. F)	2010-2015 St. Dev. Avg. Temp. (deg. F)	2018 Count	2018 Avg. Temp. (deg. F)	2018 St. Dev. Avg. Temp. (deg. F)
>70 ppb	6	88.6	8.4	7	91.77	3.46
55-70 ppb	45	86.9	7.0	15	87.85	9.34
<55 ppb	234	78.0	12.3	230	78.94	12.00

Table A 15. Avg. temp. 12-4 pm statistics for CAMS 1604

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. Temp. (deg. F)	2010-2015 St. Dev. Avg. Temp. (deg. F)	2018 Count	2018 Avg. Temp. (deg. F)	2018 St. Dev. Avg. Temp. (deg. F)
>70 ppb	0	n/a	n/a	0	n/a	n/a
55-70 ppb	39	86.03	6.70	16	85.02	9.48
<55 ppb	312	82.14	12.60	257	81.12	14.53

Table A 16. Avg. temp. 12-4 pm statistics for CAMS 1605

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. Temp. (deg. F)	2010-2015 St. Dev. Avg. Temp. (deg. F)	2018 Count	2018 Avg. Temp. (deg. F)	2018 St. Dev. Avg. Temp. (deg. F)
>70 ppb	n/a	n/a	n/a	0	n/a	n/a
55-70 ppb	n/a	n/a	n/a	16	91.34	8.09
<55 ppb	n/a	n/a	n/a	322	77.70	15.65

Table A 17. Avg. temp. 12-4 pm statistics for CAMS 1675

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. Temp. (deg. F)	2010-2015 St. Dev. Avg. Temp. (deg. F)	2018 Count	2018 Avg. Temp. (deg. F)	2018 St. Dev. Avg. Temp. (deg. F)
>70 ppb	3	93.9	4.2	6	92.67	4.71
55-70 ppb	46	82.9	9.7	24	82.47	9.51
<55 ppb	311	80.6	11.9	243	78.47	12.70

Table A 18. Avg. temp. 12-4 pm statistics for CAMS 6602

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. Temp. (deg. F)	2010-2015 St. Dev. Avg. Temp. (deg. F)	2018 Count	2018 Avg. Temp. (deg. F)	2018 St. Dev. Avg. Temp. (deg. F)
>70 ppb	4	84.0	7.3	1	86.13	n/a
55-70 ppb	34	86.9	6.1	56	71.80	11.69
<55 ppb	164	83.4	8.7	251	79.01	13.76

9.4 Monitor-by-Monitor Diurnal Temperature Change Statistics

Table 9-15. Diurnal temp. change statistics for CAMS 3

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. Temp Chg. (deg. F)	2010-2015 Avg. Temp. Chg. St. Dev. (deg. F)	2018 Count	2018 Avg. Temp Chg. (deg. F)	2018 Avg. Temp. Chg. St. Dev. (deg. F)
>70 ppb	36	23.1	4.8	6	19.82	3.53
55-70 ppb	254	21.3	4.3	26	21.07	4.48
<55 ppb	1776	17.2	6.0	327	16.18	5.72

Table 9-16. Diurnal temp. change statistics for CAMS 38

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. Temp Chg. (deg. F)	2010-2015 Avg. Temp. Chg. St. Dev. (deg. F)	2018 Count	2018 Avg. Temp Chg. (deg. F)	2018 Avg. Temp. Chg. St. Dev. (deg. F)
>70 ppb	25	23.1	2.9	1	21.30	n/a
55-70 ppb	270	22.2	22.2	25	22.04	2.83
<55 ppb	1791	18.1	6.1	330	17.08	6.60

Table 9-17. Diurnal temp. change statistics for CAMS 614

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. Temp Chg. (deg. F)	2010-2015 Avg. Temp. Chg. St. Dev. (deg. F)	2018 Count	2018 Avg. Temp Chg. (deg. F)	2018 Avg. Temp. Chg. St. Dev. (deg. F)
>70 ppb	24	25.0	3.8	3	29.63	2.19
55-70 ppb	211	24.6	4.6	31	27.36	4.79
<55 ppb	951	18.8	5.4	242	19.74	6.37

Table 9-18. Diurnal temp. change statistics for CAMS 690

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. Temp Chg. (deg. F)	2010-2015 Avg. Temp. Chg. St. Dev. (deg. F)	2018 Count	2018 Avg. Temp Chg. (deg. F)	2018 Avg. Temp. Chg. St. Dev. (deg. F)
>70 ppb	28	26.8	2.9	3	30.60	1.47
55-70 ppb	230	24.6	4.5	31	27.24	4.79
<55 ppb	961	19.2	5.3	237	20.56	6.37

Table A 23. Diurnal temp. change statistics for CAMS 1603

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. Temp Chg. (deg. F)	2010-2015 Avg. Temp. Chg. St. Dev. (deg. F)	2018 Count	2018 Avg. Temp Chg. (deg. F)	2018 Avg. Temp. Chg. St. Dev. (deg. F)
>70 ppb	6	23.9	1.9	7	55.34	84.90
55-70 ppb	45	24.7	4.0	15	23.47	4.87
<55 ppb	231	17.5	5.9	230	19.42	20.40

Table 9-19. Diurnal temp. change statistics for CAMS 1604

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. Temp Chg. (deg. F)	2010-2015 Avg. Temp. Chg. St. Dev. (deg. F)	2018 Count	2018 Avg. Temp Chg. (deg. F)	2018 Avg. Temp. Chg. St. Dev. (deg. F)
>70 ppb	0	n/a	n/a	0	n/a	n/a
55-70 ppb	39	26.8	3.4	16	29.10	5.51
<55 ppb	310	20.6	6.5	257	21.86	7.60

Table 9-20. Diurnal temp. change statistics for CAMS 1605

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. Temp Chg. (deg. F)	2010-2015 Avg. Temp. Chg. St. Dev. (deg. F)	2018 Count	2018 Avg. Temp Chg. (deg. F)	2018 Avg. Temp. Chg. St. Dev. (deg. F)
>70 ppb	n/a	n/a	n/a	0	n/a	n/a
55-70 ppb	n/a	n/a	n/a	16	21.46	3.70
<55 ppb	n/a	n/a	n/a	322	17.04	5.68

Table 9-21. Diurnal temp. change statistics for CAMS 1675

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. Temp Chg. (deg. F)	2010-2015 Avg. Temp. Chg. St. Dev. (deg. F)	2018 Count	2018 Avg. Temp Chg. (deg. F)	2018 Avg. Temp. Chg. St. Dev. (deg. F)
>70 ppb	3	23.9	1.6	6	25.47	5.22
55-70 ppb	46	23.3	4.4	24	25.35	4.14
<55 ppb	310	18.0	5.6	243	18.53	6.11

Table 9-22. Diurnal temp. change statistics for CAMS 6602

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. Temp Chg. (deg. F)	2010-2015 Avg. Temp. Chg. St. Dev. (deg. F)	2018 Count	2018 Avg. Temp Chg. (deg. F)	2018 Avg. Temp. Chg. St. Dev. (deg. F)
>70 ppb	4	26.7	3.8	1	31.70	n/a
55-70 ppb	34	24.8	3.4	23	24.43	4.22
<55 ppb	164	19.2	5.6	251	19.38	5.85

9.5 Monitor-by-Monitor Relative Humidity Statistics

Table 9-23. Avg. relative humidity 12-4 pm statistics for CAMS 614

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. RH (%)	2010-2015 Avg. RH St. Dev. (%)	2018 Count	2018 Avg. RH (%)	2018 Avg. RH. St. Dev. (%)
>70 ppb	5	25.2	2.0	3	26.68	3.77
55-70 ppb	60	28.6	7.6	31	30.45	7.09
<55 ppb	292	47.2	17.7	241	50.12	19.32

Table 9-24. Avg. relative humidity 12-4 pm statistics for CAMS 690

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. RH (%)	2010-2015 Avg. RH St. Dev. (%)	2018 Count	2018 Avg. RH (%)	2018 Avg. RH. St. Dev. (%)
>70 ppb	5	24.5	2.9	3	19.20	2.60
55-70 ppb	53	26.0	8.0	31	22.27	6.52
<55 ppb	298	41.7	17.6	237	40.02	18.41

Table 9-25. Avg. relative humidity 12-4 pm statistics for CAMS 1603

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. RH (%)	2010-2015 Avg. RH St. Dev. (%)	2018 Count	2018 Avg. RH (%)	2018 Avg. RH. St. Dev. (%)
>70 ppb	6	28.5	3.2	7	25.83	5.53
55-70 ppb	45	27.8	6.6	14	31.23	9.51
<55 ppb	234	51.5	20.1	230	47.27	18.59

Table 9-26. Avg. relative humidity 12-4 pm statistics for CAMS 1604

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. RH (%)	2010-2015 Avg. RH St. Dev. (%)	2017 Count	2017 Avg. RH (%)	2017 Avg. RH. St. Dev. (%)
>70 ppb	0	n/a	n/a	0	n/a	n/a
55-70 ppb	39	29.5	8.2	16	29.49	7.19
<55 ppb	312	47.6	17.2	257	46.13	18.35

Table 9-27. Avg. relative humidity 12-4 pm statistics for CAMS 1605

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. RH (%)	2010-2015 Avg. RH St. Dev. (%)	2017 Count	2017 Avg. RH (%)	2017 Avg. RH. St. Dev. (%)
>70 ppb	n/a	n/a	n/a	0	n/a	n/a
55-70 ppb	n/a	n/a	n/a	16	29.49	7.19
<55 ppb	n/a	n/a	n/a	257	46.13	18.35

Table 9-28. Avg. relative humidity 12-4 pm statistics for CAMS 1675

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. RH (%)	2010-2015 Avg. RH St. Dev. (%)	2018 Count	2018 Avg. RH (%)	2018 Avg. RH. St. Dev. (%)
>70 ppb	3	30.2	2.9	6	27.86	8.38
55-70 ppb	46	31.1	7.8	24	32.98	5.92
<55 ppb	319	49.2	17.2	242	48.25	17.26

Table 9-29. Avg. relative humidity 12-4 pm statistics for CAMS 6602

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. RH (%)	2010-2015 Avg. RH St. Dev. (%)	2018 Count	2018 Avg. RH (%)	2018 Avg. RH. St. Dev. (%)
>70 ppb	4	28.9	3.7	1	30.20	n/a
55-70 ppb	32	30.2	6.3	23	29.15	5.76
<55 ppb	162	46.5	17.4	250	47.79	17.87

9.6 Monitor-by-Monitor Solar Radiation Statistics

Table 9-30. Avg. solar radiation 12-4pm statistics for CAMS 38

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. SR (langleys / min)	2010-2015 Avg. SR St. Dev. (langleys / min)	2018 Count	2018 Avg. (langleys / min)	2018 Avg. SR. St. Dev. (langleys / min)
>70 ppb	25	1.18	0.11	1	1.12975	n/a
55-70 ppb	276	1.11	0.17	25	1.07254	0.118515
<55 ppb	1,819	0.81	0.35	329	0.70668	0.336052