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Task 3, Deliverable 3.6

Analysis of 2017 Monitoring Data

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Executive Summary

The purpose of this project is to compare ambient air monitoring data collected in 2017 in the Capital Area Council of Governments (CAPCOG) 10-county region of Central Texas with CAPCOG's most recent ozone (O_3) "conceptual model," which evaluated data from 2010-2015.[1] The CAPCOG region includes Bastrop, Blanco, Burnet, Caldwell, Fayette, Hays, Lee, Llano, Travis, and Williamson Counties. Five of these counties constitute the Austin-Round Rock Metropolitan Statistical Area (MSA): Bastrop, Caldwell, Hays, Travis, and Williamson Counties. This report is based on:

- O_3 data collected at:
    - two "regulatory" O_3 continuous air monitoring stations (CAMS) operated by TCEQ in Travis County (CAMS 3 and 38);
    - eight non-regulatory O_3 CAMS operated by CAPCOG throughout the region (CAMS 601, 614, 684, 690, 1603, 1604, 1675, and 6602); and
    - one non-regulatory O_3 CAMS operated by St. Edward's University (CAMS 1605);
- Meteorological data collected at these 11 CAMS and two weather stations operated by the National Weather Service (NWS) – CAMS 5003 and CAMS 5005;
- Co-located fine particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) data collected at CAMS 3.

CAPCOG's analysis shows that, compared to 2016 when there was only one day with Maximum Daily 8-Hour Ozone Average (MDA8 O_3) measured >70 ppb, there were fewer days in 2017 with high relative humidity and more days with a high diurnal temperature change. Both of these conditions could have led to the increase in MDA8 O_3 measured >70 ppb days in 2017. However, 2017 data for co-pollutants, namely NO_2 and SO_2, were not consistent with either 2010-2015 or 2016 data trends which showed that as MDA8 O_3 increases so to would those pollutants.

Other significant findings included:

- There were fewer days in 2017 with high relative humidity and more days with a high diurnal temperature change than there were in 2016, both of these conditions make ozone formation more likely.
- The 2017 data continued the 2016 trend of February having substantially more days with MDA8 $O_3 \geq 55$ ppb than was measured from 2010-2015.
- The general relationships between meteorology and high MDA8 O_3 in 2017 were consistent with the relationships observed 2010-2015 and 2016.
- Background MDA8 O_3 levels were slightly, but statistically significantly, higher in 2017 and 2016 than what was typical for 2010-2015.
- Local contributions to MDA8 O_3 levels were substantially and statistically significantly lower in 2017 and 2016 than what was typical for 2010-2015.

This report includes:

- General summaries of O_3 data in the region from 2017 compared to 2010-2015 and 2016 (Section 2);

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

- Analysis of the temporal profiles and features of O_3 pollution in the region in 2017 compared to 2010-2015 and 2016 (Section 3);
- Investigations of potential relationships between meteorology and O_3 pollution in 2017 compared to 2010-2015 and 2016 (Section 4);
- Analysis of correlations between O_3 pollution and ambient $PM_{2.5}$, NO_2, and SO_2 concentrations in 2017 compared to 2010-2015 and 2016 (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 2017 compared to 2010-2015 and 2016 (Section 6); and
- Analysis of the potential the changes in NOX emissions between 2016 and 2017 could explain the increase in the O3 levels observed within the region in 2017 compared to 2016 (Section 8)

Contents

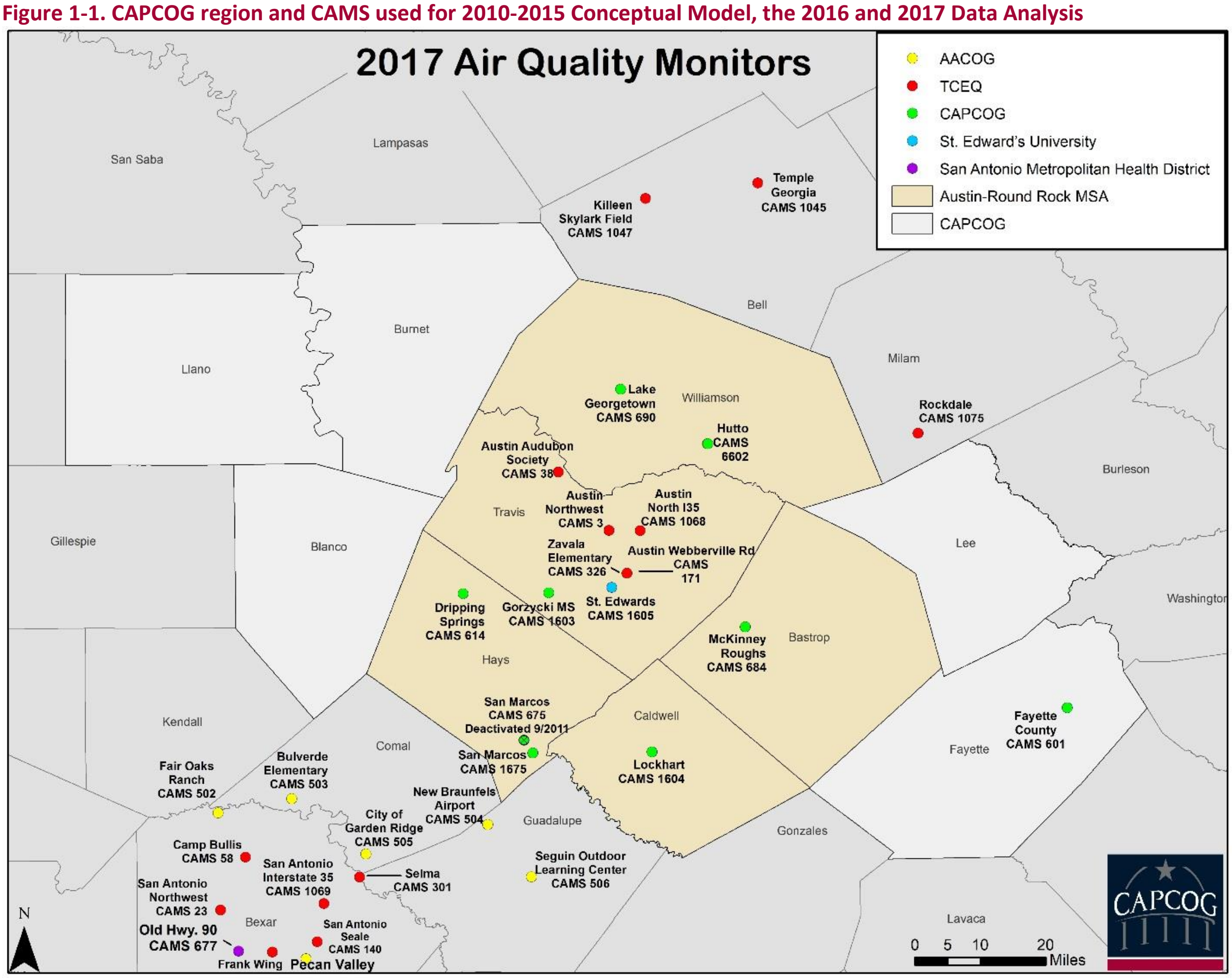
1 Introduction

The purpose of this project is to compare 2017 ambient air monitoring data collected in CAPCOG's 10-county region of Central Texas that consists of Bastrop, Blanco, Burnet, Caldwell, Fayette, Hays, Lee, Llano, Travis, and Williamson Counties with CAPCOG's most recent O_3 conceptual model. CAPCOG developed O_3 conceptual models for the Austin-Round Rock MSA in 2004, 2007, 2010, 2012, and 2015. CAPCOG's 2016 conceptual model extended to cover all 10 counties in the CAPCOG region using data from 2010-2015. This project builds on this most recent data, comparing the 2017 air pollution and meteorological data to the 2010-2015 and 2016 data used for the most recent conceptual model and 2016 data analysis.

1.1 Air Quality Monitoring Network for the CAPCOG Region

A map of the CAMS used for the 2010-2015 Conceptual Model and this report is shown below. Red circles are TCEQ stations that collected O_3 and meteorological data between 2010 and 2017, green circles are CAPCOG stations that collected O_3 and meteorological data for at least some time between 2010 and 2017, and the blue circle is a St. Edward's University station that collected O_3 and meteorological data in 2017.

Figure 1-1. CAPCOG region and CAMS used for 2010-2015 Conceptual Model, the 2016 and 2017 Data Analysis



1.2 Information on Air Monitoring Stations in the Region

Both of TCEQ's monitoring stations are Federal Reference Method (FRM) stations. CAPCOG's monitoring stations are not FRM or Federal Equivalent Method (FEM), although they do use Environmental Protection Agency (EPA) -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. The following table provides identifying information on each of the monitoring stations CAPCOG used for this analysis.

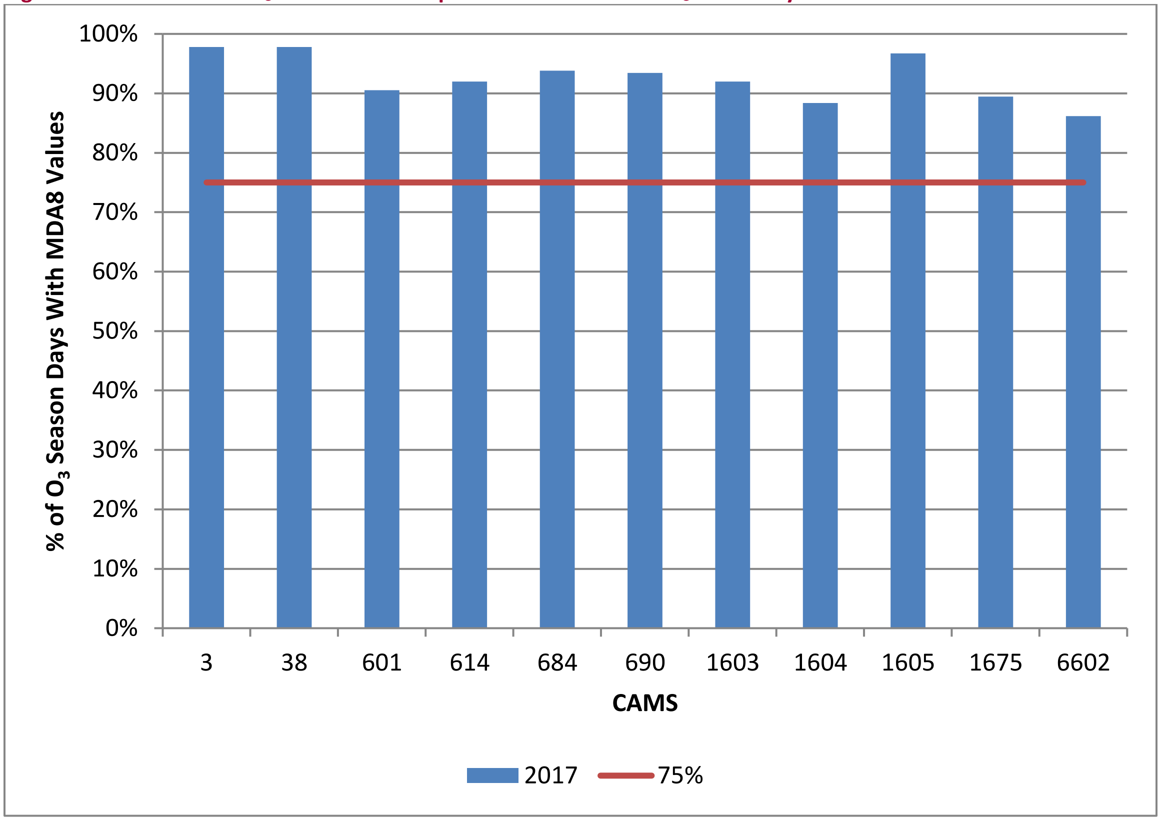
Table 1-1. Ambient air monitoring stations used in 2010-2015 Conceptual Model and 2016 Data Analysis

CAMS	Name	County	Latitude	Longitude	Owner
3	Austin Northwest	Travis	30.3544356	-97.7602554	TCEQ
38	Austin Audubon Society	Travis	30.4831681	-97.8723005	TCEQ
601	Fayette County	Fayette	29.9624745	-96.7458748	CAPCOG
614	Dripping Springs	Hays	30.2146162	-98.0833473	CAPCOG
674	CAPCOG Round Rock	Williamson	30.5327780	-97.6850000	CAPCOG
675	CAPCOG San Marcos	Hays	29.890330	-97.8908330	CAPCOG
684	McKinney Roughs	Bastrop	30.1408770	-97.4588971	CAPCOG
690	CAPCOG Lake Georgetown	Williamson	30.6664421	-97.7345790	CAPCOG
1603	Gorzycki Middle School	Travis	30.2163970	-97.8937440	CAPCOG
1604	Lockhart	Caldwell	29.8649170	-97.6649360	CAPCOG
1605	St. Edward's University	Travis	30.2285360	-97.7543950	St. Edward's Univ.
1675	CAPCOG San Marcos Staples Road	Hays	29.8622810	-97.9288560	CAPCOG
6602	CAPCOG Hutto College Street	Williamson	30.5457060	-97.5417940	CAPCOG

1.3 Availability and Completeness Statistics of O_3 Data by Monitoring Station

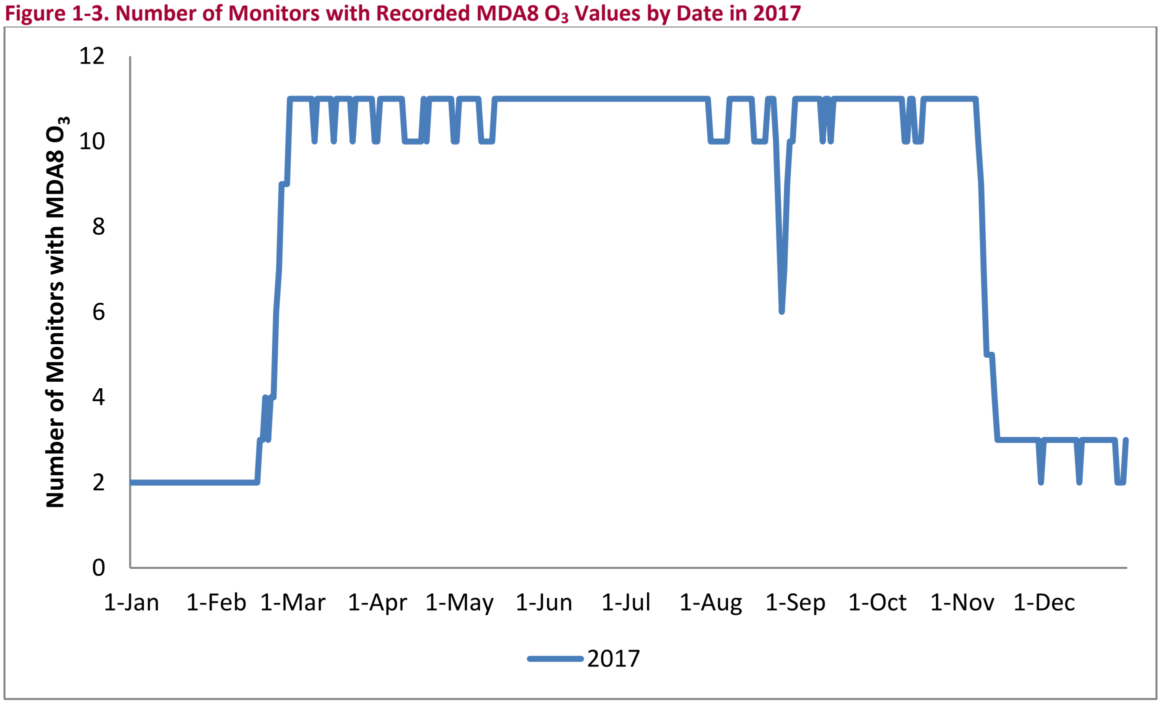
In order to provide perspective on the overall availability of MDA8 O_3 values for analysis, the following figure shows the percentage of O_3 season MDA8 values available for each monitoring station in 2017. TCEQ's two O_3 monitors collected data year-round, the eight CAPCOG CAMS collected data from 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 2017 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 2017.

Figure 1-3. Number of Monitors with Recorded MDA8 O_3 Values by Date in 2017



1.3.1 Temporary Suspension of CAPCOG Monitors

On June 06, 2017 CAPCOG suspended activities on all CAPCOG monitoring sites due to a loss of State of Texas funding. Monitors continued to collect data however monitoring oversight and data validations were suspended. June data validations were completed before monitoring activities were suspended however, 5-pt calibration checks were not performed in July. Monitoring activities resumed on July 18, 2017.

1.4 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.
- CAPCOG paid for periodic manual calibrations of CAMS 1605 at St. Edwards University during 2017 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 38 for 2017.

Table 1-2. Summary of CAMS 3 and 38 Precision Calibration Checks, 2017

Statistic	CAMS 3	CAMS 38
Number of Precision Checks, Including Five-Point Calibrations	54	55
Number of Five-Point Calibrations	15	16
Avg. Bias (ppb)	-1.81	2.09
St. Deviation Bias (ppb)	0.52	0.56
Min. Bias Value (ppb)	-20.35	-20.9
Max. Bias Value (ppb)	-17.35	-16.8
Avg. Error (ppb)	1.83	2.12
St. Deviation Error (ppb)	0.52	0.56
Min. Error Value (ppb)	-0.35	-0.9
Max. Error Value (ppb)	2.65	3.2

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. Edwards University CAMS.

Table 1-3. Summary of Deviations from 70 ppb Calibration Checks at CAPCOG and St. Edwards CAMS in 2017 (ppb)

Month	CAMS 601	CAMS 614	CAMS 684	CAMS 690	CAMS 1603	CAMS 1604	CAMS 1605	CAMS 1675	CAMS 6602
Feb.	2.3	1.0	0.6	2.6	0.5	0.4	n/a	0.9	1.0
Mar.	1.0	1.5	0.5	0.8	1.0	0.5	n/a	0.5	1.4
Apr.	0.4	0.4	0.9	0.7	1.0	0.7	1.5	0.2	1.2
May	0.8	0.6	1.2	0.6	0.6	1.0	n/a	0.9	1.2
Jun.	0.9	0.9	0.8	1.0	1.0	0.6	n/a	0.9	0.7
Jul.	0.6	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Aug.	1.1	0.6	1.0	0.3	0.7	0.9	n/a	0.5	0.8
Sep.	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Oct.	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Nov.	0.6	0.8	0.6	0.9	0.6	0.8	n/a	0.7	0.4
Avg.	1.0	0.8	0.8	1.0	0.8	0.7	1.5	0.7	1.0
St.Dev.	0.6	0.4	0.3	0.7	0.2	0.2	n/a	0.3	0.3
Min.	0.4	0.4	0.5	0.3	0.5	0.4	1.5	0.2	0.4
Max.	2.3	1.5	1.2	2.6	1	1	1.5	0.9	1.4

1.5 Attainment Status

The two FRM monitors in the region have official 3-year O_3 design values of 0.069 parts per million (ppm) at CAMS 3 and 0.067 ppm at CAMS 38, meaning that they that are attaining the 2015 O_3 National Ambient Air Quality Standards (NAAQS) 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 (0.069 ppm) among all monitors in the region. Among the research monitors, CAMS 614 and 690 had the highest 3-

year average of their 4th highest MDA8 (0.068 ppm). EPA designated all ten counties in the CAPCOG region as “attainment/unclassifiable” for the 2015 O_3 NAAQS on November 16, 2017[2]

1.6 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 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 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 downwards 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.

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[2] Federal Register/Vol. 82, No. 220 - https://www.gpo.gov/fdsys/pkg/FR-2017-11-16/pdf/2017-24640.pdf [accessed 5/14/2018]

1.7 Key Questions for this Analysis

Some of the key questions for this analysis are:

- Were the conditions for high MDA8 O_3 levels in 2017 similar to the conditions that were typical of high O_3 levels in 2010-2015 and 2016?
- Did factors that lead to high MDA8 O_3 levels in the region between 2010-2015 and in 2016 occur with any greater or less frequency in 2017?

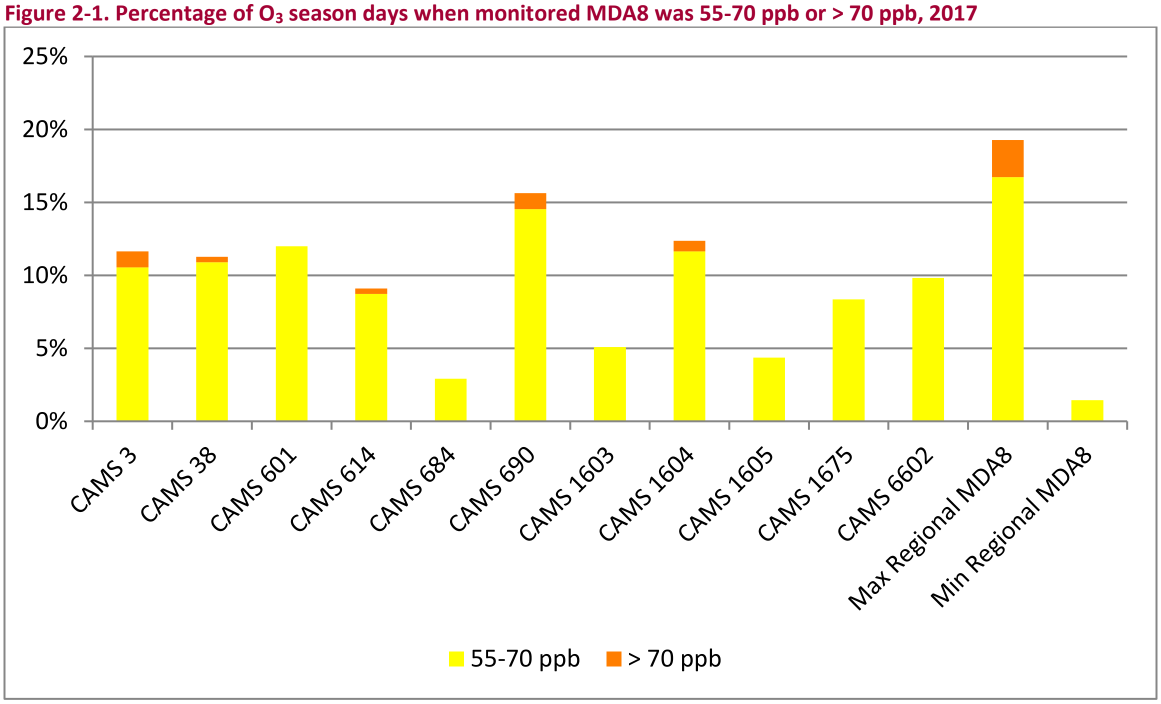
2 Analysis of Daily Maximum 8-Hour O_3 Data and Seasonal O_3 Exposure

This section provides general data on the MDA8 levels measured in the region in 2017. 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 ppb, 55-70 ppb, and >70 ppb for each monitoring station and for the region during the official O_3 season in 2017 (March-November). There was seven days in 2017 with MDA8 levels measured above 70 ppb. MDA8 was measured at 55 ppb or above on 19% of days in ozone season.

Figure 2-1. Percentage of O_3 season days when monitored MDA8 was 55-70 ppb or > 70 ppb, 2017



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 2010-2017. 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

CAMS	2010	2011	2012	2013	2014	2015	2016	2017	Total
3	8	13	6	1	0	8	1	3	40
38	3	6	6	3	0	7	0	1	26
601	1	10	1	2	1	2	0	0	17
614	4	9	6	0	0	5	0	1	25
684	0	5	4	0	0	1	0	0	10
690	1	6	8	9	0	5	0	3	32
1603	n/a	n/a	n/a	n/a	0	6	0	0	6
1604	n/a	n/a	n/a	n/a	0	0	0	2	2
1605	n/a	n/a	n/a	n/a	n/a	n/a	0	0	0
1675	n/a	2	6	3	0	3	0	0	14
6602	n/a	13	0	1	0	4	0	0	18
Region-Wide	**12**	**21**	**12**	**10**	**1**	**12**	**1**	**7**	**76**

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

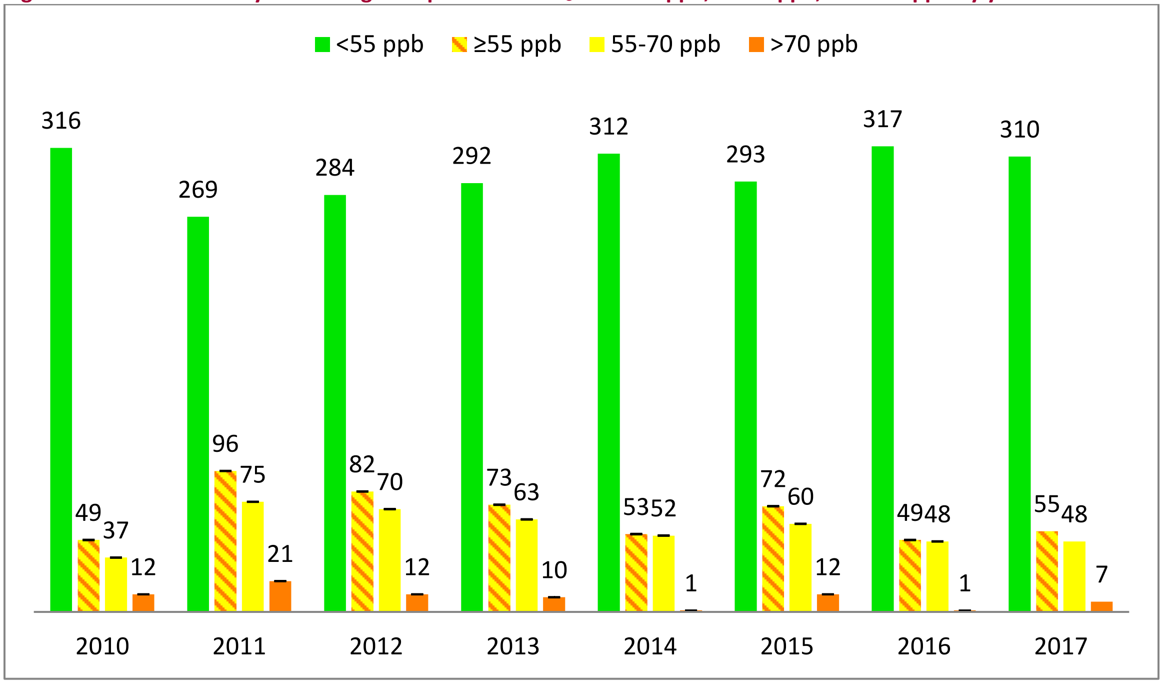
CAMS	2010	2011	2012	2013	2014	2015	2016	2017	Total
3	32	57	45	49	28	49	34	31	325
38	30	65	54	44	36	47	28	32	336
601	24	50	25	28	28	33	15	33	236
614	26	69	38	19	24	45	22	25	243
684	23	54	42	24	2	32	8	8	193
690	17	64	43	45	29	40	20	41	299
1603	n/a	n/a	n/a	n/a	8	44	23	15	90
1604	n/a	n/a	n/a	n/a	21	31	23	34	109
1605	n/a	n/a	n/a	n/a	n/a	n/a	2	12	14
1675	n/a	16	41	28	17	41	16	23	182
6602	n/a	41	31	38	0	34	15	27	186
Region-Wide	**37**	**75**	**70**	**63**	**52**	**60**	**48**	**48**	**453**

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

CAMS	2010	2011	2012	2013	2014	2015	2016	2017	Total
3	316	267	298	310	329	302	329	323	2,474
38	326	286	297	300	315	296	334	323	2,477
601	180	161	159	179	172	209	315	217	1,592
614	152	138	164	178	170	188	243	233	1,466
684	169	149	166	191	198	219	266	254	1,612
690	179	136	145	158	177	198	250	219	1,462
1603	n/a	n/a	n/a	n/a	155	204	239	244	842
1604	n/a	n/a	n/a	n/a	163	217	240	219	839
1605	n/a	n/a	n/a	n/a	n/a	n/a	318	295	613
1675	n/a	26	168	184	176	205	250	227	1,236
6602	n/a	117	168	174	0	164	257	211	1,091
Total	**316**	**269**	**284**	**292**	**312**	**293**	**317**	**310**	**2,393**

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 2017, there more days when MDA8 O_3 levels were 55 ppb or higher than 2016 but fewer than 2015. In order to determine if the distribution of days in 2017 was statistically significantly different than CAPCOG performed a series of chi-square tests on the distribution of days into the <55 ppb, ≥ 55 ppb, 55-70 ppb, and > 70 ppb ranges in 2017 compared to what would be expected for 2010-2016, 2010-2012, 2013-2015, and 2014-2016. The following table summarizes the results noting when there is a statistically significant difference at a 0.10 significance level *, 0.05 significance level **, or 0.01 significance level ***.

Table 2-4. P-values of chi-square tests comparing 2017 O_3 AQI days to 2010-2016 AQI days

Years	<55 ppb, 55-70 ppb, >70 ppb	<55 ppb, ≥ 55 ppb
2010	0.0649742769*	0.3569436134
2011	**0.0000032037*** **	**0.0000010916*** **
2012	**0.0031369419*** **	**0.0007756288*** **
2013	**0.0613899704***	**0.0185023954** **
2014	**0.0000000130*** **	0.7663595868
2015	**0.0649043437***	**0.0253438479** **
2016	**0.0000000134*** **	0.3457580363
2010-2012	**0.0154061484** **	**0.0078031474*** **
2013-2015	**0.0013755119*** **	**0.0003689137*** **
2014-2016	0.1531954609	**0.0568044862***
2010-2016	**0.0881174475***	0.2199436115

This analysis shows that the distribution of days into these AQI ranges in 2017 was not significantly different from what was typical of 2010-2016, but there was a statistical difference for two three-year periods in that span; 2010-2012, 2015 and 2013-2015. The 2017 <55 ppb, 55-70 ppb, >70 ppb distribution was also significantly statistically different from every individual year's with the exception of

2010 while the 2017 <55 ppb, ≥ 55 ppb distribution was statistically significantly different in 2011, 2012, 2013, and 2015.

2.2 Average of 4th Highest MDA8 O_3 in 2017

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 2017 values were lower than, higher than, or within the 95% confidence intervals for 2010-2012, 2013-2015, and 2014-2016. CAMS 1603 and CAMS 1604 only include 95% confidence intervals for 2014-2016 since these monitors did not start operating until 2014, and CAMS 1605 does not include 95% confidence intervals since the monitor has only operated for two years.

Table 2-5. CAMS 3 top 10 measured MDA8 O_3 values by year

Rank	2010	2011	2012	2013	2014	2015	2016	2017	2017 in C.I. for 2010-2012	2017 in C.I. for 2013-2015	2017 in C.I. for 2014-2016
1	77	82	94	79	69	85	72	71	Low	Yes	Yes
2	76	79	87	70	65	83	67	71	Low	Yes	Yes
3	75	78	80	69	63	82	66	71	Low	Yes	Yes
4	74	75	74	69	62	73	64	70	Low	Yes	Yes
5	73	75	73	68	62	73	64	69	Low	Yes	Yes
6	72	74	71	68	62	73	63	68	Low	Yes	Yes
7	72	74	68	67	61	72	63	67	Low	Yes	Yes
8	71	74	68	67	61	71	62	67	Low	Yes	Yes
9	69	73	67	66	61	70	62	64	Low	Yes	Yes
10	68	73	67	65	60	69	61	63	Low	Yes	Yes
Avg. Top 4	75.5	78.5	83.8	71.8	64.8	80.8	67.3	70.8	Low	Yes	Yes
Avg. Top 10	72.7	75.7	74.9	68.8	62.6	75.1	64.4	8.1	Low	Low	Low

Table 2-6. CAMS 38 top 10 measured MDA8 O_3 values by year

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

Rank	2010	2011	2012	2013	2014	2015	2016	2017	2017 in C.I. for 2010-2012	2017 in C.I. for 2013-2015	2017 in C.I. for 2014-2016
Avg. Top 4	72.3	75.0	78.0	72.3	64.3	79.0	65	68.8	Low	Yes	Yes
Avg. Top 10	68.6	71.6	73.6	69.4	62.8	73.3	62.3	66.1	Low	Yes	Yes

Table 2-7. CAMS 601 top 10 measured MDA8 O_3 values by year

Rank	2010	2011	2012	2013	2014	2015	2016	2017	2017 in C.I. for 2010-2012	2017 in C.I. for 2013-2015	2017 in C.I. for 2014-2016
1	73	79	72	74	73	73	67	69	Low	Low	Yes
2	67	77	69	74	69	72	60	69	Yes	Yes	Yes
3	66	76	69	68	69	70	60	67	Yes	Low	Yes
4	65	75	68	64	69	70	59	64	Yes	Low	Yes
5	65	74	64	63	68	67	57	64	Yes	Yes	Yes
6	65	73	64	62	66	65	57	64	Yes	Yes	Yes
7	64	73	63	62	66	64	57	63	Yes	Yes	Yes
8	63	73	61	61	66	62	56	62	Yes	Yes	Yes
9	61	73	61	60	64	62	56	62	Yes	Yes	Yes
10	61	72	61	60	63	62	56	62	Yes	Yes	Yes
Avg. Top 4	67.8	76.8	69.5	70.0	70.0	71.3	61.5	67.3	Yes	Low	Yes
Avg. Top 10	65.0	74.5	65.2	64.8	67.3	66.7	58.5	64.6	Yes	Low	Yes

Table 2-8. CAMS 614 top 10 measured MDA8 O_3 values by year

Rank	2010	2011	2012	2013	2014	2015	2016	2017	2017 in C.I. for 2010-2012	2017 in C.I. for 2013-2015	2017 in C.I. for 2014-2016
1	80	86	77	69	70	79	66	72	Low	Yes	Yes
2	78	83	76	69	64	76	66	68	Low	Yes	Yes
3	73	79	73	68	63	72	66	67	Low	Yes	Yes
4	72	77	73	67	63	71	65	67	Low	Yes	Yes
5	70	77	73	64	62	71	64	66	Low	Yes	Yes
6	70	76	71	64	61	70	63	66	Low	Yes	Yes
7	69	74	70	62	61	70	61	65	Low	Yes	Yes
8	67	71	70	62	61	69	61	63	Low	Yes	Yes
9	66	71	68	62	61	69	61	62	Low	Yes	Yes
10	64	70	68	59	61	68	59	62	Low	Yes	Yes
Avg. Top 4	75.8	81.3	74.8	68.3	65.0	74.5	65.8	68.5	Low	Yes	Yes
Avg. Top 10	70.9	76.4	71.9	64.6	62.7	71.5	63.2	65.8	Low	Yes	Yes

Table 2-9. CAMS 684 top 10 measured MDA8 O_3 values by year

Rank	2010	2011	2012	2013	2014	2015	2016	2017	2017 in C.I. for 2010-2012	2017 in C.I. for 2013-2015	2017 in C.I. for 2014-2016
1	68	81	80	68	58	73	64	62	Low	Yes	Yes
2	67	76	75	66	55	69	62	60	Low	Yes	Yes
3	67	75	72	65	53	69	59	59	Low	Yes	Yes
4	66	72	71	64	53	69	59	57	Low	Yes	Yes
5	65	71	68	63	52	67	56	56	Low	Yes	Yes
6	65	70	66	63	51	63	56	56	Low	Yes	Yes
7	64	70	66	62	51	63	56	55	Low	Yes	Yes
8	64	69	65	60	50	63	56	55	Low	Yes	Yes
9	61	68	65	60	49	63	54	54	Low	Yes	Yes
10	61	68	64	60	49	62	53	53	Low	Yes	Yes
Avg. Top 4	67.0	76.0	74.5	65.8	54.8	70.0	61	59.5	Low	Yes	Yes
Avg. Top 10	64.8	72.0	69.2	63.1	52.1	66.1	57.5	56.7	Low	Yes	Yes

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

Rank	2010	2011	2012	2013	2014	2015	2016	2017	2017 in C.I. for 2010-2012	2017 in C.I. for 2013-2015	2017 in C.I. for 2014-2016
1	71	79	81	89	70	83	70	75	Yes	Yes	Yes
2	70	79	81	79	69	79	68	73	Yes	Yes	Yes
3	66	77	78	78	66	78	66	73	Yes	Yes	Yes
4	65	73	73	75	66	75	61	70	Yes	Yes	Yes
5	65	71	73	74	65	73	60	69	Yes	Yes	Yes
6	65	71	71	73	63	67	60	68	Yes	Yes	High
7	64	70	71	72	62	66	60	67	Yes	Yes	High
8	62	70	71	71	62	65	59	67	Yes	Yes	High
9	61	69	69	71	62	65	58	67	Yes	Yes	High
10	59	69	69	70	61	64	58	66	Yes	Yes	High
Avg. Top 4	68.0	77.0	78.3	80.3	67.8	78.8	66.3	72.8	Yes	Yes	Yes
Avg. Top 10	64.8	72.8	73.7	75.2	64.6	71.5	62	69.5	Yes	Yes	Yes

Table 2-11. CAMS 1603 top 10 measured MDA8 O_3 values by year

Rank	2014	2015	2016	2017	2017 in C.I. for 2014-2016
1	63	76	64	62	Yes
2	59	72	64	60	Yes
3	58	72	63	60	Yes
4	57	72	63	59	Yes
5	57	72	63	59	Yes
6	56	72	62	58	Yes
7	56	69	62	58	Yes
8	55	69	61	58	Yes
9	54	68	61	58	Yes
10	53	67	61	57	Yes
Avg. Top 4	59.3	73.0	63.5	60.3	Yes
Avg. Top 10	56.8	70.9	62.4	58.9	Yes

Table 2-12. CAMS 1604 top 10 measured MDA8 O_3 values by year

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

Table 2-13. CAMS 1605 top 10 measured MDA8 O_3 values by year

Rank	2016	2017
1	56	66
2	56	64
3	53	62
4	52	61
5	52	60
6	51	59
7	51	58
8	51	57
9	51	56
10	50	55

Rank	2016	2017
Avg. Top 4	54.25	63.3
Avg. Top 10	52.3	59.8

Table 2-14. CAMS 675/1675 top 10 measured MDA8 O_3 values by year

Rank	2010	2011	2012	2013	2014	2015	2016	2017	2017 in C.I. for 2010-2012	2017 in C.I. for 2013-2015	2017 in C.I. for 2014-2016
1	72	86	81	82	68	76	65	69	Low	Yes	Yes
2	71	82	75	74	65	73	64	67	Low	Yes	Yes
3	69	79	74	72	62	73	63	66	Low	Yes	Yes
4	68	78	72	70	61	70	62	63	Low	Yes	Yes
5	67	77	72	69	61	70	61	62	Low	Yes	Yes
6	67	75	71	67	61	69	60	61	Low	Yes	Yes
7	67	75	70	67	60	67	60	61	Low	Yes	Yes
8	64	73	69	66	60	67	60	60	Low	Low	Yes
9	64	72	69	66	60	66	59	60	Low	Low	Yes
10	64	72	68	65	59	66	59	60	Low	Yes	Yes
Avg. Top 4	70.0	81.3	75.5	74.5	64.0	73.0	63.5	66.3	Low	Yes	Yes
Avg. Top 10	67.3	86.0	72.1	69.8	61.7	69.7	61.3	62.9	Low	Yes	Yes

Table 2-15. CAMS 6602 top 10 measured MDA8 O_3 values by year

Rank	2011	2012	2013	2014[3]	2015	2016	2017	2017 in C.I. for 2010-2012	2017 in C.I. for 2013-2015	2017 in C.I. for 2014-2016
1	80	70	77	n/a	77	62	68	Low	Yes	Yes
2	80	70	70	n/a	75	59	67	Yes	Yes	Yes
3	79	69	70	n/a	72	58	66	Low	Yes	Yes
4	75	69	69	n/a	71	58	65	Low	Yes	Yes
5	74	69	65	n/a	70	58	63	Low	Yes	Yes
6	72	67	64	n/a	69	57	63	Low	Yes	Yes
7	72	66	63	n/a	68	57	62	Yes	Yes	Yes
8	72	64	63	n/a	65	57	62	Yes	Yes	Yes
9	71	64	63	n/a	64	56	61	Low	Yes	Yes
10	71	63	63	n/a	62	56	60	Low	Yes	Yes
Avg. Top 4	78.5	69.5	71.5	n/a	73.8	59.25	66.5	Low	Yes	Yes
Avg. Top 10	74.6	67.1	66.7	n/a	69.3	57.8	63.7	Low	Yes	Yes

[3] CAMS 6602 2014 data not presented here due to data quality concerns.

2.3 3-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 - 2017. Consistent with the data-handling conventions for the 2015 O_3 NAAQS, values beyond the units' digit are truncated.

Table 2-16. Average of 4th-highest MDA8 values, 2013-2017 (ppb)

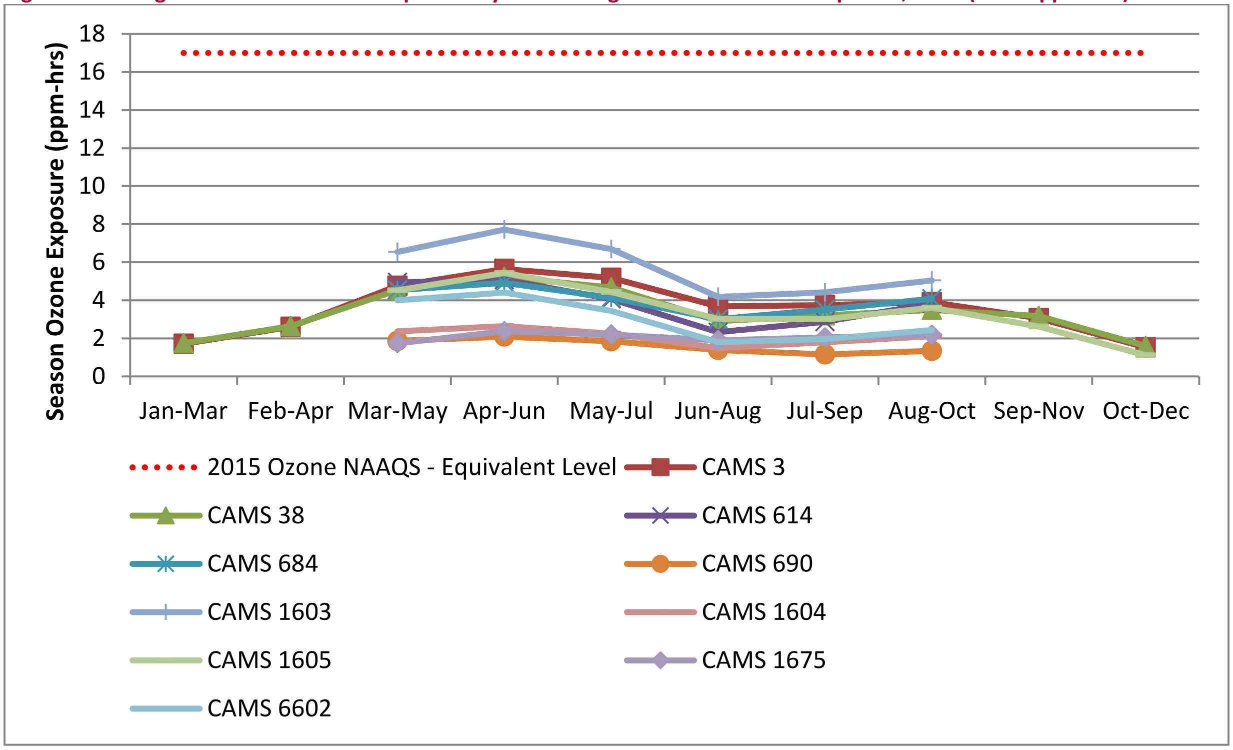
CAMS	2013	2014	2015	2016	2017	2013-2015 Avg.	2014-2016 Avg.	2015-2017 Avg.
3	69	62	73	64	70	68	66	69
38	70	63	73	62	67	68	66	67
601	64	69	70	59	64	67	66	64
614	67	63	71	65	67	67	66	68
684	64	53	69	59	57	62	60	62
690	75	66	75	61	70	72	67	68
1603	n/a	57	72	63	59	n/a	64	65
1604	n/a	64	67	60	67	n/a	63	65
1675	70	61	70	62	63	67	64	65
6602	69	n/a	71	58	65	n/a	n/a	65

As the table shows, CAMS 684 has the lowest three-year average from 2015-2017, which continues this monitor's trend of registering the lowest averages in the region. CAMS 3 had the highest three-year average from 2015-2017 at 69 ppb. All ozone monitors in the region averaged a higher three-year average from 2015-2017 than from 2014-2016. This suggests that there was in increase in ozone formation from 2015-2017 compared to 2014-2016. There is one research monitoring station operated by CAPCOG (CAMS 690) that had a three-year average over 70 ppb from 2013 – 2015. However, the three-year average has since dropped below 70 ppb.

2.4 W126 O_3

While EPA set the 2015 secondary O_3 standard identical to the 2015 primary O_3 standard, 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 3-year W126 index." EPA did not set a separate secondary standard because, "such control of cumulative seasonal exposure will be achieved with a standard set at a level of 0.070 ppm, and the same indicator, averaging time, and form as the current standard." The region's peak seasonal O_3 exposure levels were well below the 17 ppm-hrs levels 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 Ozone Exposure by Monitoring Station and 3-month period, 2017 (W126 ppm-hrs)



3 Temporal Analysis

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

3.1 Earliest and Latest Dates for High O_3 in 2017

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 Ozone" 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, and 2017.

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

MDA8 O_3	2010-2015 Earliest Date	2010-2015 Latest Date	2016 Earliest Date	2016 Latest Date	2017 Earliest Date	2017 Latest Date
Regional Peak ≥ 55 ppb	2/10/2015	11/8/2012	2/11/2016	10/27/2016	2/22/2017	10/26/2017
Regional Peak > 70 ppb	3/25/2012	10/17/2015	10/3/2016	10/3/2016	5/6/2017	9/13/2017
CAMS 3 Top 4	4/13/2011	10/24/2014	2/12/2016	10/3/2016	5/6/2017	9/1/2017
CAMS 3 Top 10	3/13/2013	10/25/2014	2/12/2016	10/3/2016	4/7/2017	9/13/2017
CAMS 38 Top 4	5/2/2015	10/24/2014	2/12/2016	10/2/2016	5/6/2017	9/13/2017
CAMS 38 Top 10	3/13/2013	10/26/2014	2/12/2016	10/2/2016	4/7/2017	9/13/2017

This table shows that MDA8 O_3 values in the region reached "moderate" and "unhealthy for sensitive groups" AQI levels in 2017 within the range of times observed from 2010-2015.

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 and 2015, 2016, and 2017.

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

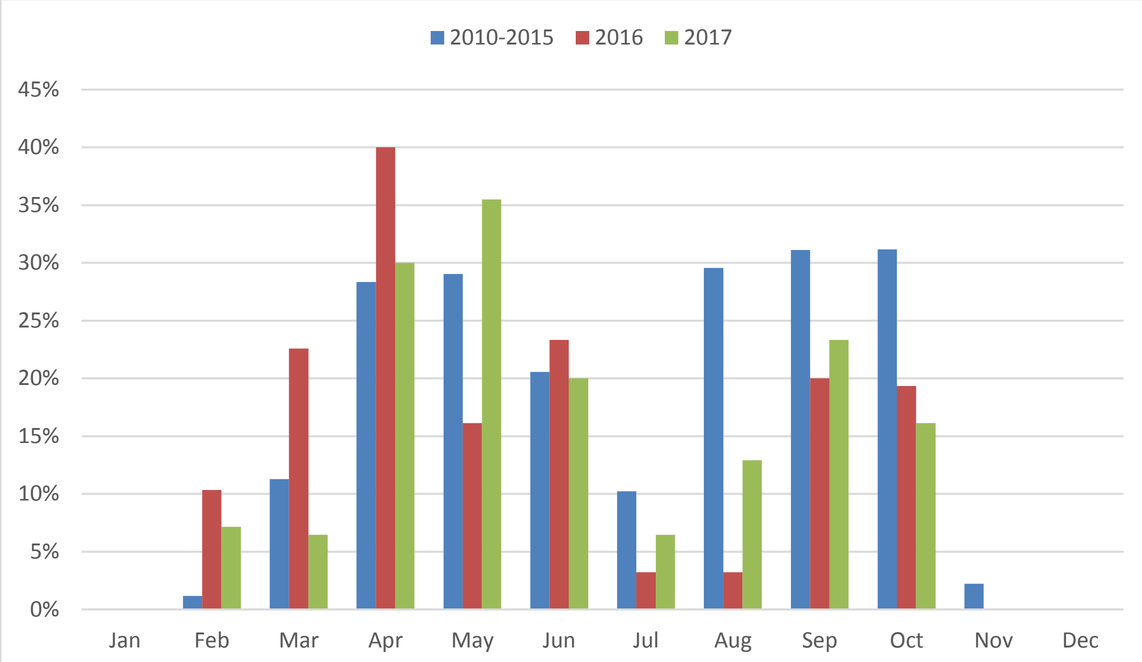
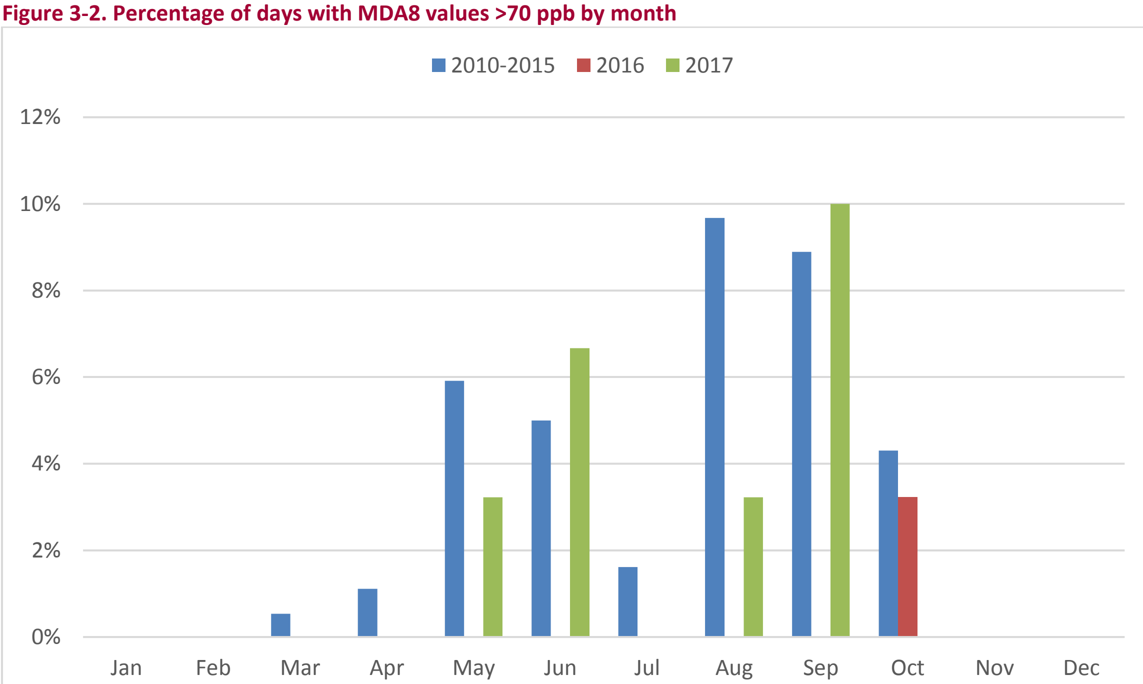


Figure 3-2. Percentage of days with MDA8 values >70 ppb by month



Considering that there had only been two instances when MDA8 O_3 values had been 55 ppb or higher in February from 2010-2015, it is surprising to see that there were three in February 2016 and two in 2017. This may suggest that, while there is an overall improvement in ozone quality, there are more months which can see elevated MDA8 values.

As the table below shows, distribution of MDA8 O_3 values 55 ppb or higher were significantly different in August, September, and October 2017 from those months in the 2010-2015 timeframe and significantly different in March, April and August 2017 from those month in 2016.

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

Month	Chi-Squared Value for 2010-2015 Comparison	Chi-Squared Value for 2016 Comparison
January	n/a	n/a
February	3.609714	1.771073
March	2.381965	**7.207757**
April	1.339855	**5.41875**
May	1.358809	2.341935
June	1.484058	0.914286
July	2.381965	0.13172
August	**10.16576**	**7.69422**
September	**4.408333**	0.016667
October	**8.500061**	3.145257
November	1.066667	n/a
December	n/a	n/a
TOTAL	**36.69719**	**28.64167**

As the table below shows, distribution of MDA8 O_3 values over 70 ppb that were statistically significantly different in June and September 2017 from those months in the 2010-2015 timeframe.

Table 3-3 Chi-squared values for comparison of 2017 monthly distribution of MDA8 O_3 concentrations above 70 ppb to 2016 and 2010-2015

Month	Chi-Squared Value for 2010-2015 Comparison	Chi-Squared Value for 2016 Comparison
January	n/a	n/a
February	n/a	n/a
March	0.037634	n/a
April	0.077778	n/a
May	0.829563	n/a
June	**7.778571**	n/a
July	0.112903	n/a
August	0.15361	n/a
September	**9.086508**	n/a
October	0.301075	0.225806
November	n/a	n/a
December	n/a	n/a
TOTAL	**18.37764**	**0.225806**

3.3 High O_3 Days by Day of the Week

CAPCOG analyzed the frequency of high O_3 days by day of 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. There was no statistically significant difference in the day-of-week distributions for either range of MDA8 values at a significance level of 0.05. However, at a significance level of 0.10, Sunday was statistically significantly less likely to have an MDA8 value of ≥55 ppb region-wide, MSA-wide, and at CAMS 38, 684, and 690, while Saturday was statistically significantly more likely to have an MDA8 value of ≥55 ppb at CAMS 1604.

Figure 3-3. Distribution of MDA8 O_3 55 ppb or above by day of the week

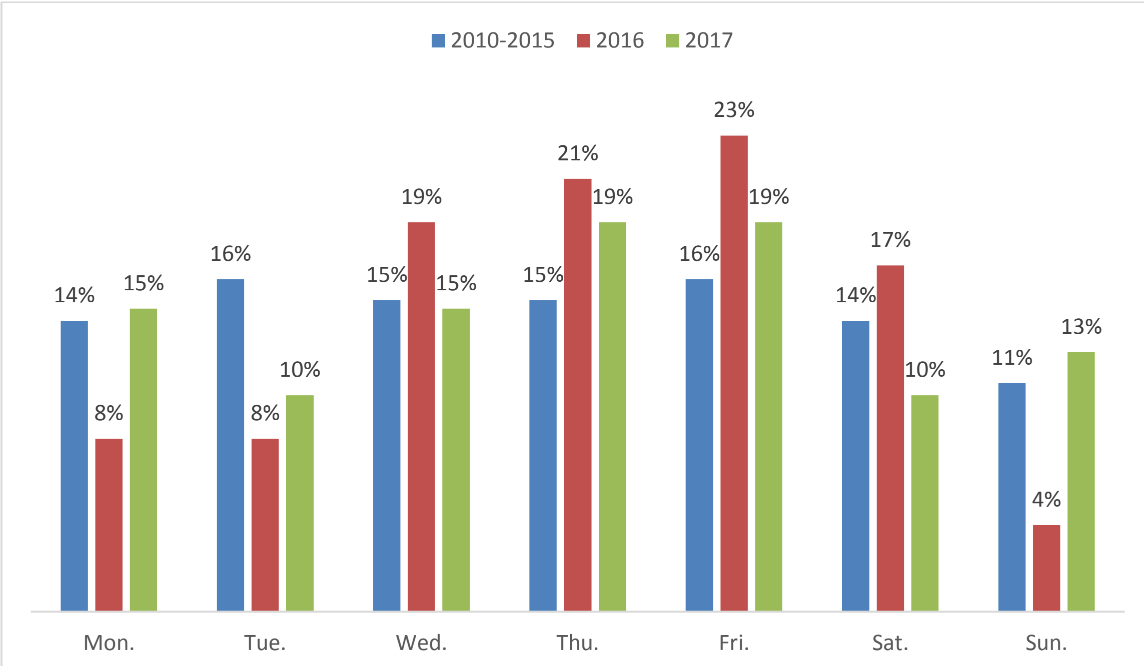
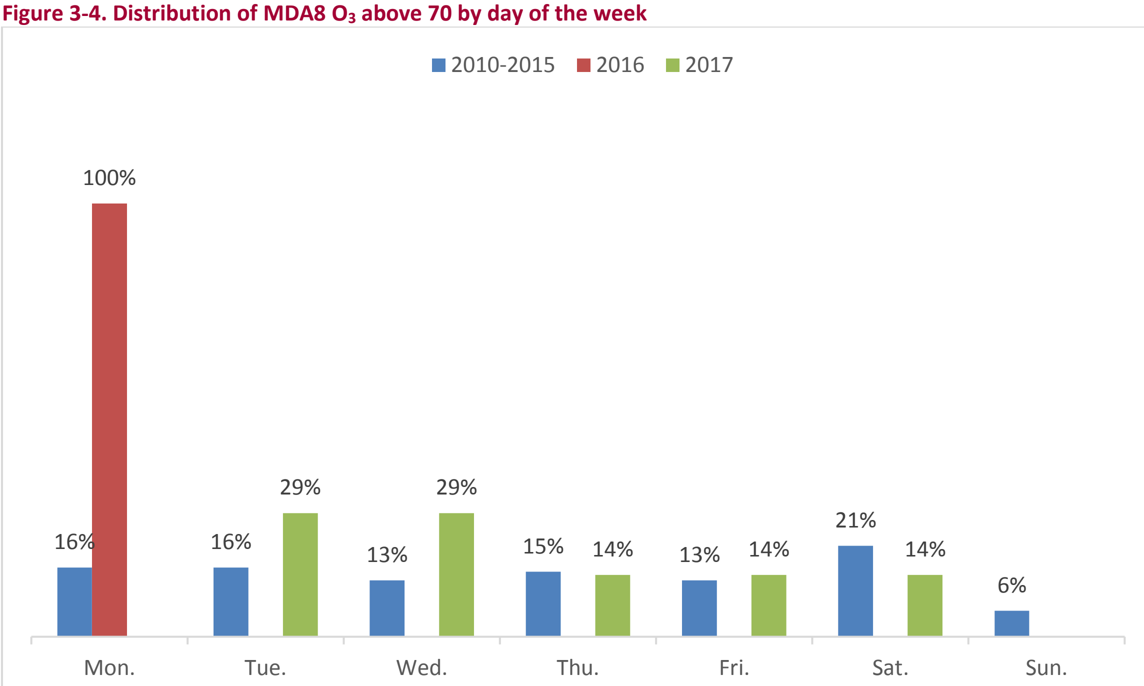


Figure 3-4. Distribution of MDA8 O_3 above 70 by day of the week



CAPCOG performed statistical analyses based on days with MDA8 O_3 ≥55 ppb and >70 ppb, comparing 2010-2015 and 2016 data to 2017 data. As the tables below show, Tuesdays were the only day that were statistically significantly different on days with MDA8 O_3 ≥55 ppb in 2010-2015 compared to 2017. Monday, Wednesday, Friday, Saturday, and Sunday were all statistically significantly different on days with MDA8 O_3 ≥55 ppb. There were no statistically significant differences in the data on days with MDA8 >70 ppb when comparing 2010-2015 data to 2017 data; 2016 data was not valuated for differences since there was only one day in 2016 with MDA8 >70 ppb.

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

Month	Chi-Squared Value for 2010-2015 Comparison	Chi-Squared Value for 2016 Comparison
Monday	0.0784	**9.009603**
Tuesday	**7.1824**	1.003203
Wednesday	0.04	**4**
Thursday	3.24	0.996803
Friday	1.7424	**4.006403**
Saturday	2.9584	**9.009603**
Sunday	0.5184	**15.9872**
TOTAL	**15.76**	**44.01282**

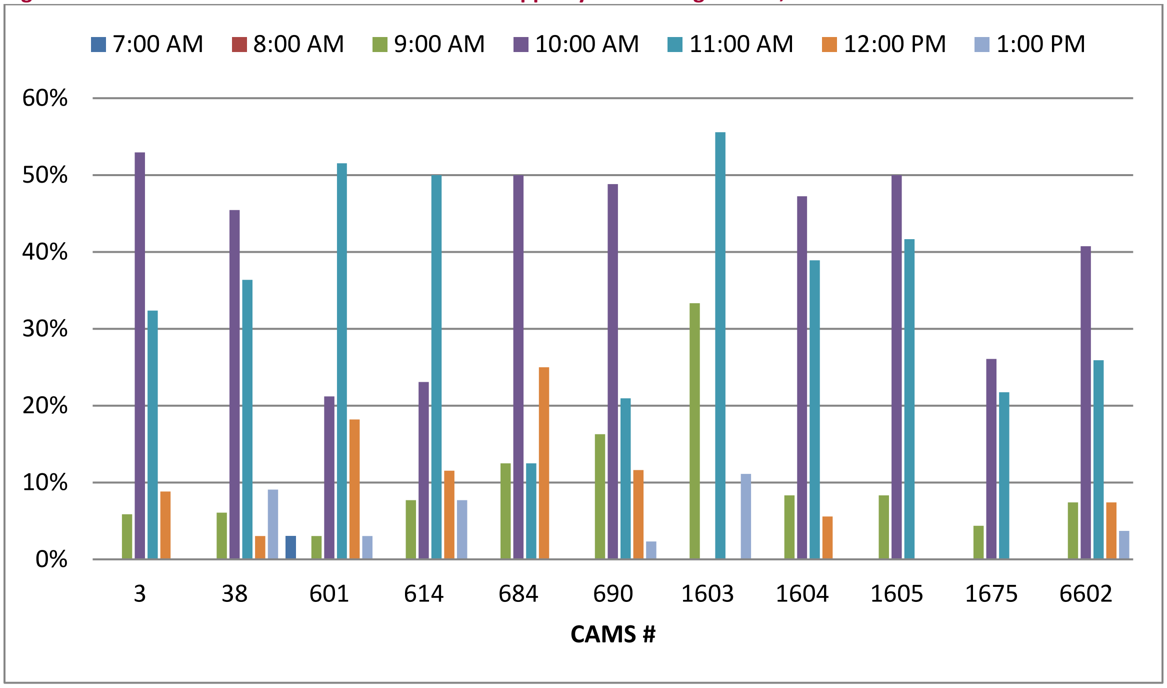
Table 3-5 Chi-squared values for comparison of 2017 daily distribution of MDA8 O_3 concentrations above 70 ppb to 2010-2015

Month	Chi-Squared Value for 2010-2015 Comparison
Monday	1.2544
Tuesday	0.7744
Wednesday	1.1881
Thursday	0.0025
Friday	0.0081
Saturday	0.2209
Sunday	0.1764
TOTAL	**3.6248**

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 2017. 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, 2017



CAPCOG compared the distribution of start hours in 2017 to what was typical for 2010-2015 and 2016. The 2017 distributions were statistically significantly different from 2010-2015 distributions at a significance level of 0.05 for CAMS 690, CAMS 1603, and CAMS 6602. The following figures show comparisons of these distributions.

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

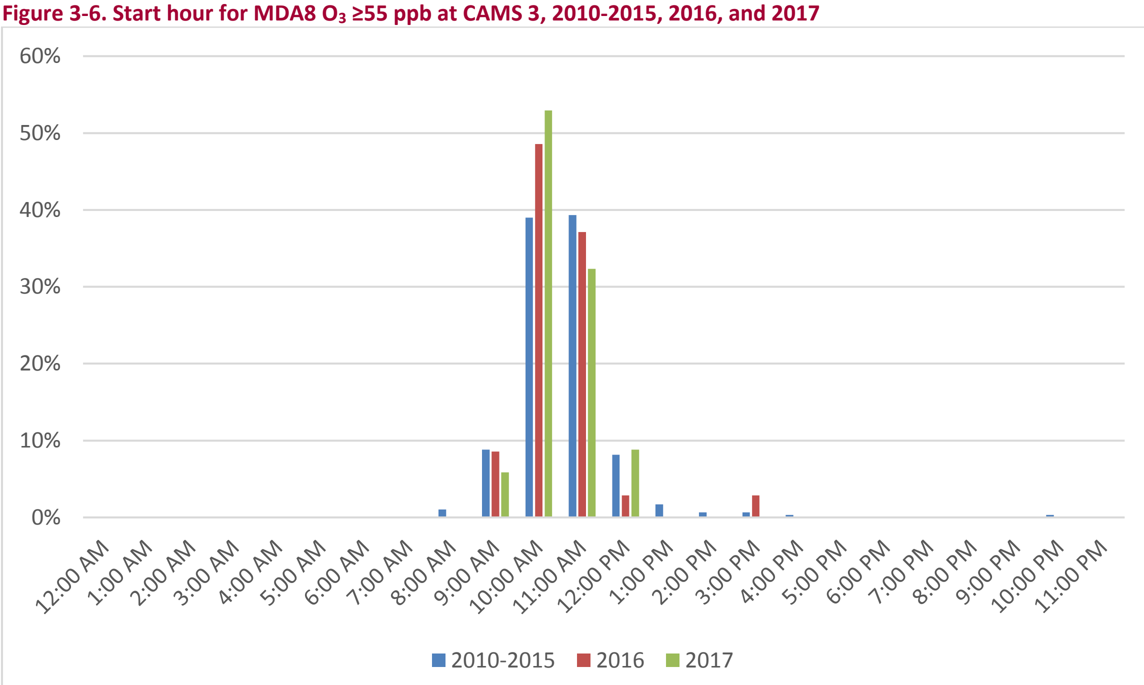


Figure 3-7. Start hour for MDA8 O_3 ≥55 ppb at CAMS 38, 2010-2015, 2016, and 2017

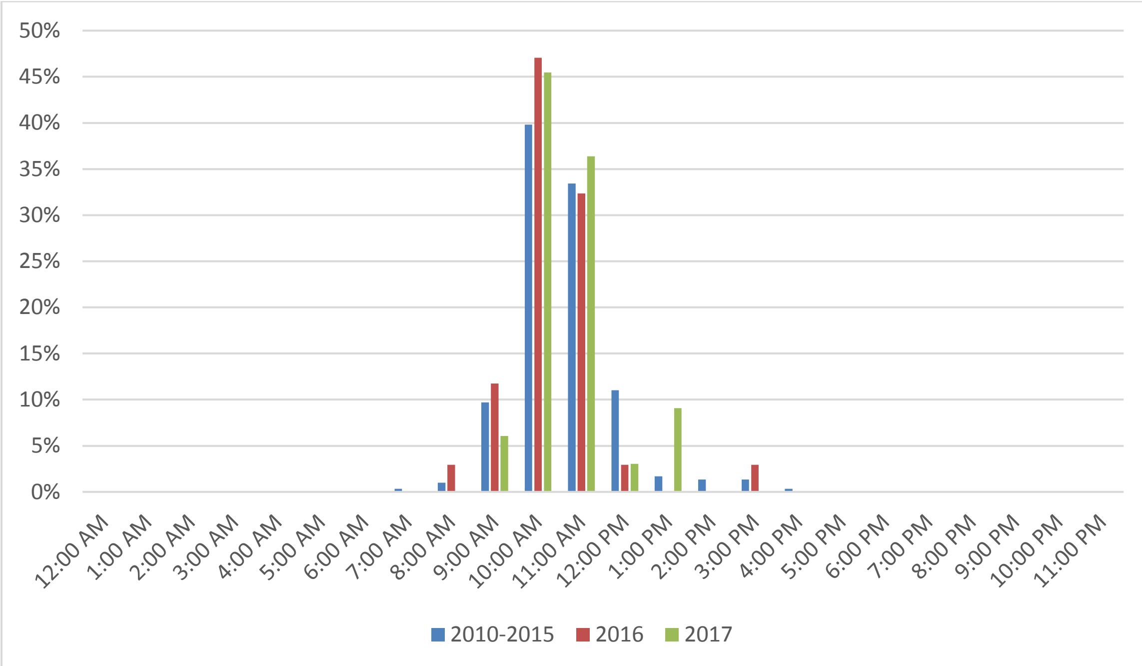


Figure 3-8. Start hour for MDA8 O_3 ≥55 ppb at CAMS 601, 2010-2015, 2016, and 2017

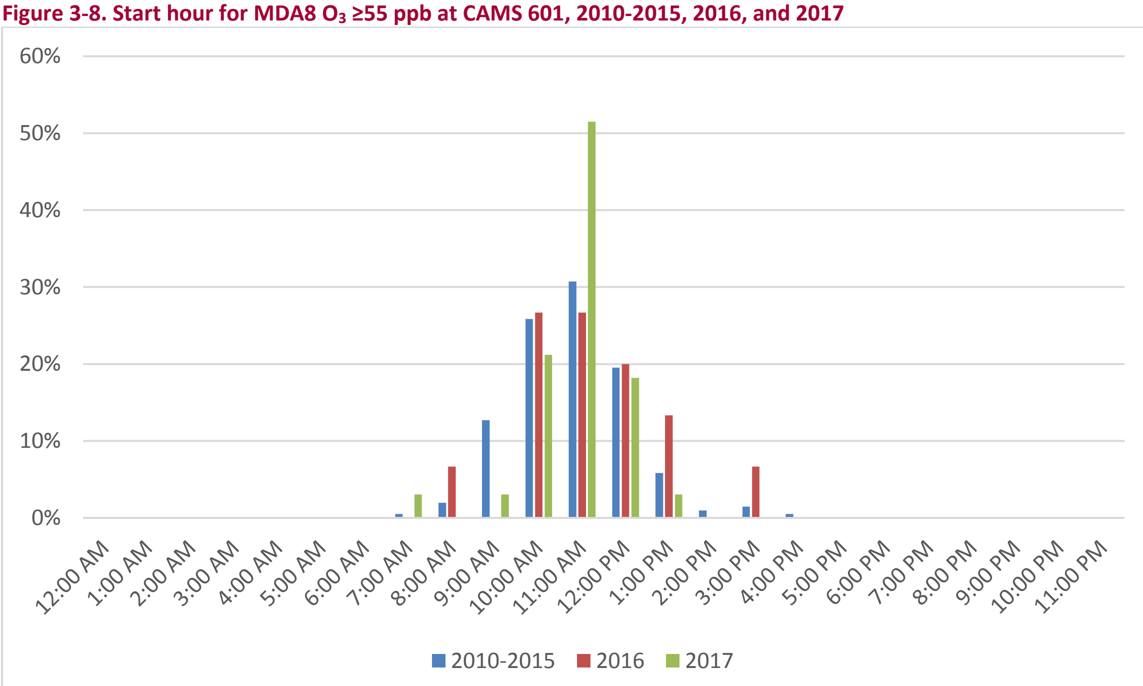


Figure 3-9. Start hour for MDA8 O_3 ≥55 ppb at CAMS 614, 2010-2015, 2016, and 2017

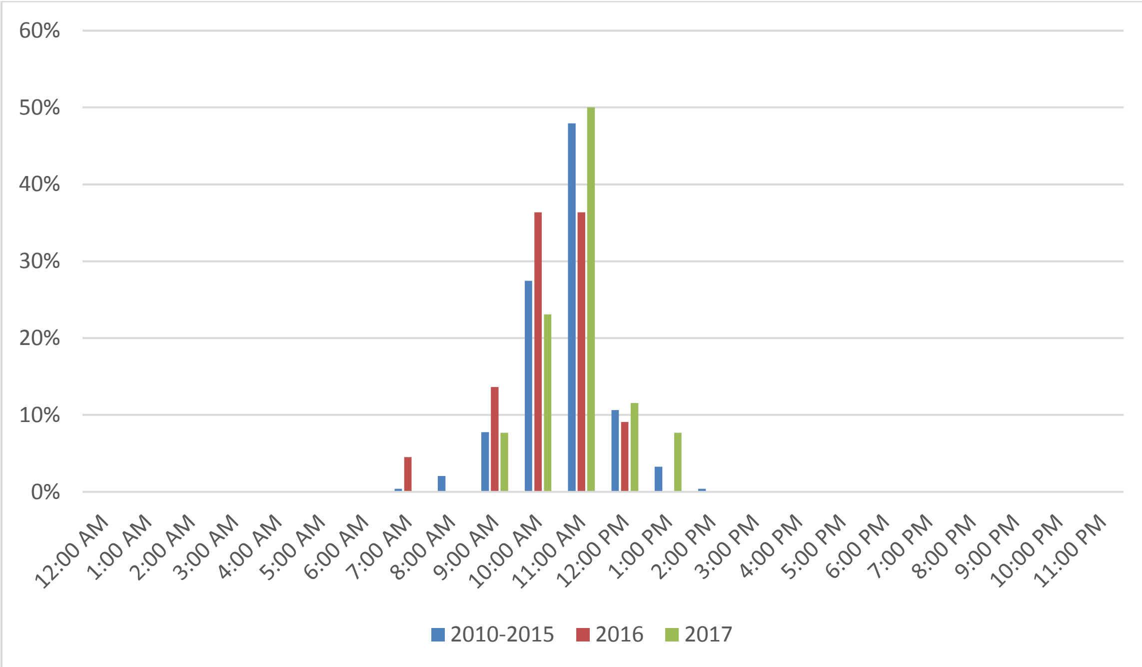


Figure 3-10. Start hour for MDA8 O_3 ≥55 ppb at CAMS 684, 2010-2015, 2016, and 2017

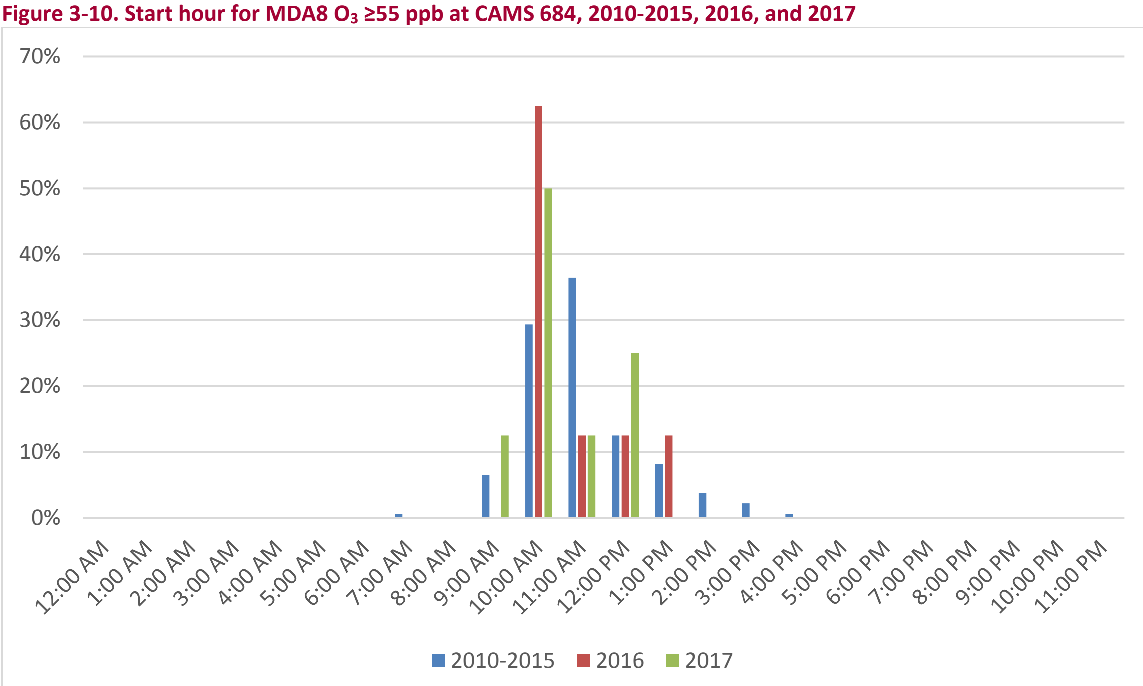


Figure 3-11. Start hour for MDA8 O_3 ≥55 ppb at CAMS 690, 2010-2015, 2016, and 2017

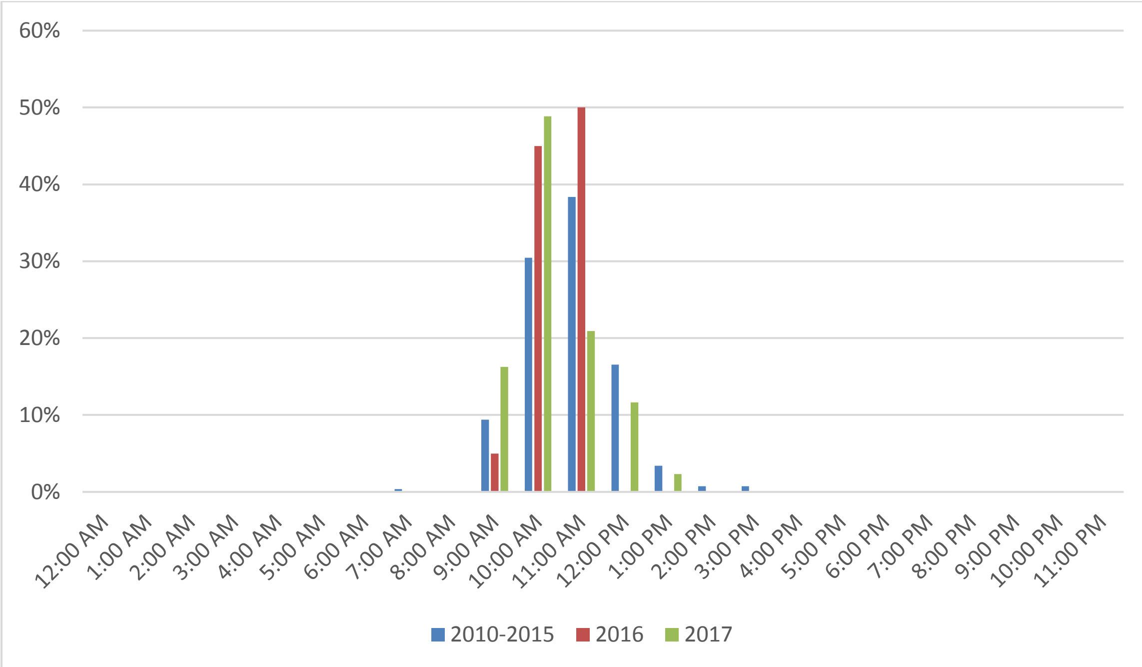


Figure 3-12. Start hour for MDA8 O_3 ≥55 ppb at CAMS 1603, 2010-2015, 2016, and 2017

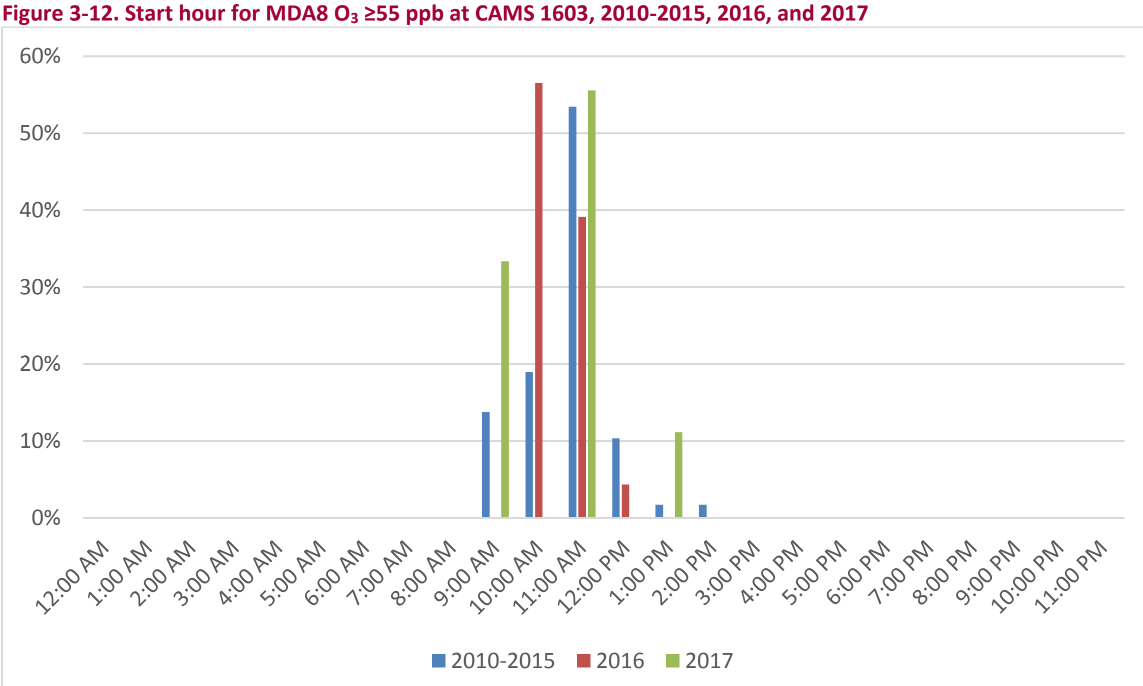


Figure 3-13. Start hour for MDA8 O_3 ≥55 ppb at CAMS 1604, 2010-2015, 2016, and 2017

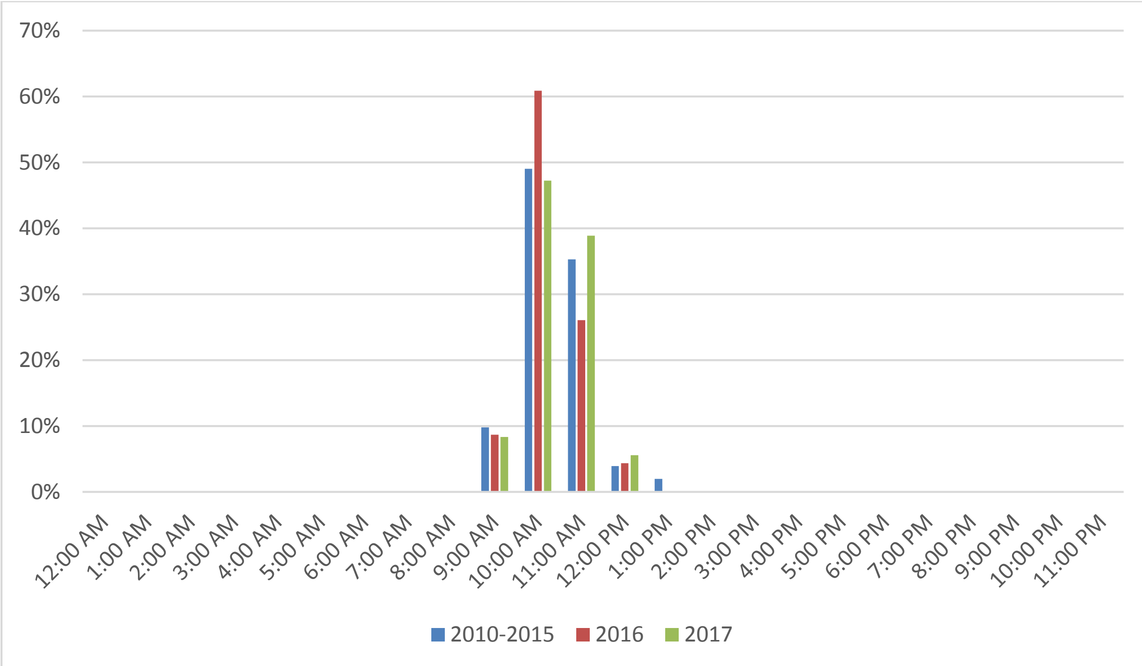


Figure 3-14. Start hour for MDA8 O_3 ≥55 ppb at CAMS 1675, 2010-2015, 2016, and 2017

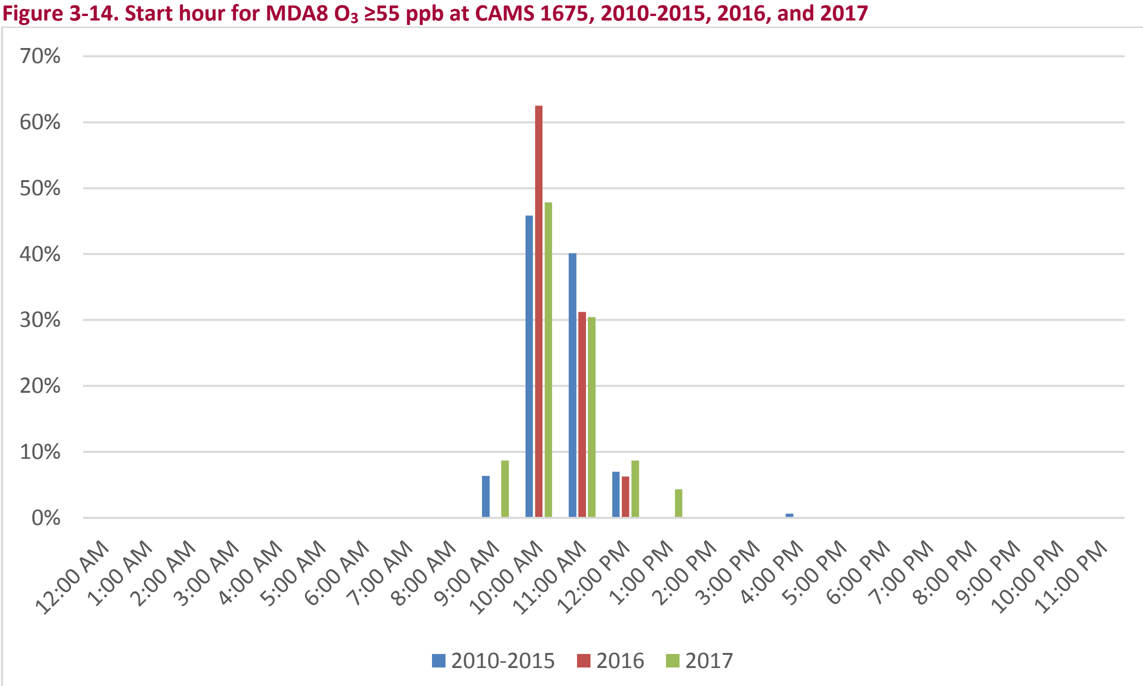
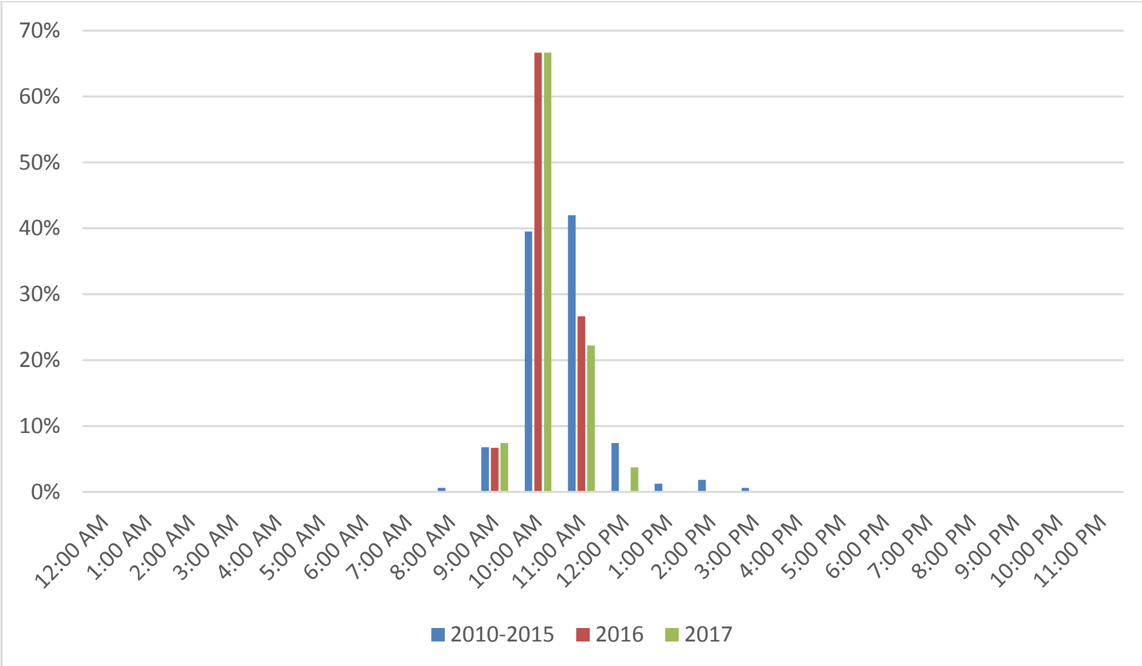


Figure 3-15. Start hour for MDA8 O_3 ≥55 ppb at CAMS 6602, 2010-2015, 2016, and 2017



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 over 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 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 data at Camp Mabry [CAMS 5002]

- solar radiation data at CAMS 38

4.1 Wind Speed

CAPCOG's most recent O_3 conceptual model showed that average wind speeds between 12 pm-4 pm had a 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 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 2017 wind speeds were statistically significantly different from wind speeds observed 2010-2015 or if the relationship between O_3 and wind speed was statistically significantly different from the relationship observed 2010-2015.

4.1.1 Comparison of Relationship between Wind Speed and MDA8 O_3 in 2017 to 2010-2015

The figures below are scatter plots of MDA8 O_3 values compared to average wind speed between 12 pm and 4pm at CAMS 3 for 2010-2015, 2016, and 2017.The very small R^2 values for the data suggests that this is not a very good predictor for MDA8 O_3 values. There was a slightly negative correlation for the 2010-2015 data and a slightly positive correlation for the 2016 and 2017 data, but all data sets are still fairly consistent in showing MDA8 O_3 values not being very substantially influenced by wind speed.

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

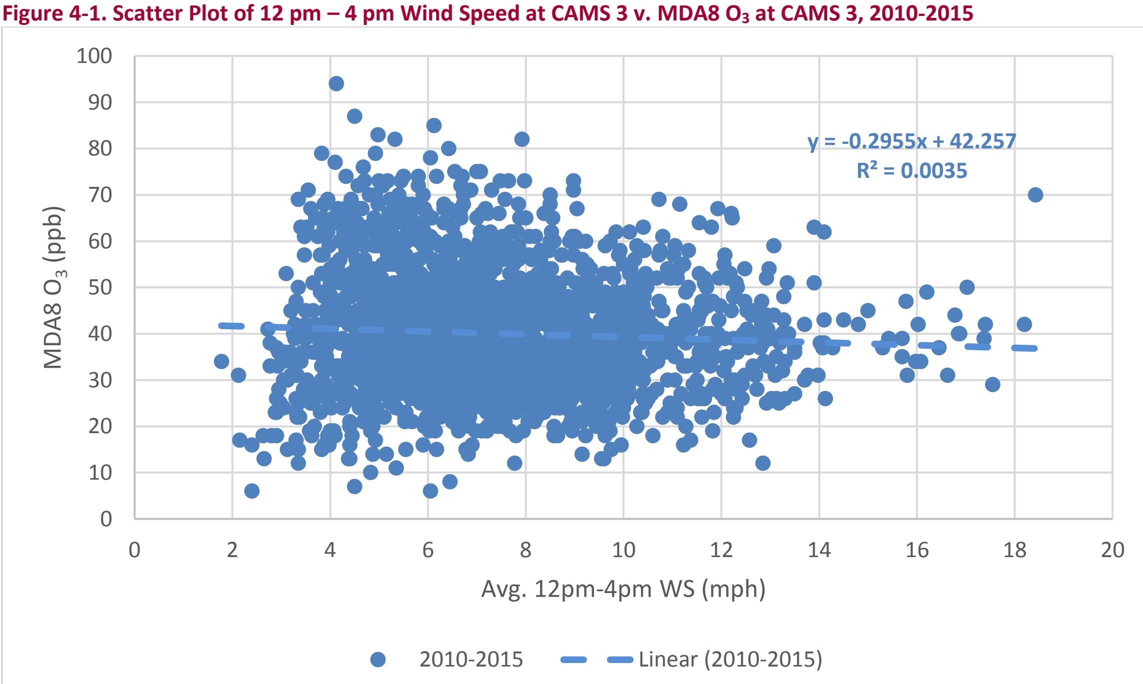


Figure 4-2. Scatter Plot of 12 pm – 4 pm Wind Speed at CAMS 3 v. MDA8 O_3 at CAMS 3, 2016

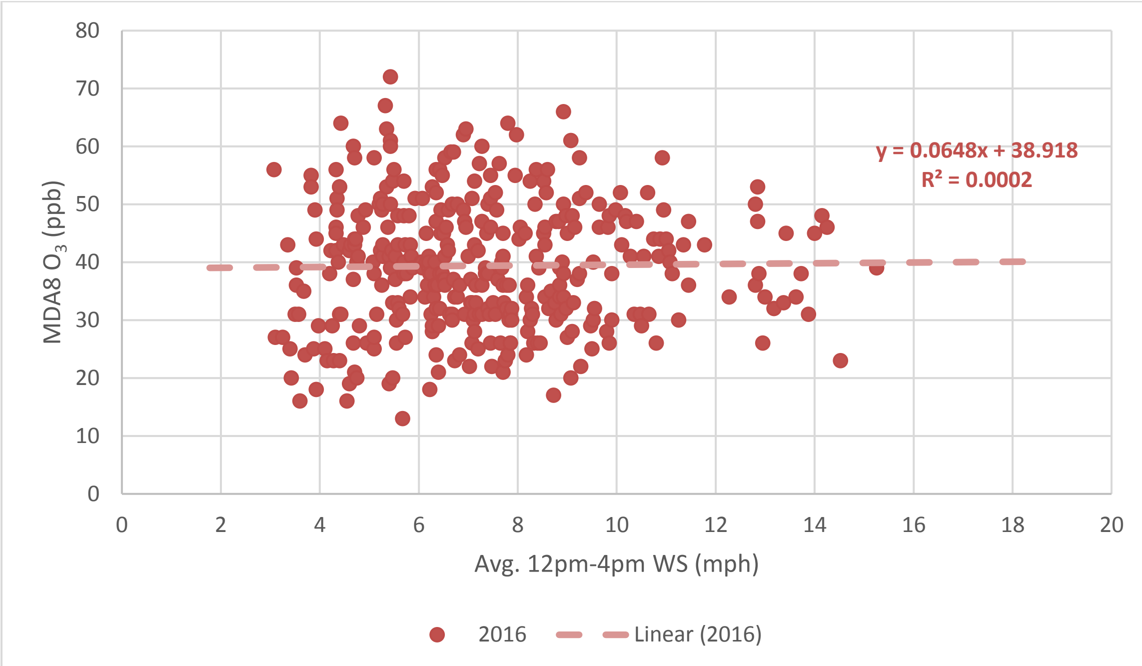
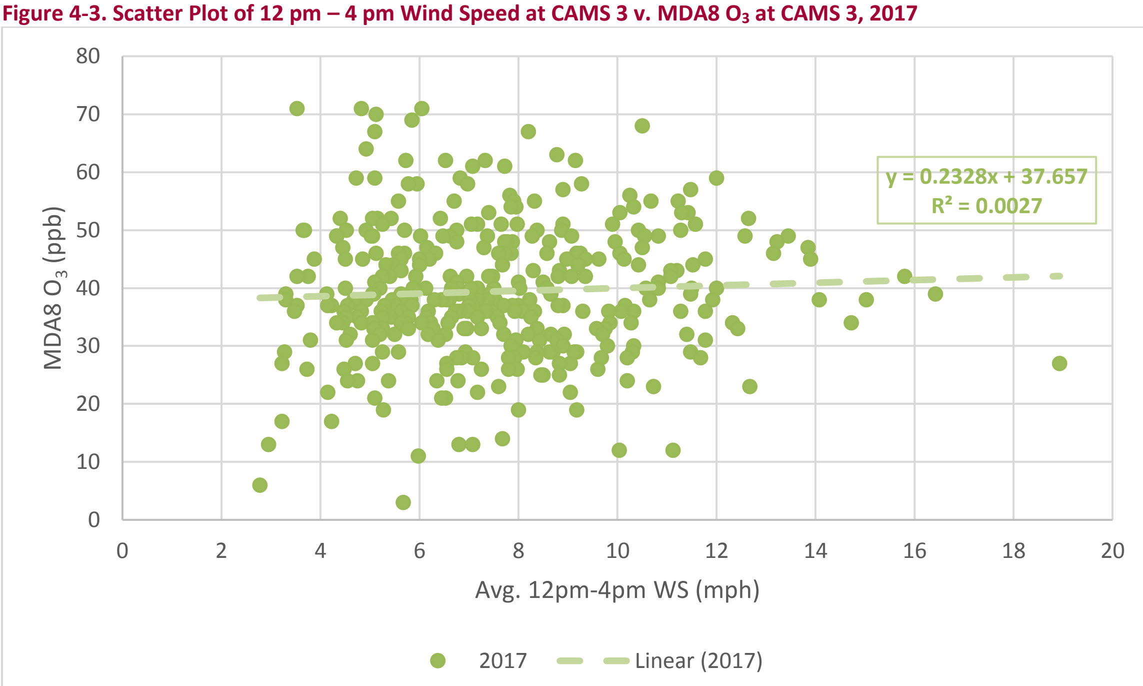
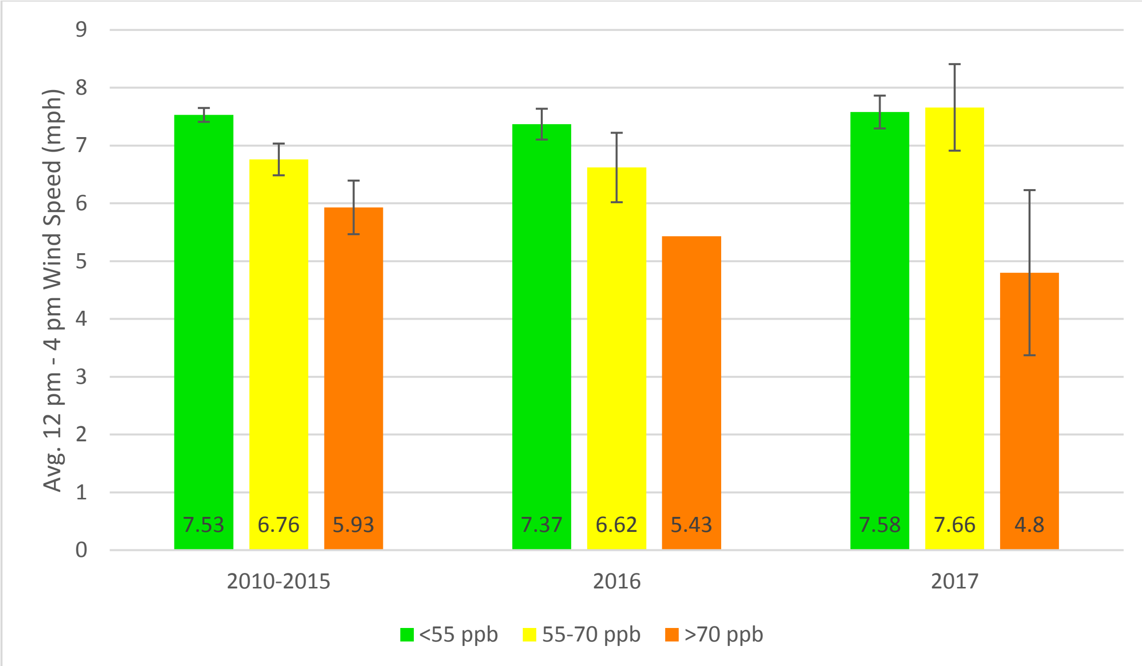


Figure 4-3. Scatter Plot of 12 pm – 4 pm Wind Speed at CAMS 3 v. MDA8 O_3 at CAMS 3, 2017



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 2017 compared to 2010-2015 and 2016.

Figure 4-4. 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, and 2017

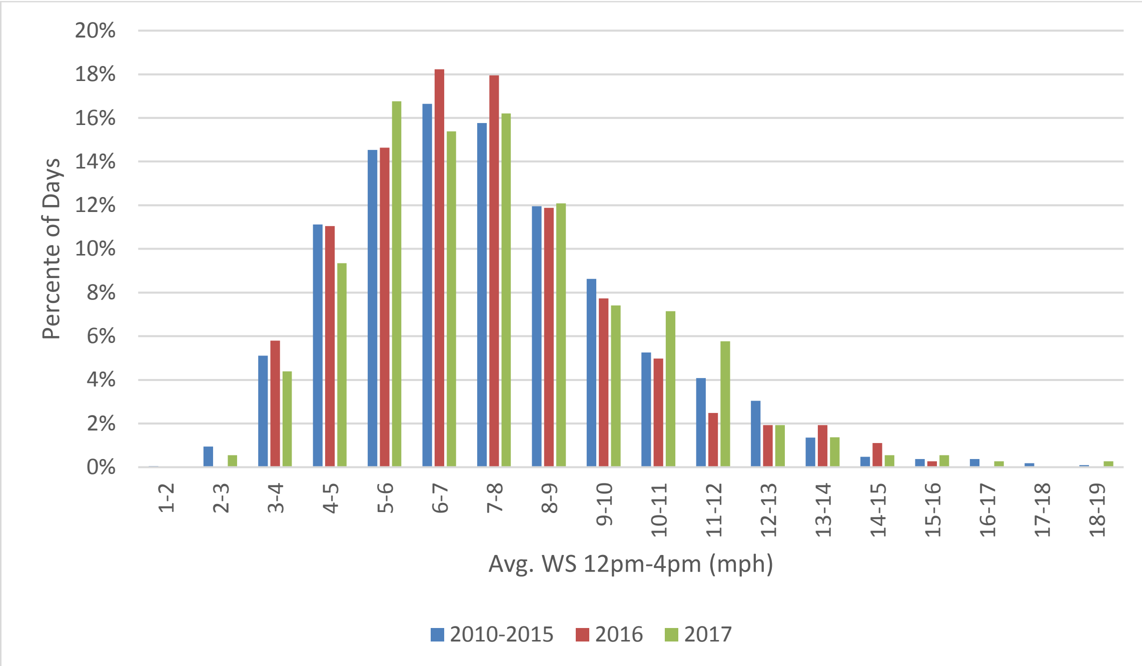


Typical 12 pm – 4 pm wind speeds were statistically significantly lower in 2016 for the <55 ppb range at a 0.05 significance level, and the single MDA8 O_3 value >70 ppb was below the lower end of the 95% confidence interval for the typical >70 ppb wind speed for 2010-2015. However, average wind speeds for days 55-70 ppb in 2016 were not statistically significantly different from wind speeds 2010-2015 at a 0.05 significance level. In 2017, wind speeds were statistically significantly higher for the 55-70 ppb range and statistically significantly lower for the >70 ppb range. Additionally, unlike 2010-2015 and 2016, the 55-70 ppb range was higher in 2017 than the >55 ppb range.

4.1.2 Comparison of 2017 Wind Speeds to 2010-2015 and 2016 Wind Speeds

Based on CAPCOG's review of wind speed data at CAMS 3 from 2010-2015, 2016, and 2017, CAPCOG determined that average 12 pm – 4 pm wind speeds in 2017 were not statistically significantly different from average 12 pm – 4 pm average wind speeds from 2010-2015 and 2016 at a 0.05 significance level. The figure below shows the distribution of daily average wind speeds between 12 pm and 4 pm at CAMS 3.

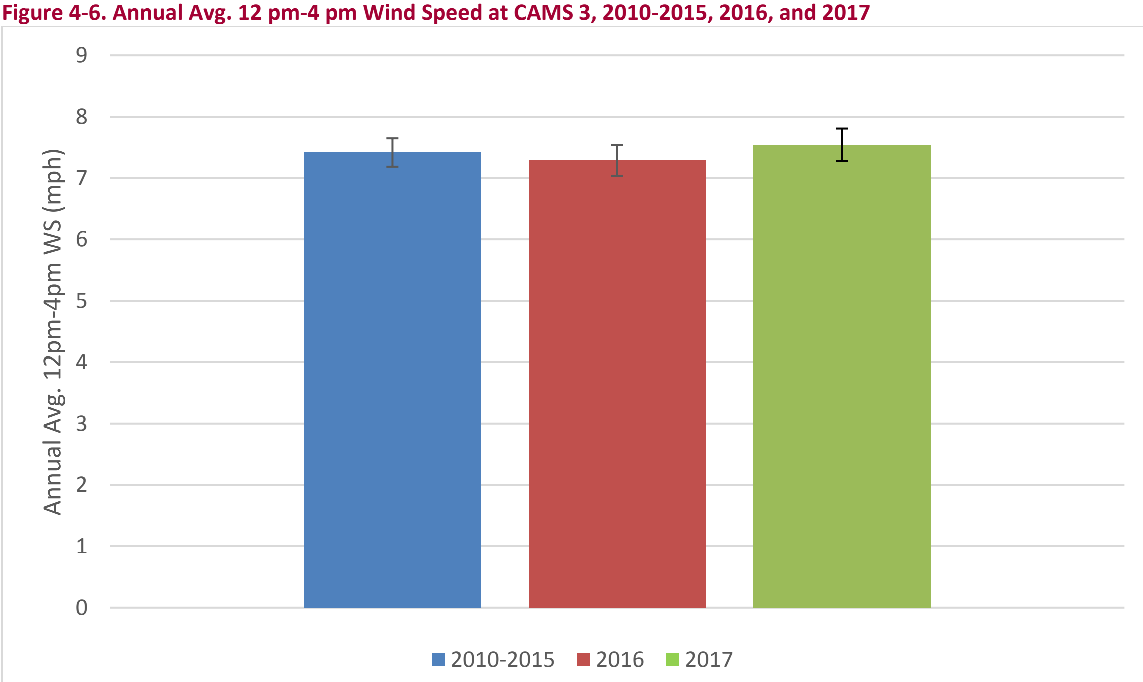
Figure 4-5. Histogram of 12 pm – 4 pm Wind Speeds at CAMS 3, 2010-2015, 2016, and 2017



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.

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 each year from 2010-2015, as well as the average for 2016, along with the 95% confidence intervals.

Figure 4-6. Annual Avg. 12 pm-4 pm Wind Speed at CAMS 3, 2010-2015, 2016, and 2017



As the figure above shows, the annual average 12 pm-4 pm wind speeds in 2016 and 2017 were within the 95% confidence interval for the 2010-2015 annual average 12pm-4pm wind speed. The 2010-2015 average and confidence interval was calculated using the 6 annual averages for 2010, 2011, 2012, 2013, 2014, and 2015.

4.2 Temperature

CAPCOG's most recent O_3 conceptual model showed that average temperatures between 12 pm-4 pm had a statistically significantly 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 typically included the peak O_3 concentrations for the day. 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 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 2017 temperatures were statistically significantly different from temperatures observed 2010-2015 or if the relationship between O_3 and temperature was statistically significantly different from the relationship observed 2010-2015.

4.2.1 Comparison of Relationship between Temperature and MDA8 O_3 in 2017 to 2010-2015

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

Figure 4-7. Scatter Plot of 12 pm – 4 pm Temperature at CAMS 3 v. MDA8 O_3 at CAMS 3, 2010-2015

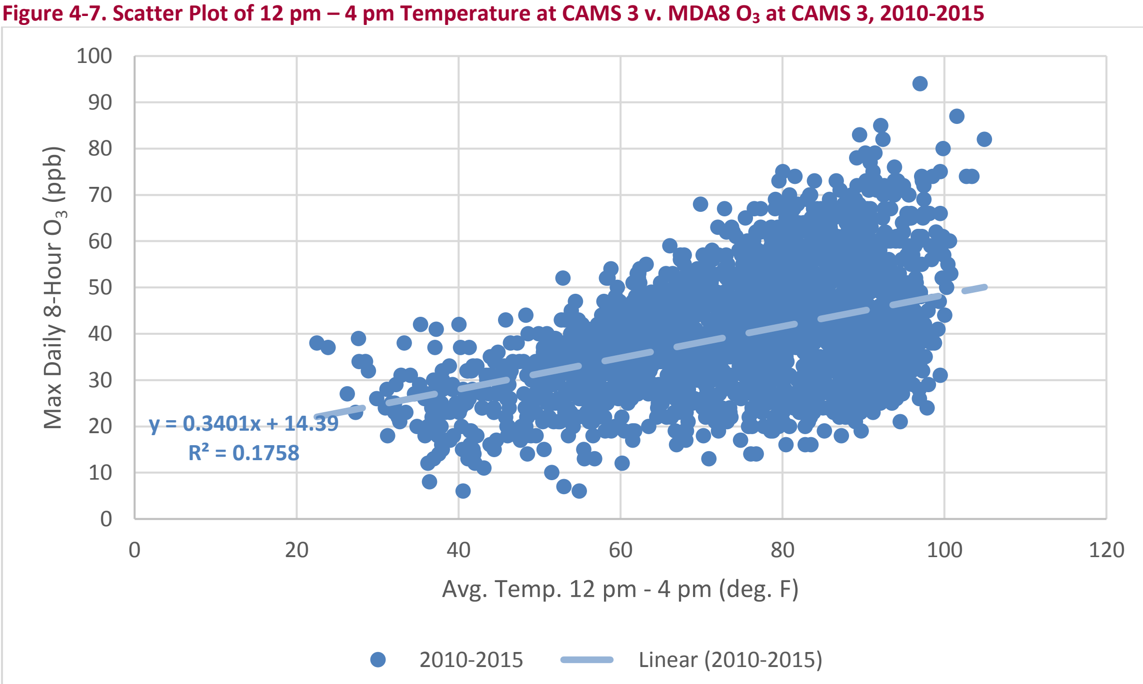


Figure 4-8. Scatter Plot of 12 pm – 4 pm Temperature at CAMS 3 v. MDA8 O_3 at CAMS 3, 2016

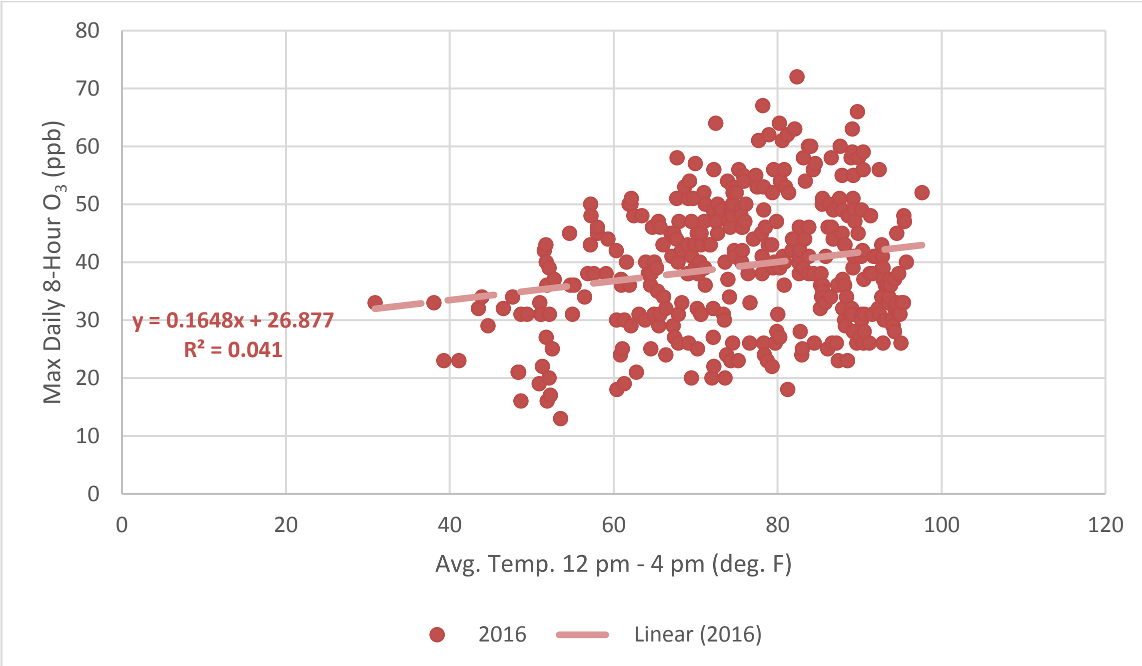
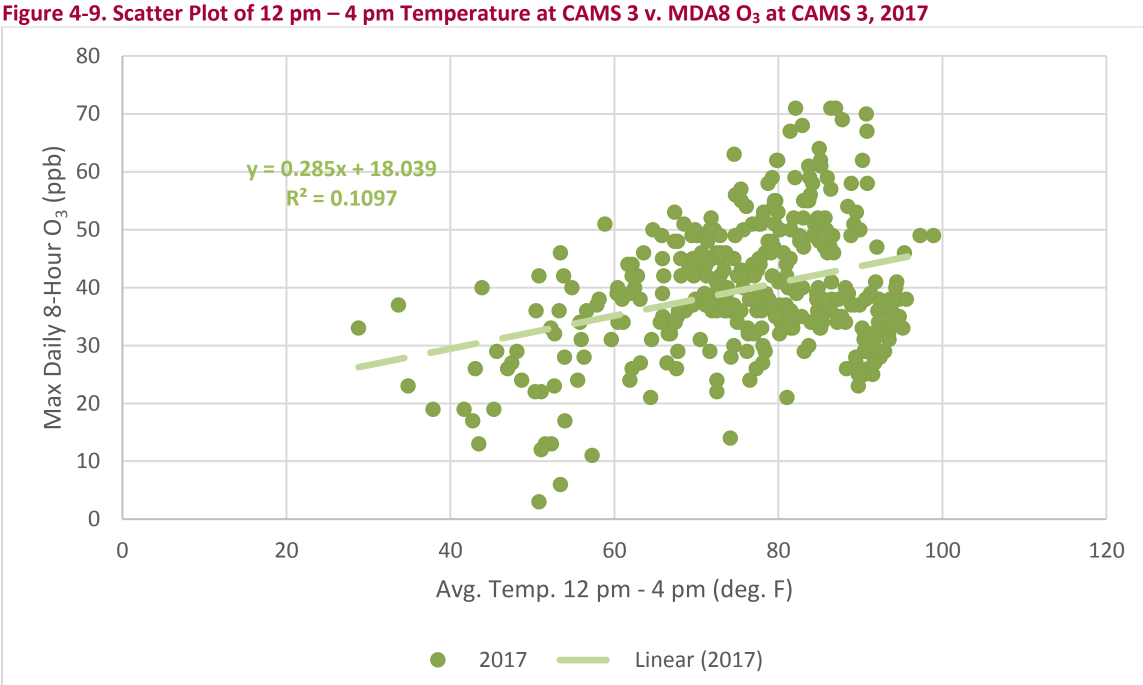
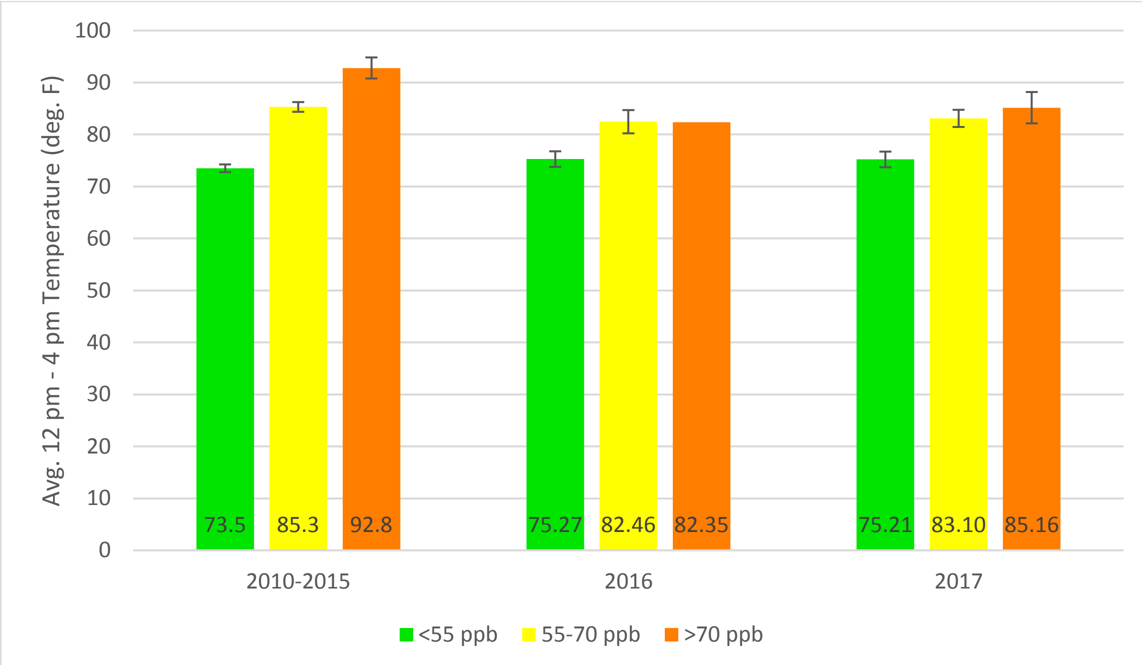


Figure 4-9. Scatter Plot of 12 pm – 4 pm Temperature at CAMS 3 v. MDA8 O_3 at CAMS 3, 2017



The figure below shows a comparison of the typical temperatures between 12 pm and 4 pm on days <55 ppb, 55-70 ppb, and >70 ppb in 2017 relative to 2016 and 2010-2015. Like 2016, the temperatures typical for days with MDA8 O_3 days < 55 ppb in 2017 were statistically significantly higher than what was typical for such days in 2010-2015, while temperatures typical for MDA8 O_3 55-70 ppb and >70 ppb days in 2017 were statistically significantly lower than what was typical for 2010-2015. In addition, the 2017 data did continue to show statistically significant differences between temperatures for days with MDA8 O_3 <55 ppb and days with MDA8 O_3 of 55-70 ppb and >70 ppb.

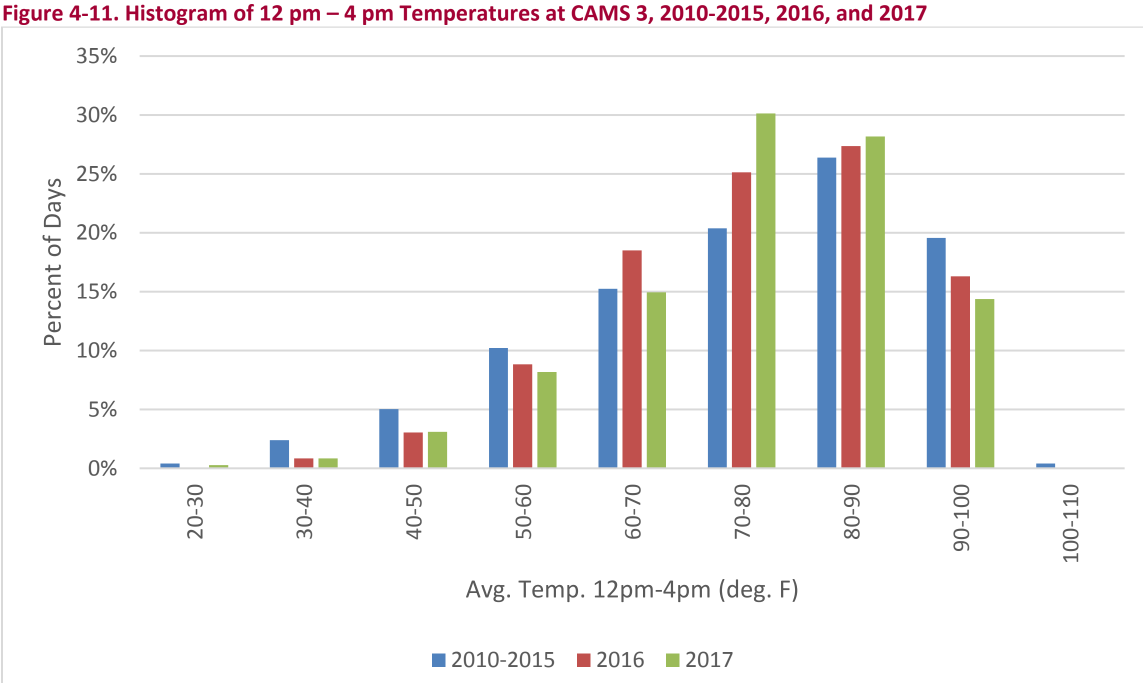
Figure 4-10. Typical Temperature 12 pm – 4pm at CAMS 3 on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 3, 2010-2015, 2016, and 2017



4.2.2 Comparison of 2017 Temperatures to 2010-2015 Temperatures

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

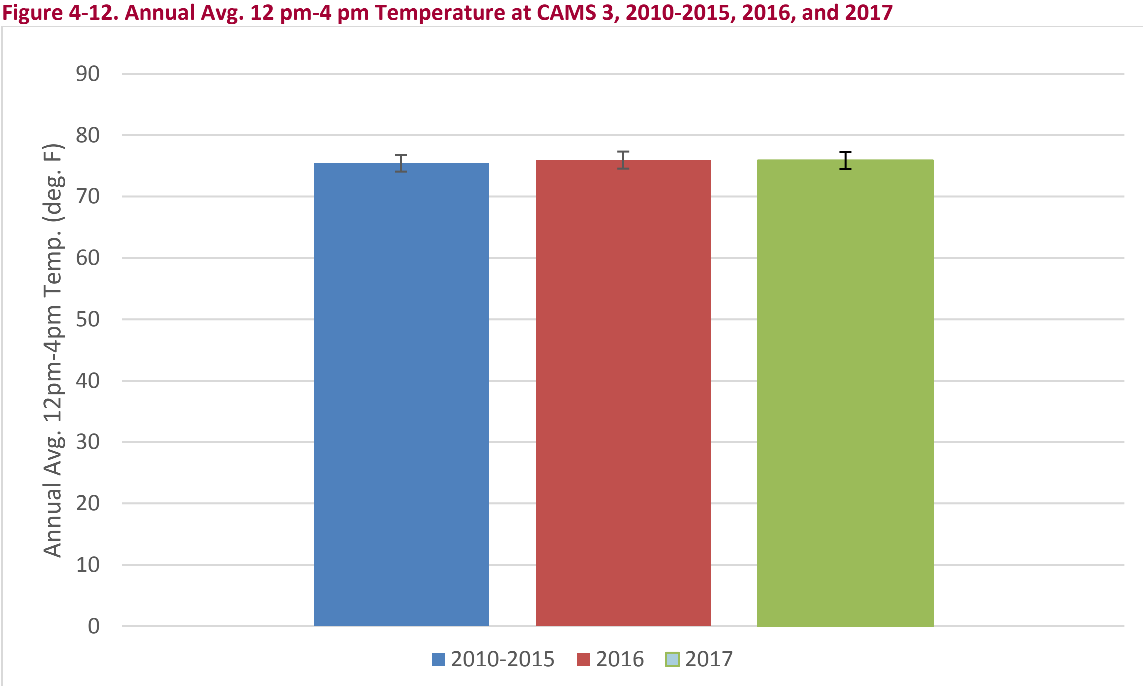
Figure 4-11. Histogram of 12 pm – 4 pm Temperatures at CAMS 3, 2010-2015, 2016, and 2017



CAPCOG performed a chi-squared test of independence on the data to determine if the distribution of the average temperatures from 12 pm – 4 pm into these 10°F bins was statistically significantly different from the distribution in 2010-2015 or 2016. CAPCOG found that there was a statistically significant difference in the distribution using this test at a 0.05 significance level between 2017 and 2010-2015 data but not statistically significantly different when comparing 2017 and 2016 data.

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

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



The figure above shows, the annual average 12pm-4pm temperature in 2017 was within the 95% confidence interval for the 2010-2015 annual average 12pm-4pm temperature. The 2010-2015 average and confidence interval was calculated using the 6 annual averages for 2010, 2011, 2012, 2013, 2014, and 2015.

These analyses show that there was a statistically significantly different distribution of days in 2017 compared to what was observed 2010-2015, with fewer days on the higher end of the spectrum (>90 degrees) that are most conducive to high MDA8 O_3 levels, even though the overall averages were not statistically significantly different.

4.3 Diurnal Temperature Change

CAPCOG's most recent O_3 conceptual model showed that diurnal temperature change had a statistically significantly 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 2017 diurnal temperature changes were statistically significantly different from temperature changes observed 2010-2015 or if the relationship between O_3 and temperature change was statistically significantly different from the relationship observed 2010-2015.

4.3.1 Comparison of Relationship between Diurnal Temperature Change and MDA8 O_3 in 2017 to 2010-2015

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

Figure 4-13. Scatter Plot of Diurnal Temperature Change at CAMS 3 v. MDA8 O_3 at CAMS 3, 2010-2015

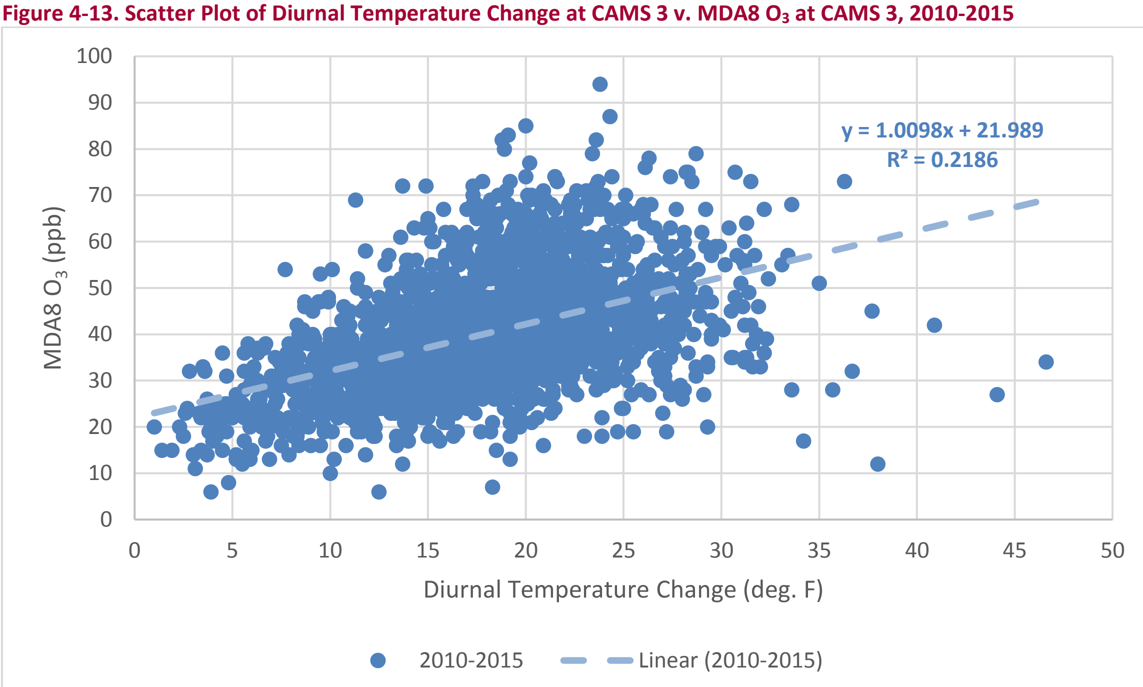


Figure 4-14. Scatter Plot of Diurnal Temperature Change at CAMS 3 v. MDA8 O_3 at CAMS 3, 2016

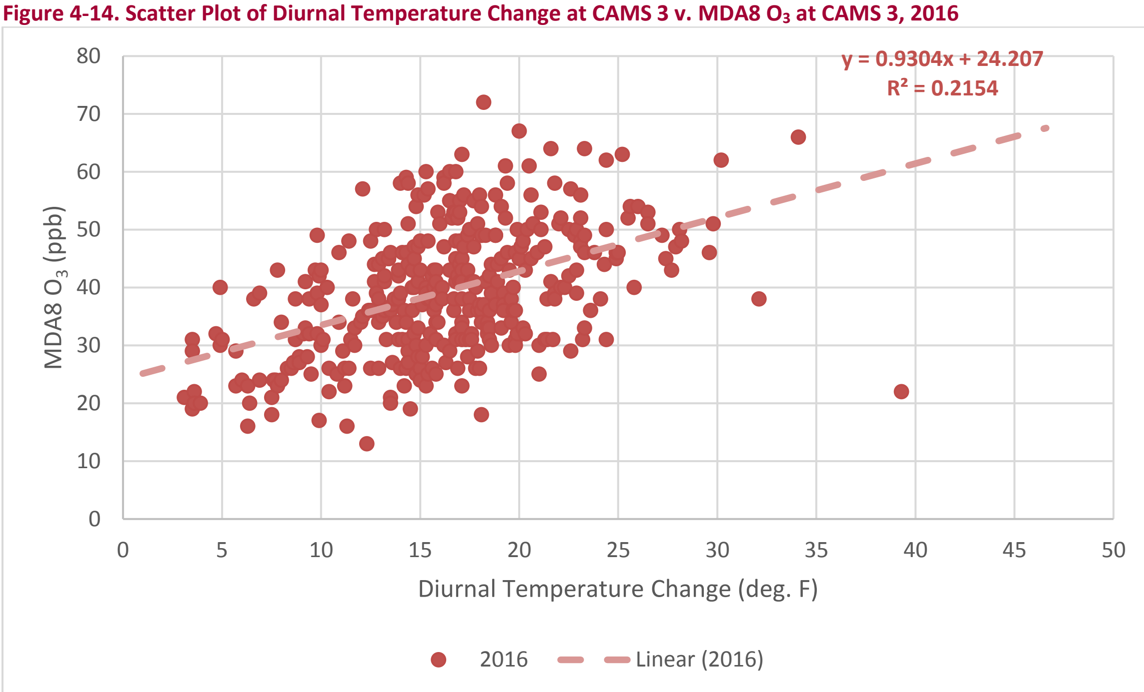
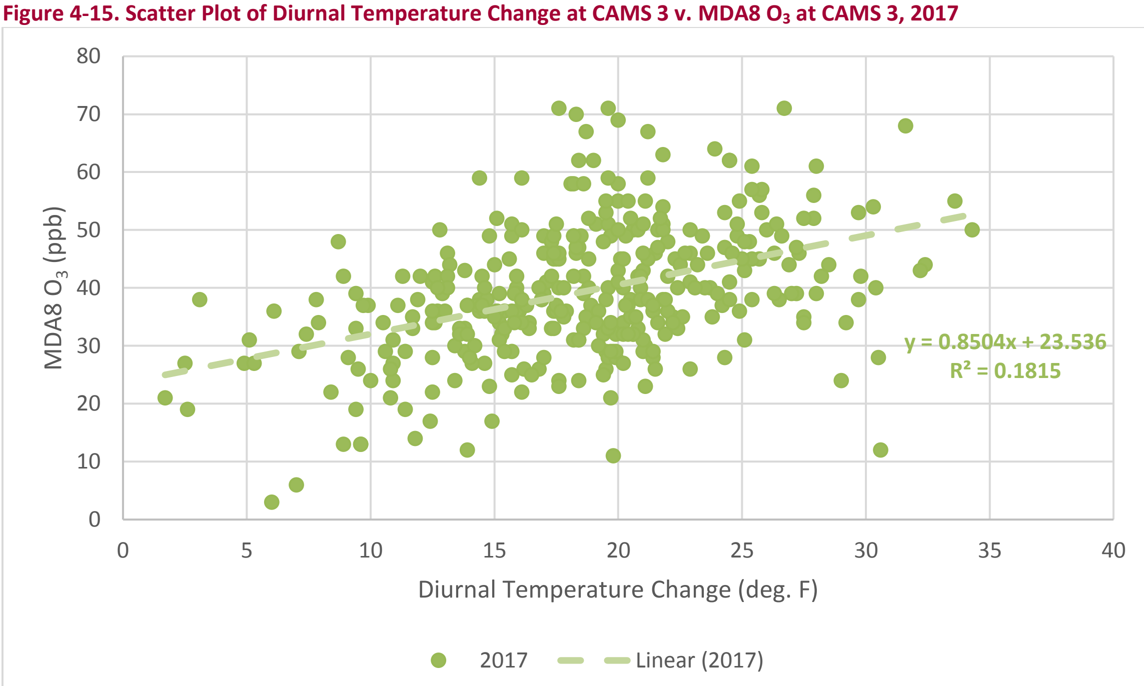
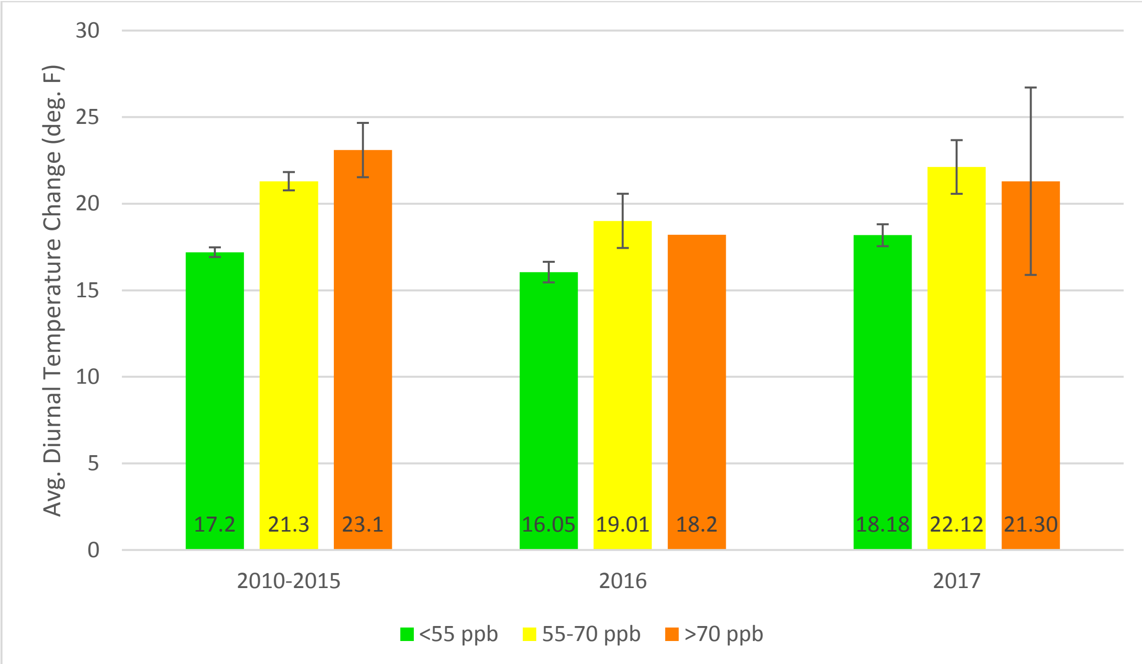


Figure 4-15. Scatter Plot of Diurnal Temperature Change at CAMS 3 v. MDA8 O_3 at CAMS 3, 2017



The figure below shows a comparison of the typical diurnal temperature changes on days <55 ppb, 55-70 ppb, and >70 ppb in 2016 relative to 2010-2015. The temperature change typical for days with MDA8 O_3 values in all three ranges were statistically significantly lower in 2016 than what was typical for such days in 2010-2015. However, the 2017 data was statistically significantly higher at the <55 ppb and 55-70 ppb ranges and statistically significantly lower at the >70 ppb range. Like the 2016 data, the 2017, continued to show a statistically significant difference between temperature changes for days with MDA8 O_3 <55 ppb and days with MDA8 O_3 of 55-70 ppb.

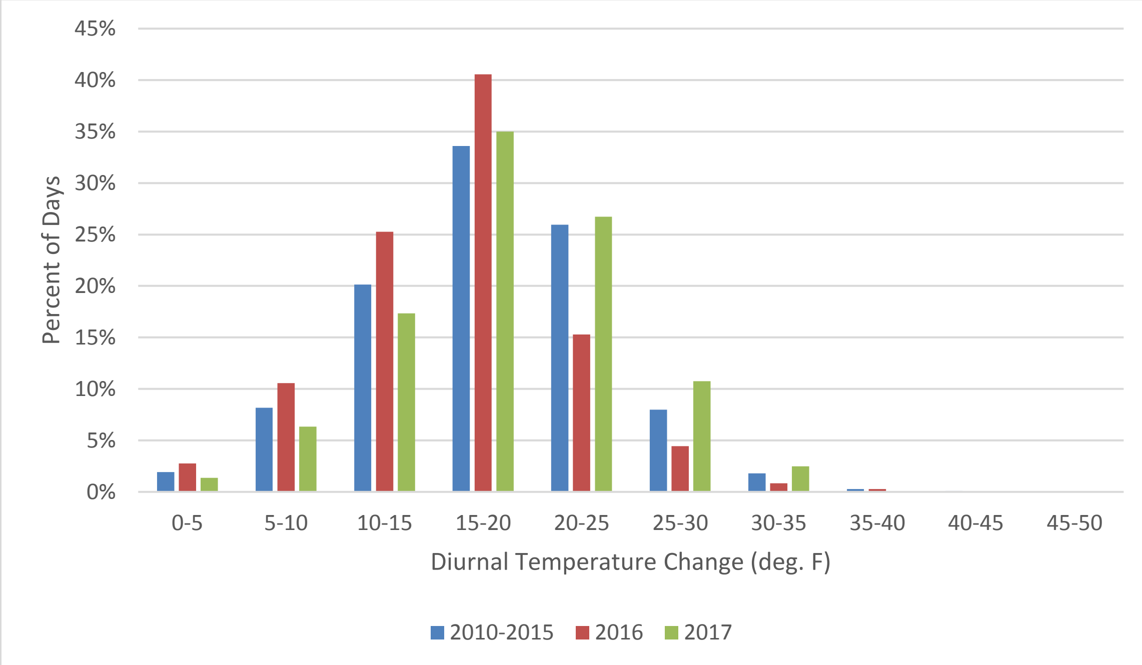
Figure 4-16. Figure 5 10. Typical Diurnal Temperature Change at CAMS 3 on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 3, 2010-2015, 2016, and 2017



4.3.2 Comparison of 2017 Diurnal Temperature Changes to 2010-2015 Diurnal Temperature Changes

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

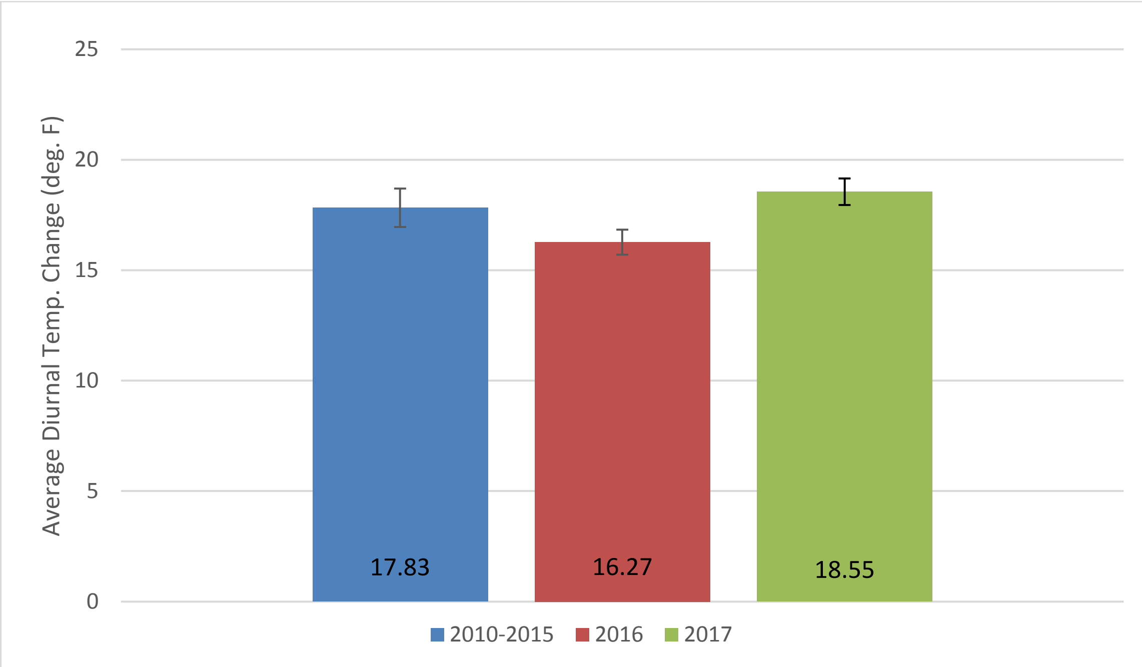
Figure 4-17. Histogram of Diurnal Temperature Changes at CAMS 3, 2010-2015, 2016, and 2017



CAPCOG performed a chi-squared test for independence on these distributions and was able to determine that the distribution of days into these bins in 2017 was not statistically significantly different at a 0.05 significance level from the 2010-2015 data, but was statistically significantly different from 2016 data.

CAPCOG also performed a confidence interval analysis of the average annual daily diurnal temperature change. The average 18.55°F diurnal change in 2017 was within the confidence interval for the 2010-2015 average. The 2016 average was below the 2010-2015 confidence interval, and the 2017 average is above the confidence interval for the 2016 data. This provides one potential explanation for the higher O_3 levels in 2017 compared to 2016 – the typical temperature change in 2016 was smaller than what was typical for the region, and the temperature change in 2017 returned to normal.

Figure 4-18. Annual Avg. Diurnal Temperature Change at CAMS 3, 2010-2015, 2016, and 2017



4.4 Relative Humidity

CAPCOG's most recent O_3 conceptual model showed that average relative humidity between 12 pm and 4 pm had a statistically significantly negative correlation with MDA8 O_3. 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 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 2017 12 pm – 4 pm relative humidity measurements were statistically significantly different from the relative humidity measurements in 2010-2015 or if the relationship between O_3 and relative humidity was statistically significantly different from the relationship observed 2010-2015.

4.4.1 Comparison of Relationship between Relative Humidity and MDA8 O_3 in 2017 to 2010-2015

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

Figure 4-19. Scatter Plot of 12 pm – 4 pm Relative Humidity at Camp Mabry v. MDA8 O_3 at CAMS 3, 2010-2015

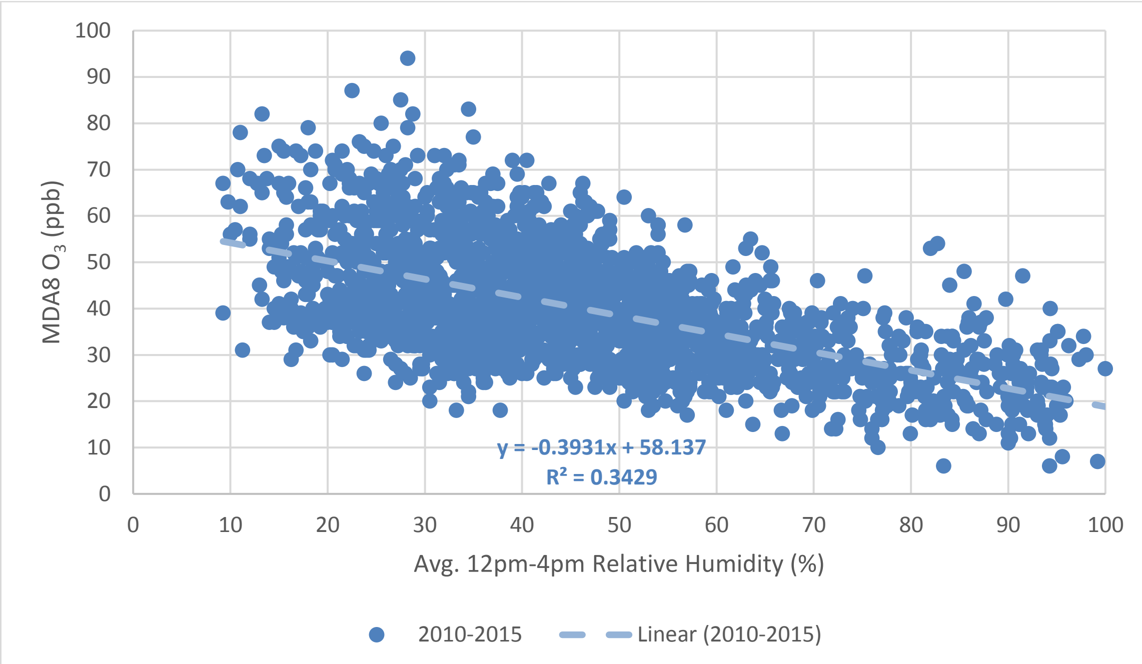


Figure 4-20. Scatter Plot of 12 pm – 4 pm Relative Humidity at Camp Mabry v. MDA8 O_3 at CAMS 3, 2016

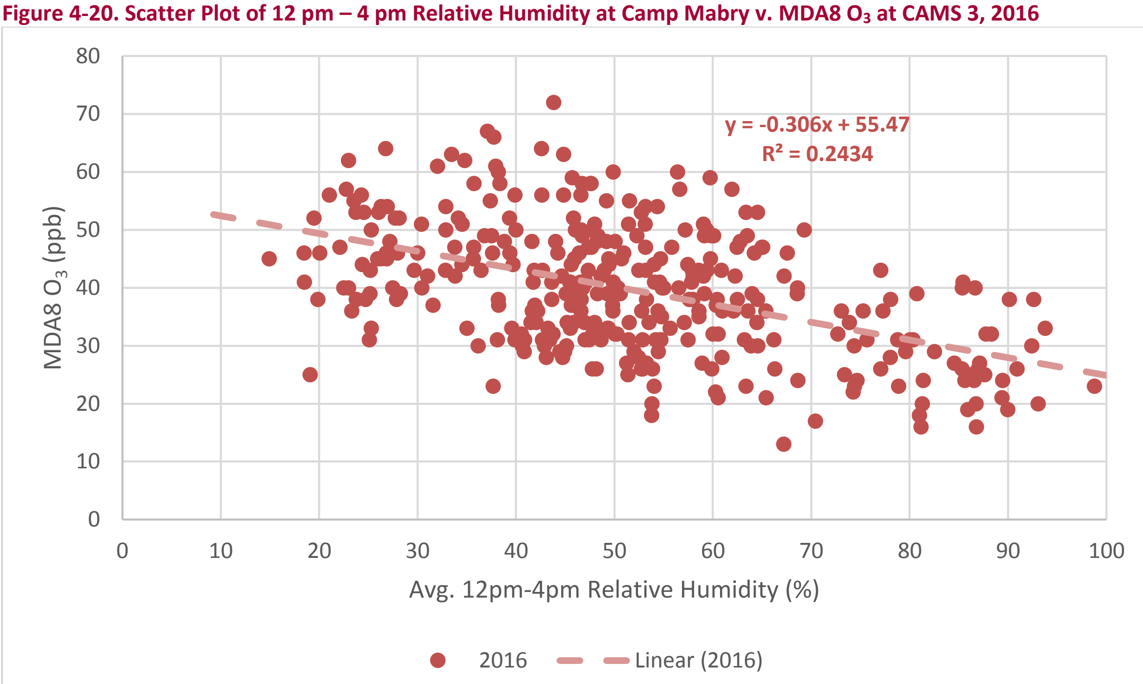
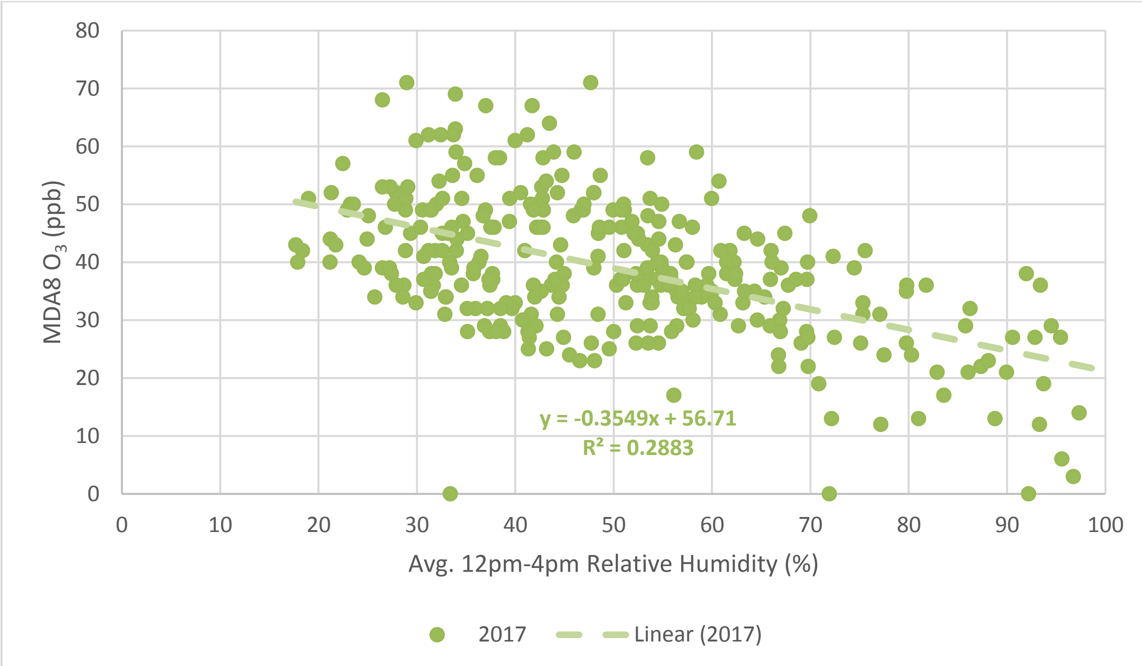
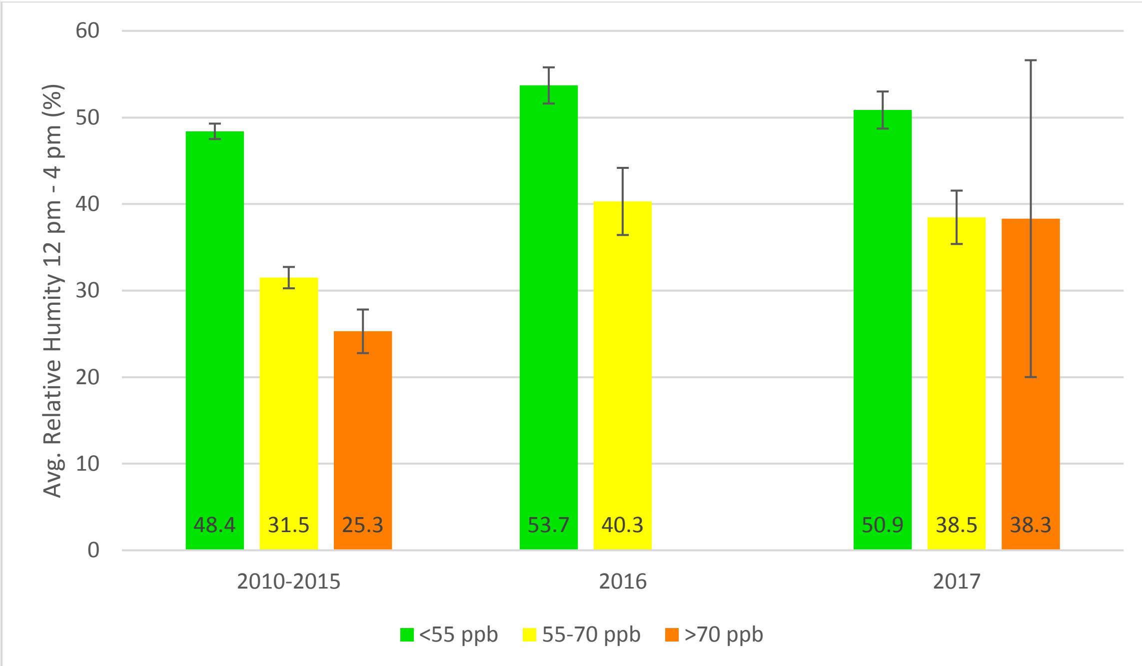


Figure 4-21. Scatter Plot of 12 pm – 4 pm Relative Humidity at Camp Mabry v. MDA8 O_3 at CAMS 3, 2017



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 2017 relative to 2016 and 2010-2015. The relative humidity typical for days with MDA8 O_3 values in all three ranges were statistically significantly higher in 2016 and 2017 than what was typical for such days in 2010-2015. However, the 2017 data did continue to show statistically significant differences between relative humidity for days with MDA8 O_3 <55 ppb and days with MDA8 O_3 of 55-70 ppb.

Figure 4-22. 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, and 2017

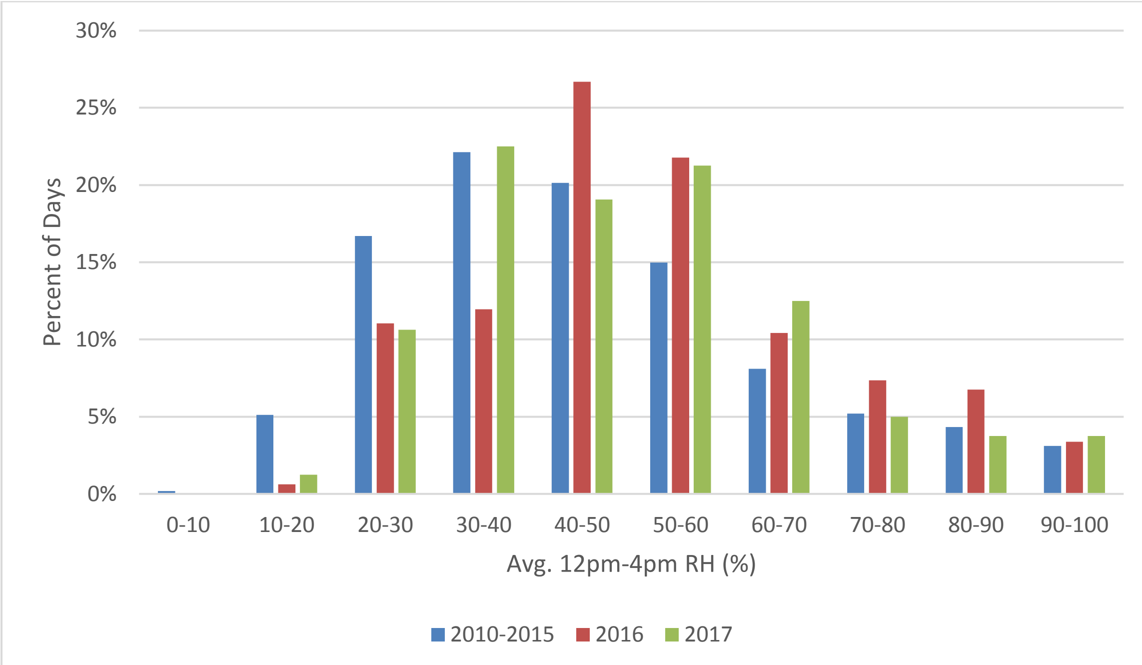


The data in the figure above show that relative humidity tended to be higher on both days that were <55 ppb and days that were 55-70 ppb. The 2017 data continued to show statistically significantly lower relative humidity from 12 pm – 4 pm on days with MDA8 O_3 55-70 ppb than the relative humidity typical on days with MDA8 O_3 <55 ppb.

4.4.2 Comparison of 2017 Relative Humidity to 2010-2015 Relative Humidity

Based on CAPCOG's review of the meteorological data in 2010-2015, 2016, and in 2017, CAPCOG was able to determine that there were statistically significant differences in the 12 pm – 4 pm relative humidity at Camp Mabry in 2017 compared to 2010-2015 and 2016. The distribution of days into 10 percentage points in the histogram below shows that 2016 had substantially fewer days with low relative humidity that are associated with high MDA8 O_3.

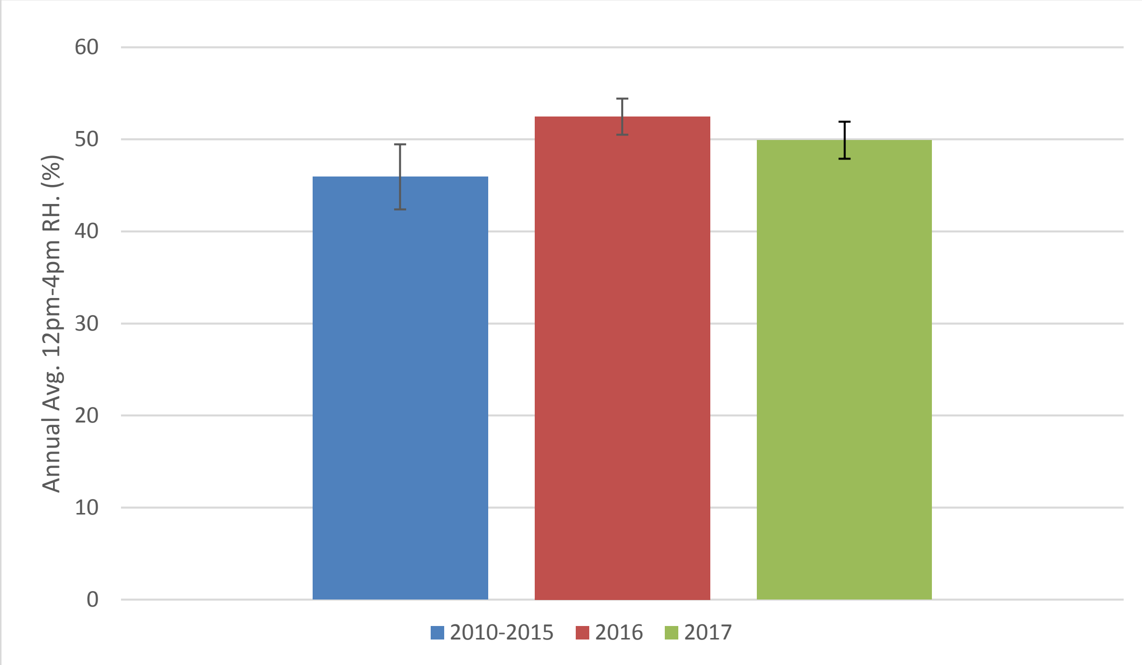
Figure 4-23. Histogram of 12 pm – 4 pm Relative Humidity at Camp Mabry, 2010-2015, 2016, and 2017



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 and the 2016 data at a 0.05 significance level. Based on the graph above, 2017 appeared to have substantially fewer days with relative humidity (RH) of less than 30% than what was observed from 2010-2015, but a similar number of days within that range as what was observed in 2016. There does appear to have been a substantially higher number of days in 2017 that were in the 30-40% range than there were in 2016, which may help explain the higher O_3 levels in 2017 compared to 2016. In 2017, 34.4% of the days had 12 pm – 4 pm RH levels of less than 40%, whereas 44.1% of the days from 2010-2015 had RH levels of less than 40% and 23.6% of days in 2016 had RH levels this low. This means that RH levels during these hours were 46% more likely to be below 40% in 2017 than they were in 2016, but 22% less likely to be below 40% than what was observed between 2010 and 2015.

CAPCOG also performed a confidence interval analysis of the average annual 12 pm – 4 pm relative humidity. The average 49.91% 12 pm – 4 pm relative humidity in 2017 was above the upper bound of the confidence interval for the 2010-2015 average and below the confidence interval for the 2016 average.

Figure 4-24. Annual Avg. 12 pm-4 pm Relative Humidity at Camp Mabry, 2010-2015, 2016, and 2017



4.5 Solar Radiation

CAPCOG's most recent O_3 conceptual model showed that average solar radiation at CAMS 38 between 12 pm and 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 2017 12 pm – 4 pm solar radiation measurements were statistically significantly different from the measurements in 2010-2015 or if the relationship between O_3 and solar radiation was statistically significantly different from the relationship observed 2010-2015.

4.5.1 Comparison of Relationship between Solar Radiation and MDA8 O_3 in 2017 to 2010-2015

The figures below shows 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 figure shows, the 2017 data was consistent in showing a positive correlation between these two factors.

Figure 4-25. Scatter Plot of 12 pm – 4 pm Solar Radiation at CAMS 38 v. MDA8 O3 at CAMS 38, 2010-2015

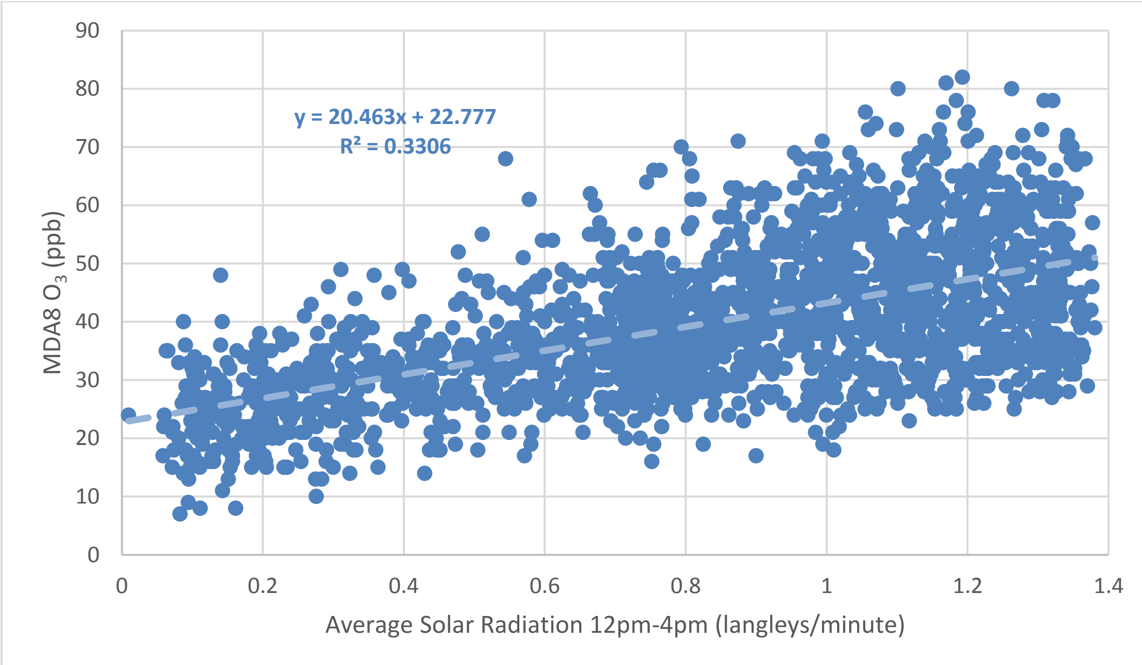


Figure 4-26. Scatter Plot of 12 pm – 4 pm Solar Radiation at CAMS 38 v. MDA8 O3 at CAMS 38, 2016

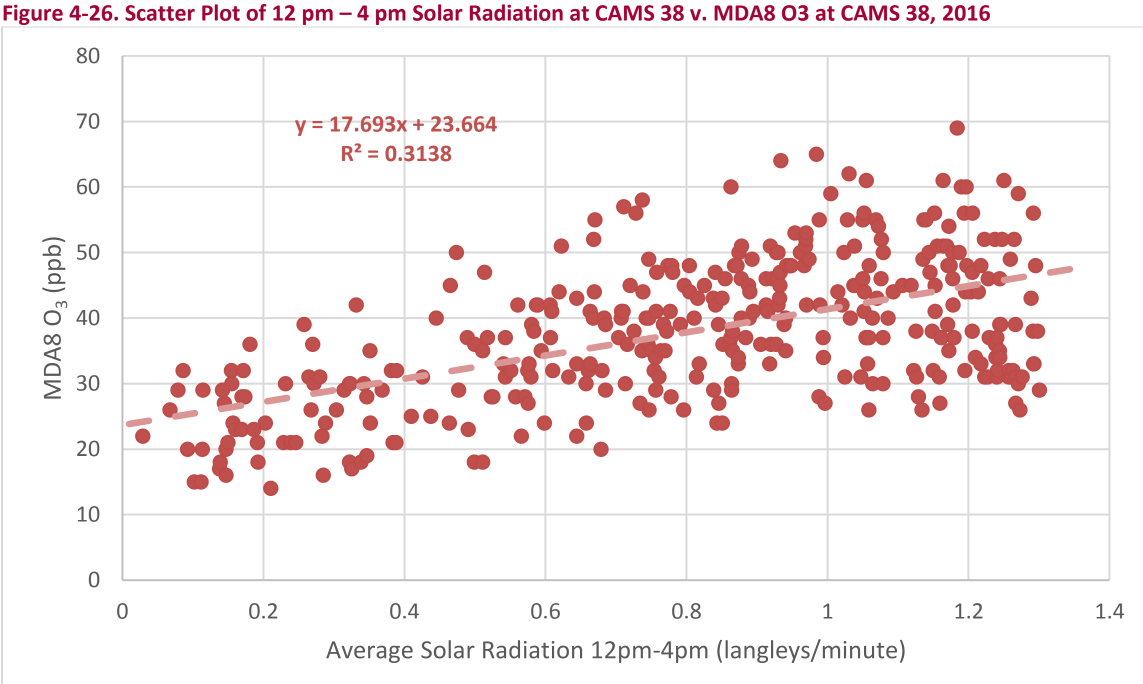
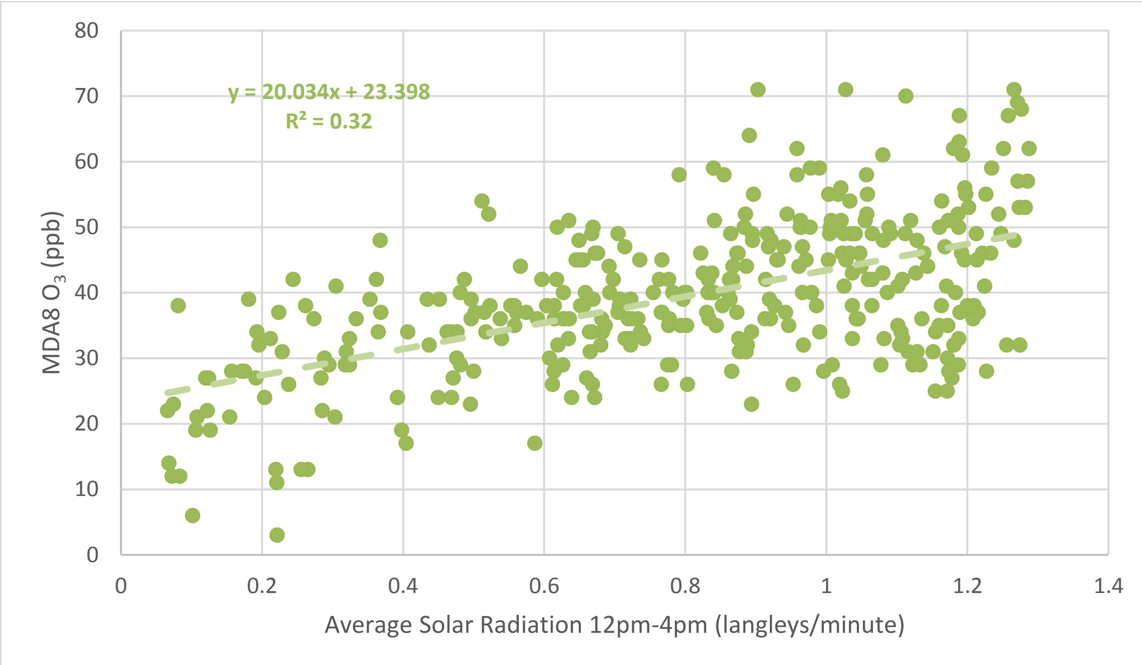
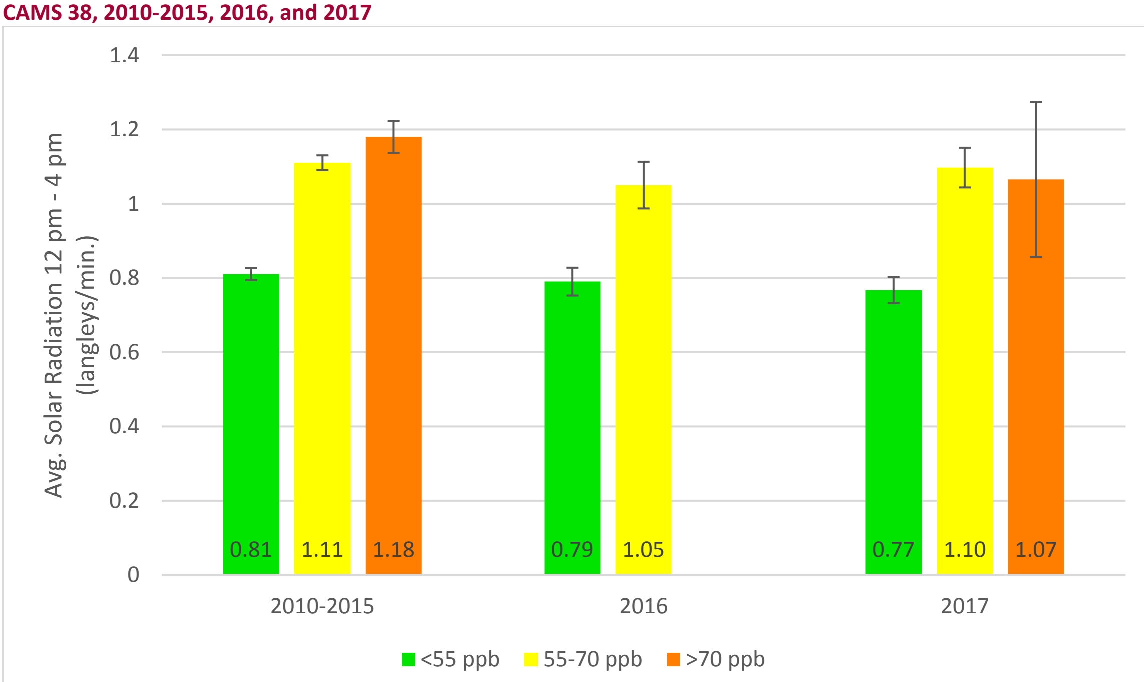


Figure 4-27. Scatter Plot of 12 pm – 4 pm Solar Radiation at CAMS 38 v. MDA8 O3 at CAMS 38, 2017



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 2017 relative to 2016 and 2010-2015. The solar radiation typical for days with MDA8 O_3 values in all three ranges was statistically significantly lower in 2017 than what was typical for such days in 2010-2015. However, the 2017 data did continue to show statistically significant differences between solar radiation for days with MDA8 O_3 <55 ppb and days with MDA8 O_3 of 55-70 ppb and >70 ppb.

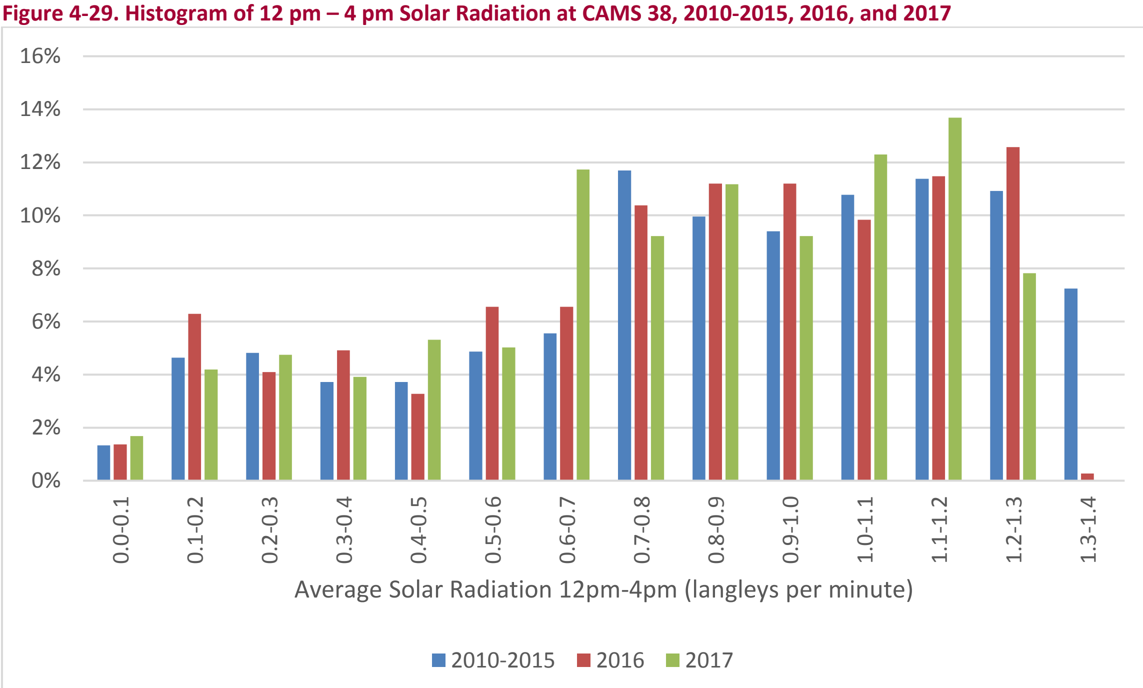
Figure 4-28. Typical Solar Radiation 12 pm – 4pm at CAMS 38 on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 38, 2010-2015, 2016, and 2017



4.5.2 Comparison of 2017 Solar Radiation to 2010-2015 Radiation

Based on CAPCOG's review of the meteorological data in 2010-2015, 2016, and in 2017, CAPCOG was able to determine that there were statistically significant differences in the 12 pm – 4 pm solar radiation at CAMS 38 in 2017 compared to 2010-2015 and 2016. The distribution of days into 0.1 langley/minute bins in the histogram below shows that 2017 had substantially fewer days with the highest level of solar radiation (0 days above 1.3 langleys/minute and substantially fewer days in the 1.2 – 1.3 langleys/minute range) than what was observed in 2010-2015 and in 2016. This suggests that if solar radiation levels had been consistent with levels recorded in 2010-2015 and 2016, O_3 levels in 2017 would have been even higher than what were observed in 2016.

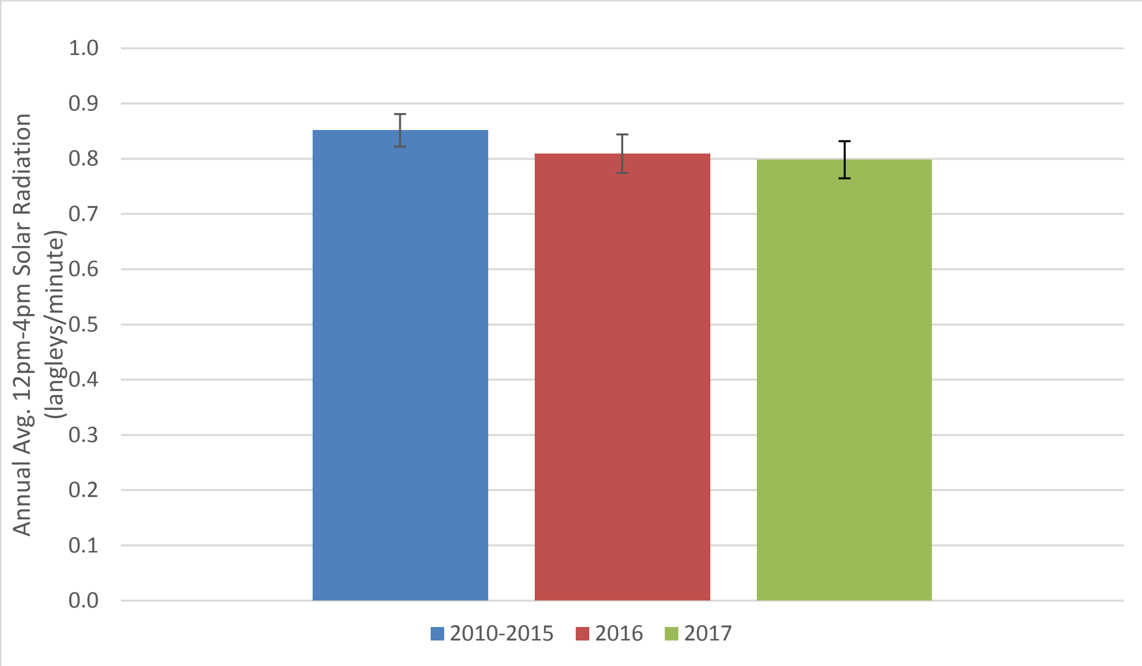
Figure 4-29. Histogram of 12 pm – 4 pm Solar Radiation at CAMS 38, 2010-2015, 2016, and 2017



A chi-square test of independence for these distributions showed them to be statistically significantly different at a 0.05 significance level for data from 2010-2015 and 2016.

CAPCOG also performed a confidence interval analysis of the average annual 12 pm – 4 pm solar radiation. The average 0.80 langley/minute average for 2017 was below the lower limit of the 95% confidence interval for the average annual solar radiation values for 2010-2015 but within the confidence interval for 2016.

Figure 4-30. Annual Avg. 12 pm-4 pm Solar Radiation at CAMS 38, 2010-2015, 2016, and 2017



4.6 Wind Direction

CAPCOG's wind direction analyses included calculating the back trajectories of CAMS with MDA8 O_3 levels measured above 70 ppb.

In CAPCOG's 2010-2015 Conceptual Model, CAPCOG developed HYSPLIT[4] 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 2017 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 1000 m
- 24-hour back trajectories

The table below shows all of the instances when MDA8 O_3exceeded 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 no days when MDA8 O_3 exceeded 70 ppb at CAMS 601.

Table 4-1. MDA8 O_3 >70 ppb, 2017

Date	Start Hour for Peak 1-hr. Avg.	MDA8 Level	Location
May 6, 2017	10:00 AM	71	CAMS 3
May 6, 2017	11:00 AM	73	CAMS 690
June 7, 2017	10:00 AM	74	CAMS 1604
June 8, 2017	11:00 AM	71	CAMS 3

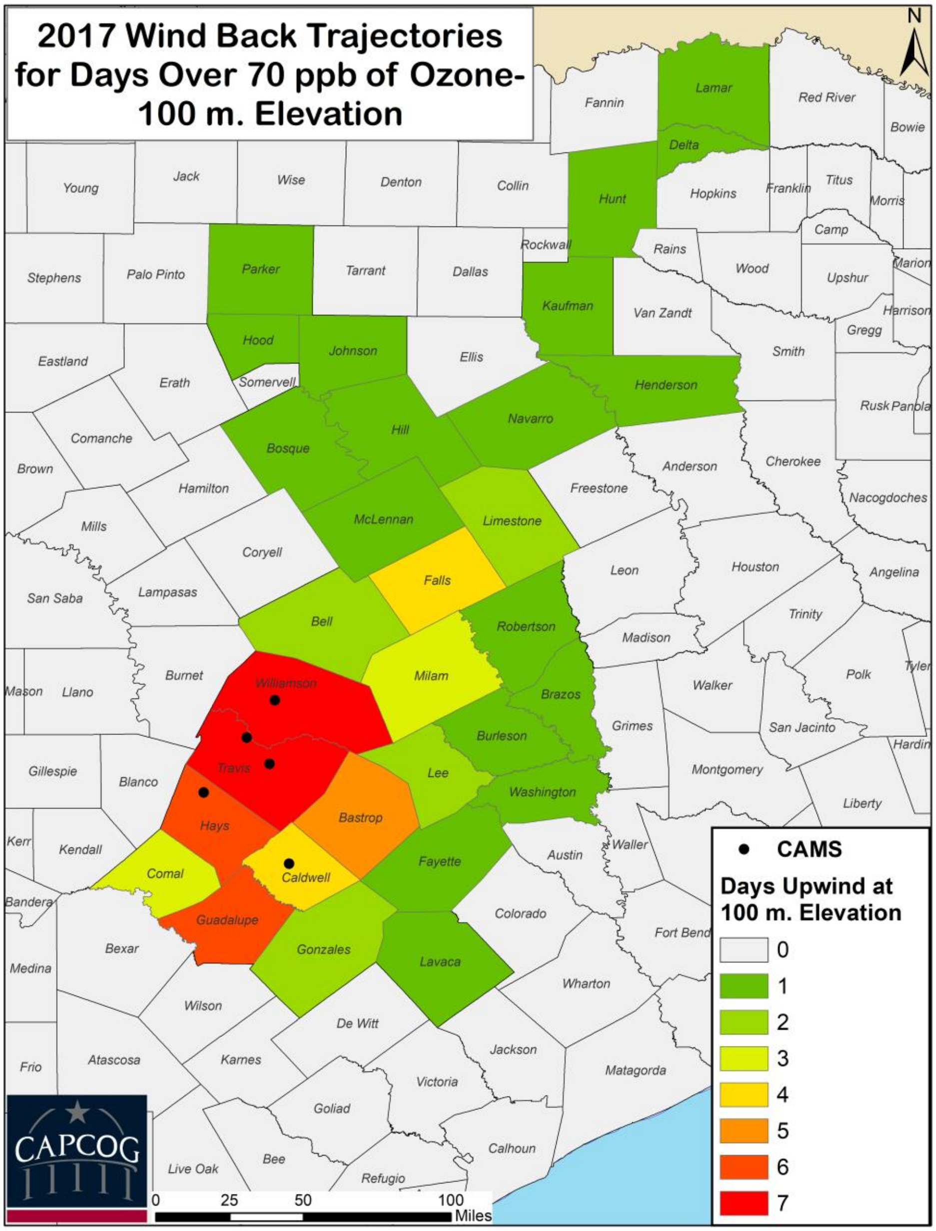
[4] Hybrid Single-Particle Lagrangian Integrated Trajectory

Date	Start Hour for Peak 1-hr. Avg.	MDA8 Level	Location
June 8, 2017	11:00 AM	73	CAMS 38
June 8, 2017	11:00 AM	75	CAMS 690
August 1, 2017	11:00 AM	72	CAMS 614
September 1, 2017	10:00 AM	71	CAMS 3
September 12, 2017	9:00 AM	74	CAMS 1604
September 13, 2017	10:00 AM	73	CAMS 690

The figures below display the back-trajectories of counties on days measured over 70 ppb at three evaluations – 100 m, 500 m, and 1,000 m.

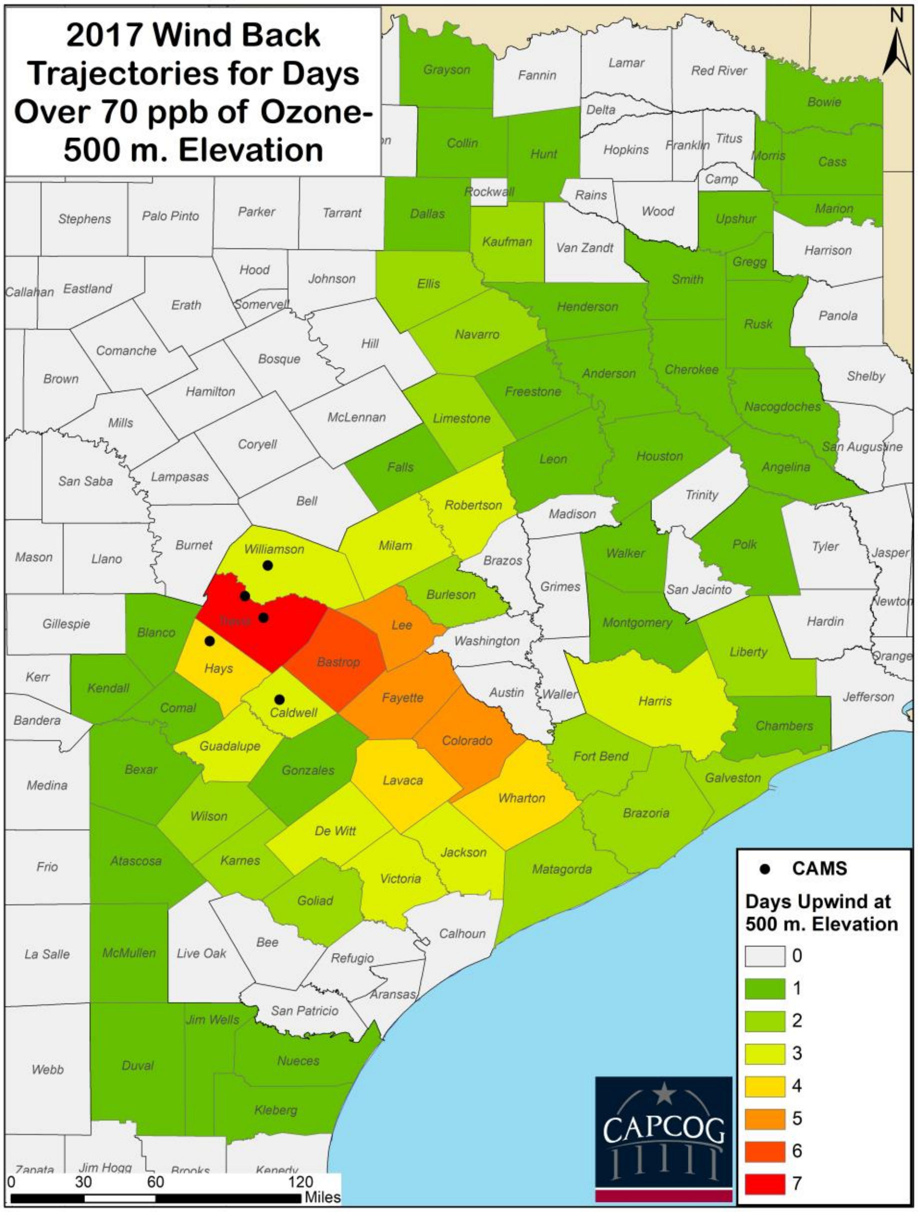
As the figure below shows, at 100 m, the county outside of the Austin-Round Rock MSA that was upwind of a CAMS MDA8 O_3 reading above 70 ppb most often was Guadalupe County. Guadalupe County was part of six out of the ten back trajectories analysis. At this elevation, there was pattern of the back trajectories coming from northeast of the Austin-Round Rock MSA and then running south below the MSA before turning north and entering the MSA. Notably, none of these back trajectories intersect with the densest urbanized and industrialized counties in the Dallas-Fort Worth, Houston, or San Antonio areas.

Figure 4-31. Count of Back Trajectories entering counties on MDA8 O_3 days >70 ppb at 100 m, 2017



At 500 m, the counties outside of the Austin-Round Rock MSA that were upwind of a CAMS MDA8 O_3 reading above 70 ppb most often were Lee, Fayette, and Colorado counties; all are east of the Austin-Round Rock MSA.

Figure 4-32. Count of Back Trajectories entering counties on MDA8 O_3 days >70 ppb at 500 m, 2017



At 1,000 m, the counties outside of the Austin-Round Rock MSA that were upwind of a CAMS MDA8 O_3 reading above 70 ppb most often were Lee, Burleson, Brazos, and Leon counties; all northeast of the Austin-Round Rock MSA.

Figure 4-33. Count of Back Trajectories entering counties on MDA8 O3 days >70 ppb at 1,000m, 2017

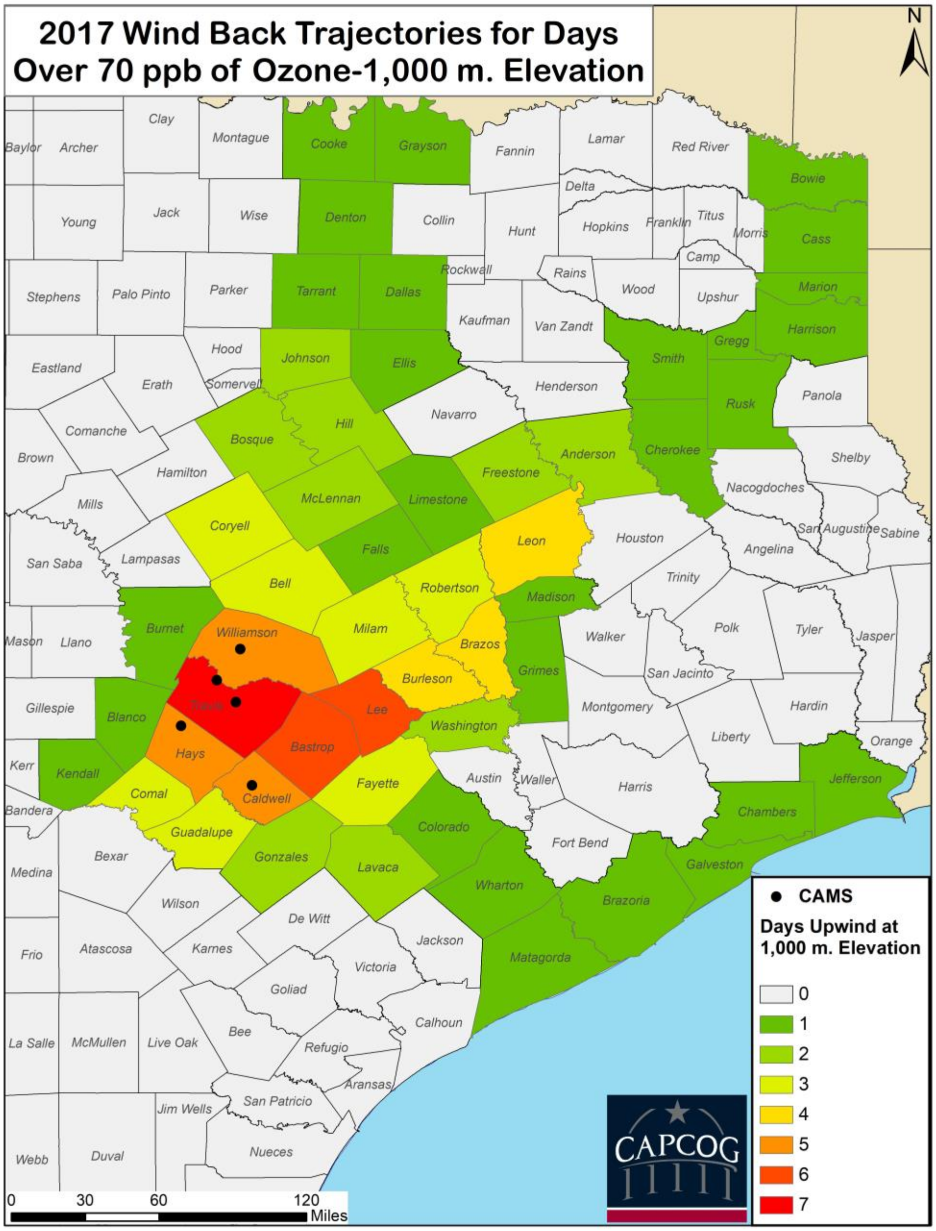


Table 4.2 compares the 2017 counties intercepted by back trajectories at CAMS 3 on days when MDA8 O_3 > 70 ppb to 2010-2015. This was no statistically significant difference at a 0.05 significance level.

Table 4-2. Percentage of CAMS 3 Back Trajectories entering counties on MDA8 O3 days >70 ppb at 100m, 500, and 1,000m, 2010-2015 and 2017

County	2010-2015	2017	Chi-Squared Value for 2010-2015 Comparison
Anderson	0%	0%	n/a
Andrews	0%	0%	n/a
Angelina	0%	0%	n/a

County	2010-2015	2017	Chi-Squared Value for 2010-2015 Comparison
Aransas	1%	0%	n/a
Atascosa	2%	0%	n/a
Austin	1%	0%	n/a
Bandera	1%	0%	n/a
Bastrop	1%	6%	3.787939
Bee	1%	0%	n/a
Bell	2%	2%	0.042999
Bexar	2%	0%	n/a
Blanco	1%	0%	n/a
Bosque	0%	2%	1.164192
Brazoria	0%	1%	0.656686
Brazos	1%	2%	0.657377
Brooks	0%	0%	n/a
Burleson	1%	3%	1.276602
Burnet	0%	0%	n/a
Caldwell	2%	2%	0.016352
Calhoun	1%	0%	n/a
Cameron	0%	0%	n/a
Cherokee	0%	0%	n/a
Coke	0%	0%	n/a
Collin	0%	1%	0.385297
Colorado	1%	2%	0.55315
Comal	3%	1%	3.761249
Concho	0%	0%	n/a
Cooke	0%	1%	0.512001
Coryell	0%	0%	n/a
Dallas	1%	1%	0.185834
Denton	0%	0%	n/a
DeWitt	1%	1%	0.018997
Dimmit	0%	0%	n/a
Duval	1%	0%	n/a
Edwards	0%	0%	n/a
Ellis	1%	1%	0.058297
Erath	0%	0%	n/a
Falls	1%	1%	0.018997
Fannin	0%	0%	n/a
Fayette	1%	4%	2.475316
Fort Bend	0%	0%	n/a
Franklin	0%	0%	n/a

County	2010-2015	2017	Chi-Squared Value for 2010-2015 Comparison
Freestone	0%	1%	0.385297
Frio	1%	0%	n/a
Gaines	0%	0%	n/a
Galveston	0%	1%	0.656686
Gillespie	1%	0%	n/a
Glasscock	0%	0%	n/a
Goliad	1%	1%	0.058297
Gonzales	2%	2%	3.86994
Grayson	0%	1%	0.656686
Grimes	1%	0%	n/a
Guadalupe	3%	3%	0.03969
Hamilton	0%	0%	n/a
Hardin	0%	0%	n/a
Harris	0%	1%	0.512001
Harrison	0%	0%	n/a
Hays	5%	4%	0.262869
Henderson	0%	1%	0.512001
Hidalgo	0%	0%	n/a
Hill	1%	2%	0.657377
Hood	0%	2%	1.814857
Hopkins	0%	0%	n/a
Houston	0%	0%	n/a
Hunt	0%	0%	n/a
Irion	0%	0%	n/a
Jackson	1%	1%	0.058297
Jim Hogg	0%	0%	n/a
Jim Wells	1%	0%	n/a
Johnson	0%	2%	1.313372
Karnes	1%	1%	0.054126
Kaufman	0%	1%	0.512001
Kendall	1%	0%	n/a
Kenedy	1%	0%	n/a
Kerr	0%	0%	n/a
Kimble	0%	0%	n/a
Kinney	0%	0%	n/a
Kleberg	1%	0%	n/a
La Salle	1%	0%	n/a
Lavaca	1%	3%	1.276602
Lee	1%	4%	2.943086

County	2010-2015	2017	Chi-Squared Value for 2010-2015 Comparison
Leon	0%	1%	0.385297
Liberty	0%	1%	0.819352
Limestone	1%	1%	0.002684
Live Oak	1%	0%	n/a
Llano	0%	0%	n/a
Madison	1%	0%	n/a
Martin	0%	0%	n/a
Mason	0%	0%	n/a
Matagorda	1%	1%	0.113075
Maverick	0%	0%	n/a
McLennan	1%	2%	0.371669
McMullen	1%	0%	n/a
Medina	1%	0%	n/a
Menard	0%	0%	n/a
Midland	0%	0%	n/a
Milam	2%	4%	1.008817
Montgomery	0%	0%	n/a
Nacogdoches	0%	0%	n/a
Navarro	1%	1%	0.0215
Nueces	1%	0%	n/a
Panola	0%	0%	n/a
Parker	0%	2%	1.638705
Polk	0%	0%	n/a
Rains	0%	0%	n/a
Real	0%	0%	n/a
Refugio	1%	0%	n/a
Robertson	1%	3%	1.403306
Rockwall	0%	1%	0.819352
Rusk	0%	0%	n/a
Sabine	0%	0%	n/a
San Augustine	0%	0%	n/a
San Jacinto	0%	0%	n/a
San Patricio	1%	0%	n/a
San Saba	0%	0%	n/a
Schleicher	0%	0%	n/a
Shelby	0%	0%	n/a
Starr	0%	0%	n/a
Sterling	0%	0%	n/a

County	2010-2015	2017	Chi-Squared Value for 2010-2015 Comparison
Tarrant	0%	0%	n/a
Tom Green	0%	0%	n/a
Travis	10%	10%	0.001927
Trinity	0%	0%	n/a
Tyler	0%	0%	n/a
Uvalde	0%	0%	n/a
Van Zandt	0%	0%	n/a
Victoria	1%	1%	0.113075
Walker	0%	0%	n/a
Waller	0%	0%	n/a
Washington	1%	1%	0.113075
Webb	0%	0%	n/a
Wharton	1%	2%	0.657377
Willacy	0%	0%	n/a
Williamson	3%	3%	0.03385
Wilson	2%	1%	0.267399
Wise	0%	0%	n/a
Wood	0%	0%	n/a
Zapata	0%	0%	n/a
Zavala	0%	0%	n/a

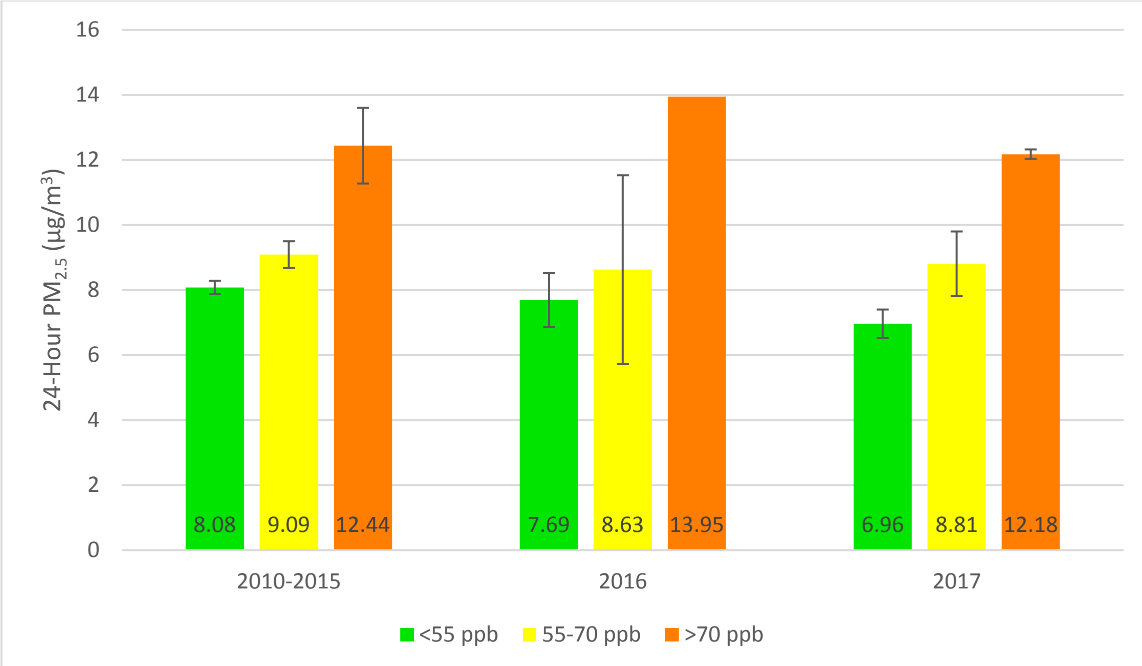
5 Correlation between MDA8 and Other Criteria Pollutants

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 2016 data compared to 2010-2015 analyzed each other pollutant based on the averaging time and form of the pollutant's NAAQS. 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 and 2017

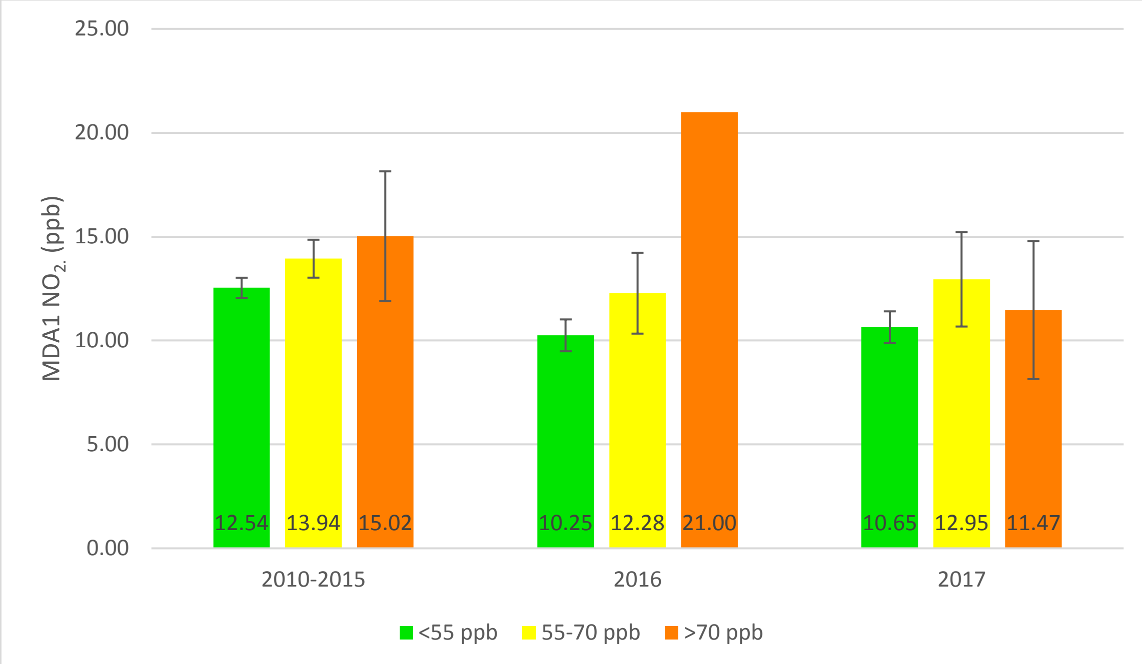


$PM_{2.5}$ concentrations were significantly statistically lower on days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb in 2017 compared to 2010-2015. However, there is still a significantly statistically higher 24-hour $PM_{2.5}$ concentration in the 55-70 ppb range than there was in the <55 ppb range and there was a significantly statistically higher 24-hour $PM_{2.5}$ concentration in the >70 ppb range than the 55-70 ppb range in 2017.

5.2 NO_2

CAPCOG calculated the average 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, and 2017

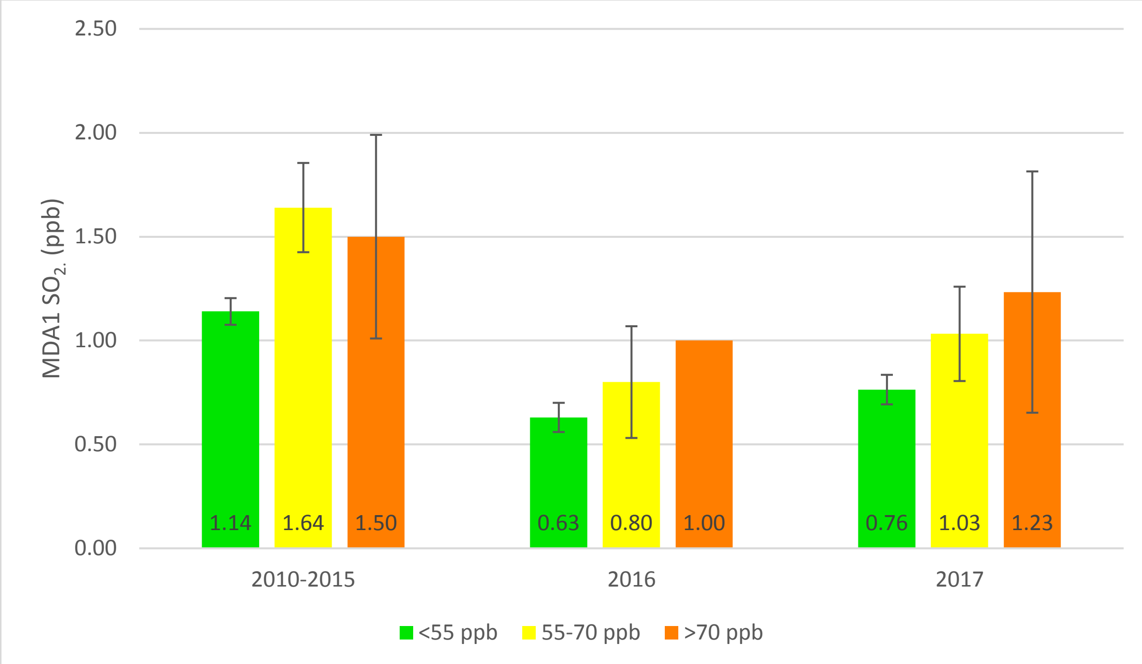


MDA1 NO_2 concentrations were significantly statistically lower on days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb in 2017 compared to 2010-2015, and while there is still a higher MDA1 NO_2 concentration in the 55-70 ppb range than there was in the <55 ppb range this difference was not statistically significant. This reduction in ground-level NO_2 concentrations in 2017 compared to 2010-2015 across all three O_3 ranges is consistent with the substantial reductions in NO_X emissions that has occurred within this time frame as well. In addition, the MDA8 O_3 >70 ppb range in 2017 was lower than the MDA8 $O_3$55-70 range, which breaks a trend from the 2010-2015 and 2016 data.

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, and 2017

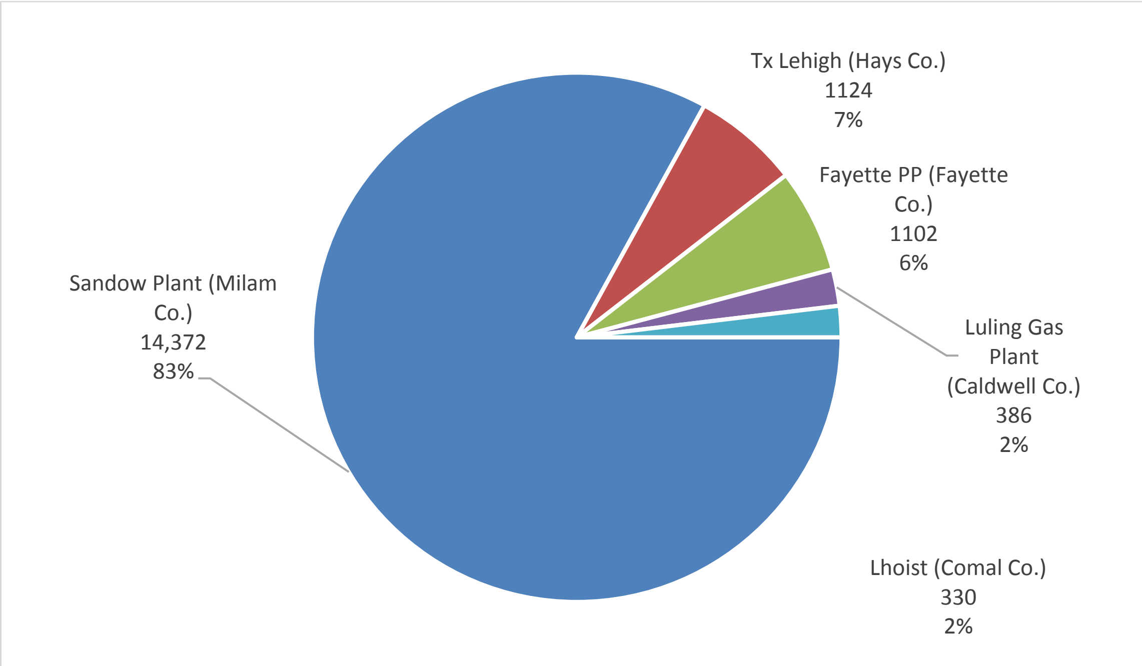


MDA1 SO_2 concentrations were significantly statistically lower on days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb in 2017 compared to 2010-2015. There was higher MDA1 SO_2 concentrations at higher MDA8 O_3 levels though the difference was not significantly statistically different.

The following figure shows the major sources of point source SO_2 emissions (>100 tpy) within the Austin-Round Rock MSA and adjacent counties (Bell, Blanco, Burnet, Comal, Guadalupe, Gonzales, Fayette, Lee, and Milam) from TCEQ's point source emissions inventory summary for 2016 (the most recent year for which a comprehensive point source emissions inventory is available for all facilities).[5] 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, which suggests that elevated SO_2 concentrations on high O_3 days are most likely to be an indication of the high O_3 levels being impacted by that plant's NO_X emissions.

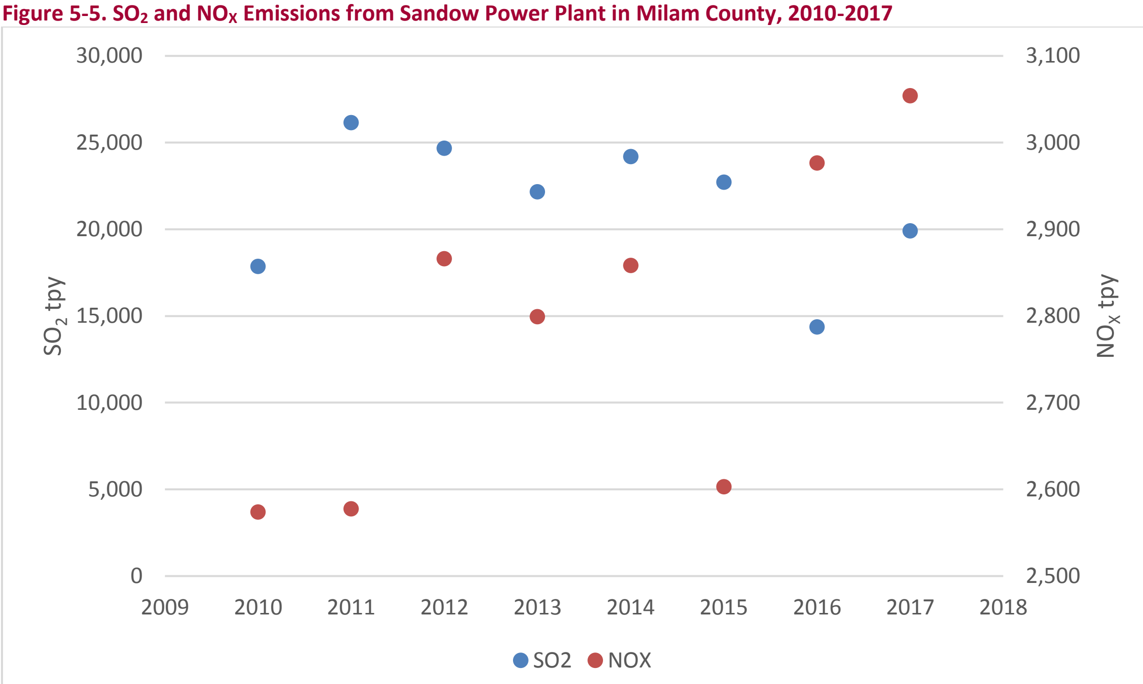
[5] https://www.tceq.texas.gov/assets/public/implementation/air/ie/pseisums/2016statesum.xlsx

Figure 5-4. Major Point Source SO_2 Emissions in the Austin-Round Rock MSA and Adjacent Counties, 2016 (tpy)



The following chart shows the SO_2 and NO_X emissions at the Sandow Plant for each year from 2010 through 2017 based on data in EPA's Air Market Data Program (AMPD) database.

Figure 5-5. SO_2 and NO_X Emissions from Sandow Power Plant in Milam County, 2010-2017



The plant averaged 22,959 tpy of SO_2 from 2010-2015, while being 37% and 13% below that average in 2016 and 2017, respectively. For comparison, the 12 pm – 4 pm SO_2 concentration in 2016 for the single day with MDA8 O_3 > 70 ppb at CAMS 3 was 33% the average for 2010-2015 and the average 12 pm – 4 pm SO_2 concentration on days with MDA8 O_3 > 70 ppb at CAMS 3 was 18% below the average for 2010-2015, ambient levels that are strikingly consistent with the SO_2 emissions at Sandow in 2016 and 2017 compared to 2010-2015. Interestingly, while the SO_2 emissions in 2016 and 2017 were lower than what was typical for 2010-2015, NO_X emissions were 10% and 13% higher in 2016 and 2017, respectively, which means that the emissions from the Sandow plant could have had a higher impact on ground-level O_3 concentration within the MSA than the reduction in average SO_2 concentrations on high O_3 days might suggest.

6 Ozone 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 3 monitors recorded. CAPCOG performed this same analysis on the data collected in the region in 2017. 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, and 2017.

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, and 2017

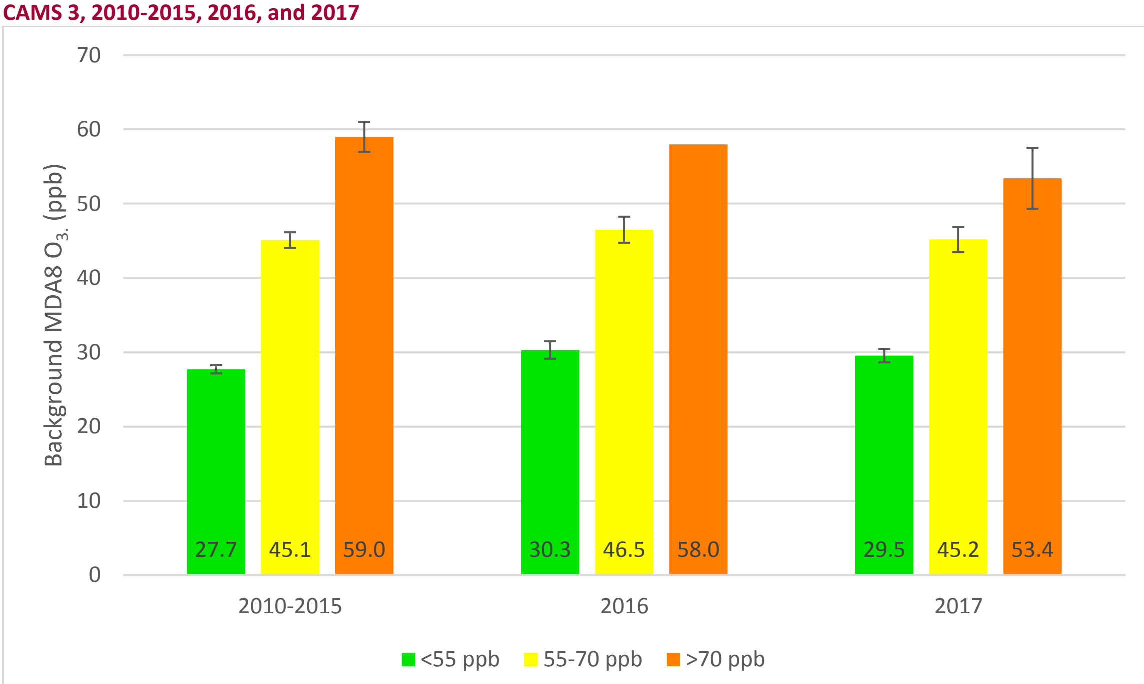
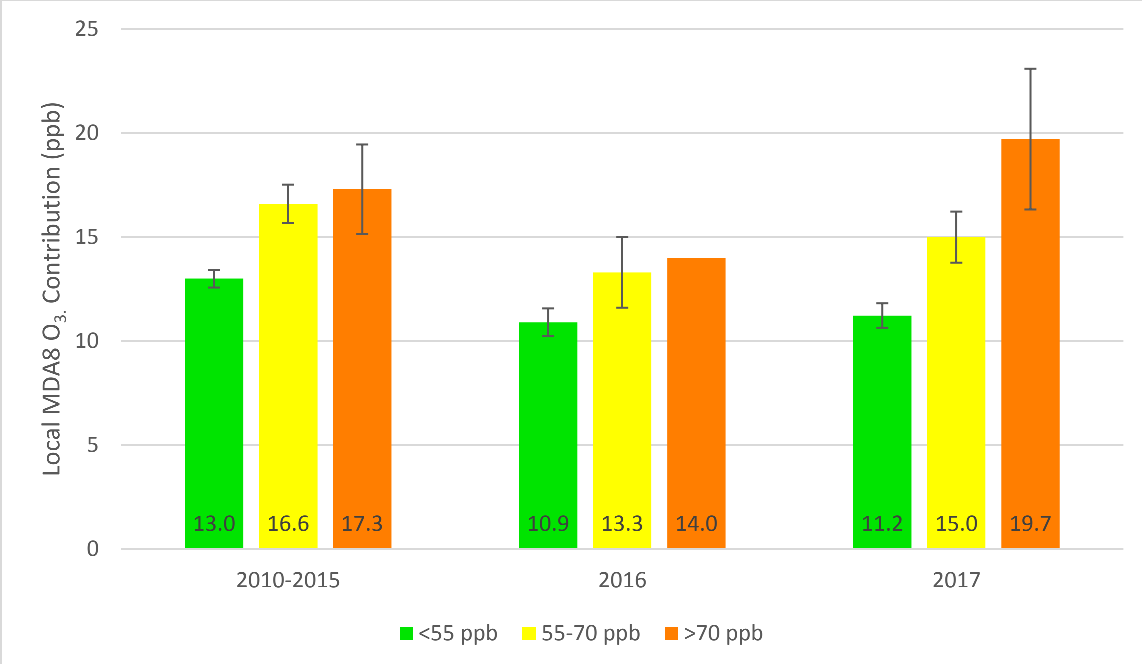


Figure 6-2. Comparison of Local Contribution to MDA8 O_3 on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 3, 2010-2015, 2016, 2017



The graphs show that "background" levels in 2017 were slightly (but significantly statistically) higher in 2016 for days when MDA8 O_3 levels were <55 ppb and significantly statistically lower for days with MDA8 O_3levels in the 55-70 ppb and >70 ppb ranges. Local contributions were significantly statistically lower in 2017 compared to 2010-2015 when MDA8 O_3 levels were in the <55 ppb and 55-70 ppb range but significantly statistically higher in the >70 ppb range compared to 2010-2015 data. The lower local contribution is consistent with lower NO_X emissions within the CAPCOG region in 2017 than the average NO_X emissions across the six years from 2010-2015.

7 NO_X Emissions Analysis

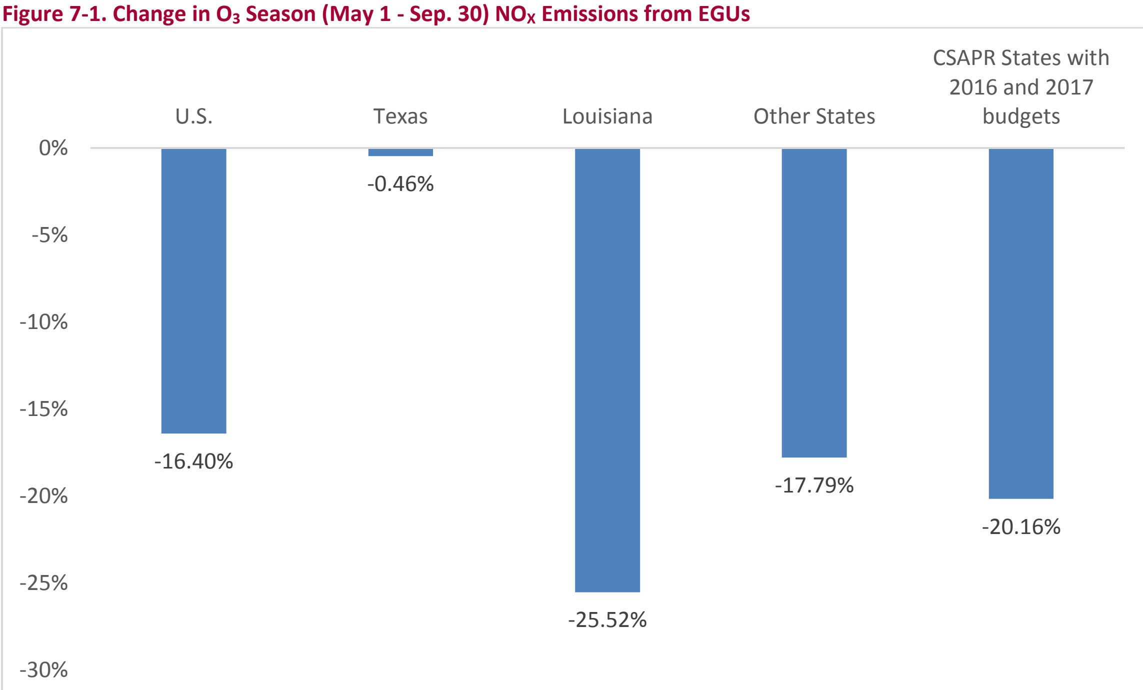
One potential explanation for the higher O_3 levels in the region in 2017 compared to 2016 is higher NO_X emissions in 2017. For mobile sources, federal engine and fuel standards are expected to continue to reduce NO_X emissions year over year well into the future, but emissions from stationary source emissions – particularly "peaker" electric generating units – can vary substantially year-to-year. In order to assess the extent to which changes in emissions from 2016 to 2017 might explain the increase in O_3 levels, CAPCOG compared NO_X emissions data from EGUs reported in EPA's AMPD for the 2017 O_3 season (defined by EPA as May 1 – Sep. 30) compared to the 2016 O_3 season.[6]

The figure below shows the change in total O_3-season NO_X emissions from 2016 to 2017 for the U.S., Texas, Louisiana, all states other than Texas and Louisiana, and states that had Cross-State Air Pollution Rule (CSAPR) O_3-season NO_X emissions for electric generating units (EGUs) for both 2016 and 2017. The CSAPR update for the 2008 O_3 NAAQS, finalized in September 2016, established NO_X emissions budgets that were 40% lower than the 2016 budgets that had been established for the 1997 O_3 NAAQS across

[6] https://ampd.epa.gov/ampd/

the 22 states with budgets for both standards. As the figure shows, there were a significant reduction in NO_X emissions across the country. Although the reductions in Texas were much less substantial, there was no increase in O_3-season NO_X emissions statewide that would explain an increase in O_3 levels within the CAPCOG region from 2016 to 2017.

Figure 7-1. Change in O_3 Season (May 1 - Sep. 30) NO_X Emissions from EGUs



CAPCOG then looked more closely at the EGUs in the Austin-Round Rock MSA and adjacent counties (Blanco, Burnet, Bell, Comal, Fayette, Gonzales, Guadalupe, Lee, and Milam) to see if there were any significant increases in NO_X emissions from 2016 to 2017. The following table summarizes the facility-wise O_3 season EGU NO_X emissions for each county in the Austin-Round Rock MSA and surrounding counties in 2016 and 2017.

Table 7-1. Average O_3 Season EGU NO_X Emissions in MSA and Surrounding Counties Reported to AMPD, 2016 and 2017 (tpd)

County	2016	2017	Difference
Bastrop	3.1778	3.0142	-0.1637
Bell	0.4418	0.3344	-0.1074
Caldwell	0.0000	0.0000	0.0000
Comal	0.0000	0.0000	0.0000
Fayette	19.5426	19.9684	+0.4259
Gonzales	0.0000	0.0000	0.0000
Guadalupe	3.2815	3.3786	+0.0971
Hays	0.6331	0.5444	-0.0887
Llano	0.2180	0.2049	-0.0131
Milam	9.0491	9.3627	+0.3136
Travis	2.5050	3.3723	+0.8673
MSA Counties	6.3159	6.9308	+0.6149
Surrounding Counties	32.5329	33.2491	+0.7161
TOTAL	**38.8489**	**40.1799**	**+1.3310**

Using the ppb O_3/tpd NO_X emissions ratios calculated in modeling analysis completed by CAPCOG in 2015 based on the impact of a number of point sources in the MSA and surrounding counties, CAPCOG calculated the following approximate impacts of the change in NO_X emissions from 2016 to 2017 on the 4 highest MDA8 O_3 values based on the average O_3 season NO_X emissions.[7]

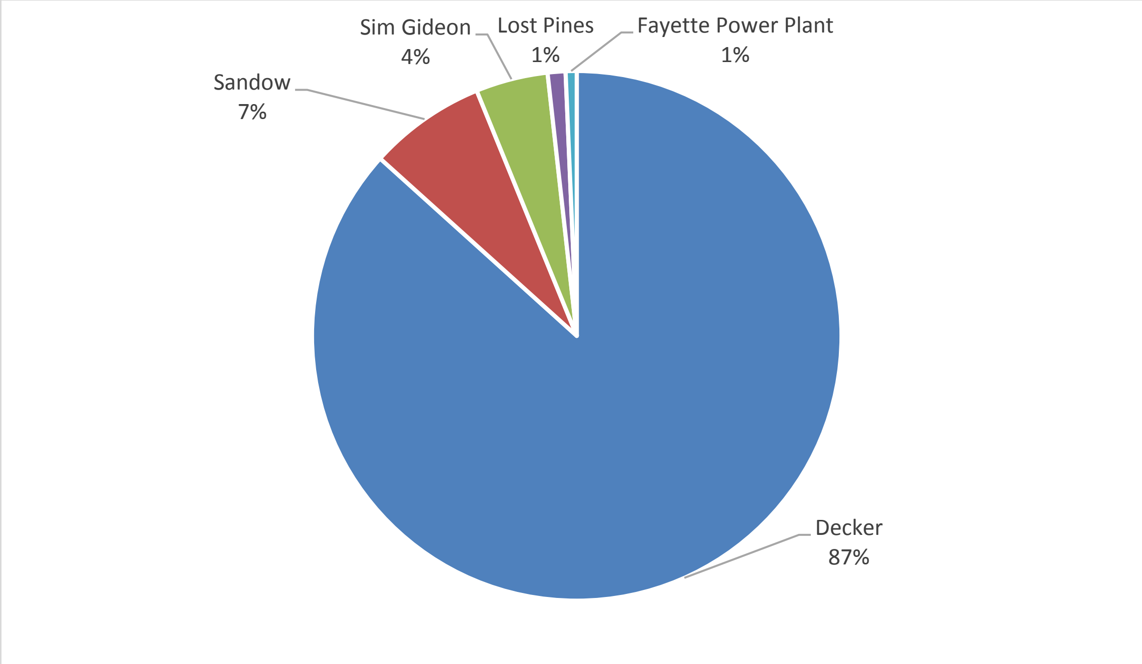
Table 7-2. Approximate Impact of Change in Avg. O_3 Season NO_X Emissions at Area EGUs on 4-Highest MDA8 O_3 Levels, 2016-2017

Facility	County	Impact Ratio for top 4 Days at CAMS 3(ppb O_3/tpd NO_X)	Change in Avg. OSD NO_X Emissions, 2016 - 2017	Estimated Impact on Top 4 MDA8 O_3 Values of NO_X Change, 2016-2017
Decker Creek Power Plant	Travis	0.1661	+1.0067	+0.1672
Sand Hill	Travis	0.1673	-0.0233	-0.0039
Sim Gideon	Bastrop	0.0419	+0.2018	+0.0085
Lost Pines	Bastrop	0.0328	+0.0644	+0.0021
Bastrop Clean Energy Center	Bastrop	0.1348	-0.4299	-0.0579
Hays Energy Center	Hays	0.0302	-0.0887	-0.0027
Sandow	Milam	0.0441	+0.3136	+0.0138
Fayette Power Plant	Fayette	0.0030	+0.4212	+0.0013
NET IMPACT	**n/a**	**0.0876**	**+1.4657**	**+0.1283**

As the figure below shows, the impact from the Decker Creek Power Plant make up the vast majority of the impact from local power plans that had an increase in NOX emissions from 2016 to 2017.

7 CAPCOG. Photochemical Modeling Analysis Report. September 4, 2015. See Table 15, Seasonal Model Column. http://www.capcog.org/documents/airquality/reports/2015/Photochemical_Modeling_Analysis_Report_2015-09-04_Final_Combined.pdf

Figure 7-2. Approximate Share of Impact of Increases in Average OSD NO_X Emissions from Local EGUs on 4-Highest MDA8 O_3 Values at CAMS 3 based on 2009 UT Seasonal Modeling, 2016-2017



Based on this analysis and the availability of more detailed modeling of the impact of emissions from the Decker Creek Power Plant by unit finalized in 2017, CAPCOG conducted a more detailed analysis of the potential impact of the increase in average O_3 season NO_X emissions from Decker between 2016 and 2017.[8] Alamo Area Council of Governments (AACOG) conducted photochemical modeling of the impact of zeroing-out the NO_X emissions from boiler unit 1, boiler unit 2, and all eight turbines (collectively) on modeled O_3 levels across East Texas in TCEQ's June 2012 base case modeling platform. Based on the modeled impact of these changes in NO_X emissions, CAPCOG calculated the following impact ratios for the Decker units on high MDA8 O_3 levels at CAMS 3.

Table 7-3. CAMS 3 MDA8 O_3/NO_X Impact Ratios Calculated for Decker Units from 2017 Control Strategy and Sensitivity Modeling Project (ppb O_3/tpd NO_X)[9]

Statistic	Boiler 1	Boiler 2	Turbines
Avg. Impact Ratio, top 4 Days	0.1393	0.1006	0.0397
Max Impact Ratio, top 4 Days	0.2670	0.1973	0.0709
Min. Impact Ratio, top 4 Days	0.0141	-0.0209	0.0054
Avg. Impact Ratio, top 10 Days >=60 ppb	0.1650	0.1113	0.0398
Max. Impact Ratio, top 10 Days >=60 ppb	0.3036	0.2353	0.0709
Min. Impact Ratio, top 10 Days. >=60 ppb	0.0020	-0.0209	0.0054

[8] AACOG. *June 2012 Photochemical Episode Sensitivity and Control Strategy Modeling Technical Report*. Prepared for CAPCOG, August 11, 2017. Available online at: http://www.capcog.org/documents/airquality/reports/2017/6.3.2a-AACOG_Sensitivity_and_Control_Strategy_Modeling_Report.pdf

[9] Note – the "minimum" ratios reflect the minimum ratios for days when the unit was actually used on the top 4 or top 10 MDA8 O3 days. Units 1 and 2 were used on all of the top 10 days, while the turbines were used on 3 of the top 4 MDA8 O3 days for CAMS 3 and 4 of the top 10 days.

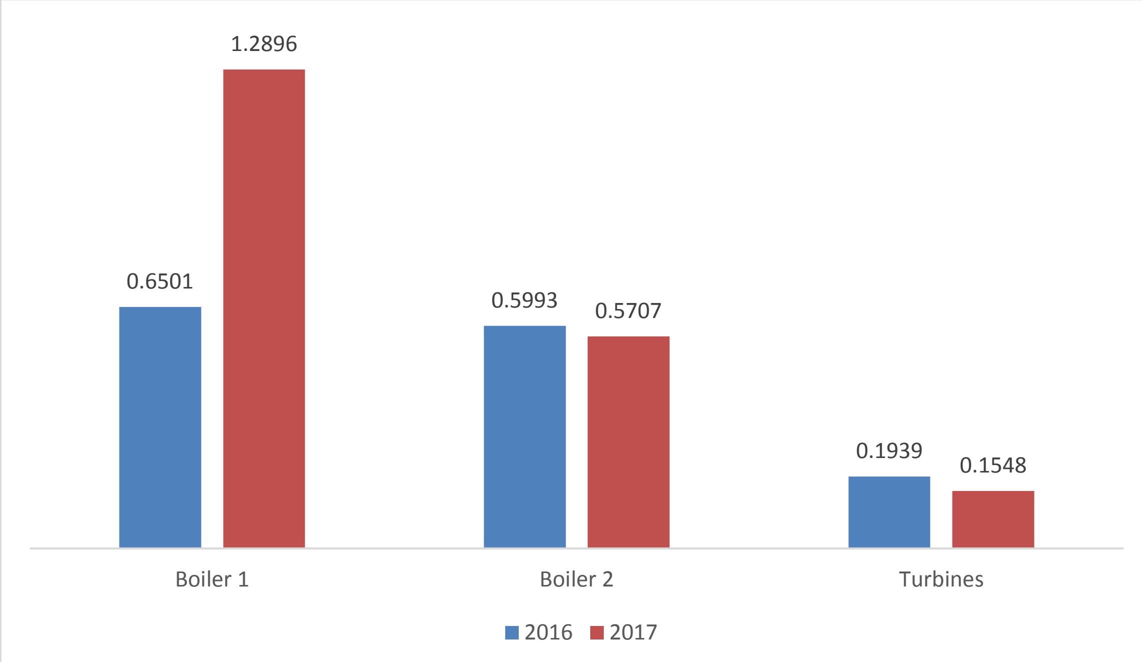
Next, CAPCOG reviewed the 2016 O_3 season NO_X emissions in EPA's Air Market Program Database (AMPD) against TCEQ's 2016 Emissions Inventory Questionnaire (EIQ) for the Decker Creek Power Plant, since previous analysis had revealed that the data reported by Austin Energy to the EPA showed much higher NO_X emissions for the eight gas turbines than what was reported to TCEQ in earlier years. This discrepancy is a result of special rules that EPA has for the use of default worst-case scenario NO_X emissions rates for certain units that do not require continuous emissions monitoring systems (CEMS) but lack recent enough stack test data. This analysis indicated that the actual NO_X emissions for these turbines was about 70-80% lower than what was in EPA's AMPD. The table below shows a unit-by-unit comparison of the 2016 OSD NO_X emissions estimates for Decker, along with an adjustment factor CAPCOG calculated to translate the 2017 Ozone Season Day (OSD) NO_X emissions estimates to estimates that would be much more in line with the more accurate estimates in the facility's EIQ for 2017 (which is not yet publicly available on TCEQ's website).

Table 7-4. Decker 2016 Average O_3 Season Day NO_X Emissions by Unit and Calculated Adjustment Factors

Unit Number	EPA AMPD (tpd)	TCEQ EIQ (tpd)	Difference (tpd)	Adjustment Factor (TCEQ/EPA)
Boiler 1	0.6418	0.6501	0.0083	1.0129
Boiler 2	0.6125	0.5993	-0.0132	0.9784
Gas Turbine 1A	0.1049	0.0173	-0.0876	0.1652
Gas Turbine 1B	0.1031	0.0301	-0.0730	0.2923
Gas Turbine 2A	0.0785	0.0167	-0.0617	0.2132
Gas Turbine 2B	0.0456	0.0092	-0.0364	0.2017
Gas Turbine 3A	0.1367	0.0292	-0.1075	0.2138
Gas Turbine 3B	0.1355	0.0306	-0.1049	0.2260
Gas Turbine 4A	0.1516	0.0299	-0.1217	0.1972
Gas Turbine 4B	0.1511	0.0308	-0.1203	0.2040
TOTAL	**2.1611**	**1.4432**	**-0.7179**	**n/a**

The following figure shows the average adjusted O_3-season day NO_X emissions for boiler 1, boiler 2, and all eight turbine units (collectively) for 2016 and 2017.

Figure 7-3. Decker Creek Power Plant Average Daily O_3 Season NO_X Emissions by Unit, 2016 and 2017 (adjusted)



Next, since an area's design value is impacted only by the top four MDA8 O_3 levels, CAPCOG analyzed the NO_X emissions on just the top 4 days in 2016 and 2017 in order to see if there was a substantial difference between the difference in NO_X emissions on those four days compared to the entire O_3 season. Across all 10 units at the Decker Power Plant, average O_3 season daily NO_X emissions was 40% higher in 2017 than they were in 2016, although all of this increase is attributable to an increase in emissions at boiler 1, which had average O_3 daily NO_X 2017 emissions that were 98% higher than 2016 emissions. As the table below shows, the difference in NO_X emissions on just the top 4 days was considerably higher than the difference in average MDA8 O_3 levels across the entire O_3 season.

Table 7-5. Comparison of Decker NO_X Emissions on Top 4 MDA8 O_3 Days at CAMS 3, 2016 and 2017 (adjusted)

Rank	2016 Date	2016 O_3 MDA8 (ppb)	2016 NO_X (tpd)	2017 Date	2017 O_3 MDA8 (ppb)	2017 NO_X (tpd)	Difference NO_X (tpd)
1	10/3/2016	72	0.9385	9/1/2017	71	1.8648	0.9263
2	4/23/2016	67	0.0000	6/8/2017	71	2.4294	2.4294
3	3/14/2016	66	0.8326	5/6/2017	71	0.0594	-0.7732
4	10/2/2016	64	0.3395	8/1/2017	70	5.0851	4.7456
Avg.	**n/a**	**67.25**	**0.5277**	**n/a**	**70.75**	**2.3597**	**1.8320**

Finally, CAPCOG multiplied the maximum unit-specific impact ratio among the top 10 MDA8 O_3 days modeled by AACOG in the 2017 Control Strategy and Sensitivity Analysis modeling and the average impact ratio for the top 4 days at CAMS 3 to each unit's NO_X emissions for the actual top 4 days in 2016 and 2017. CAPCOG applied the maximum ratio among the top 10 days modeled to the NO_X emissions on the 4th-highest days in 2016 and 2017 in order to calculate the maximum possible impact on the actual "design value day" in each year for each unit, and then also calculated the average impact of the NO_X

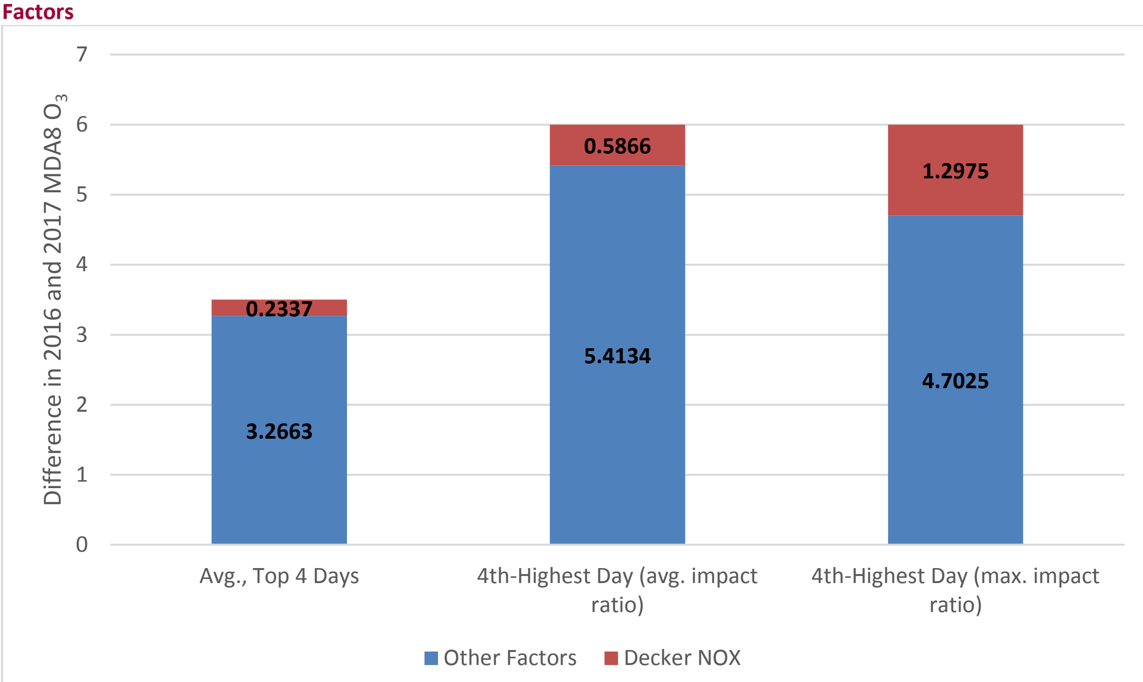
emissions for each unit for all of the top 4 days using the average ratio modeled for the top 4 days from the sensitivity/control strategy modeling. This analysis is shown in the table below.

Table 7-6. Estimated Impacts of CAMS 3 NO_X on 4 highest MDA8 Days at CAMS 3 in 2016 and 2017 (ppb)

Statistic	Boiler 1	Boiler 2	Turbines	Combined
2016, Maximum Impact, 4th-Highest Day	0.0000	0.0799	0.0000	0.0799
2016, Avg. Impact, 4th-Highest Day	0.0000	0.0342	0.0000	0.0342
2016, Avg. Impact Estimate for Top 4 Days	0.0462	0.0197	0.0000	0.0659
2017, Maximum Impact, 4th-Highest Day	0.9549	0.4080	0.0146	1.3774
2017, Avg. Impact, 4th-Highest Day	0.4381	0.1744	0.0082	0.6207
2017, Avg. Impact for top 4 Days	0.2512	0.0436	0.0049	0.2997
Difference in Max. Impact, 4th-Highest Day	0.9549	0.3281	0.0146	1.2975
Difference in Avg. Impact, 4th-Highest Day	0.4381	0.1403	0.0082	0.5866
Difference in Avg. Impact for top 4 Days	0.2049	0.0239	0.0049	0.2337

Using these data, CAPCOG compared the potential impact of the difference in the O_3 impact of the Decker Creek Power plant on the top 4 days in 2016 and 2017 to the actual difference in MDA8 O_3 levels at CAMS 3 for 2016 and 2017 in order to assess the share of the difference in the O_3 levels attributable to the increase in Decker's NO_X emissions from 2016 to 2017 compared to other factors. This is shown in the figure below.

Figure 7-4. Change in CAMS 3 MDA8 O_3 Levels from 2016-2017 Attributable to Decker NO_X Emissions Increase and Other Factors



This analysis indicates that the increase in NO_X emissions at the Decker Creek Power Plant on the 4 highest O_3 days at CAMS 3 could have accounted for about 7% and 22% of the increase in the peak O_3 at CAMS 3 (the top 4 days) between 2016 and 2017, with other factors (such as differences in meteorology, background O_3 levels, or other sources of local emissions) accounting for the other 78% - 93% of the increase. In fact, this analysis likely substantially understates the impacts of these other factors, particularly meteorology, since the nation-wide reductions in NO_X emissions from power plants and mobile sources from 2016 to 2017 would be expected to reduce the impact of both U.S. and local NO_X emissions, meaning the increased O_3 levels within the region attributable to differences in local meteorology, biogenic emissions, and international transport would need to be even larger than what is shown in the figure above to negate the nation-wide reductions in EGU and mobile source emissions year-over-year. For example:

- In 2013, EPA's initial modeling of the impact of the proposed Tier 3 fuel and light-duty vehicle engine standards on O_3 levels indicated that the rule would reduce Travis County's 2017 design value by 0.71 ppb compared to a scenario in which the standards were not implemented. [10]
- In 2014, EPA's modeling of the impact of the final Tier 3 fuel and light-duty vehicle engine standards on O_3 levels indicated that the rule would reduce Travis County's 2018 design value by 0.63 ppb compared to a scenario in which the standards were not implemented.[11]
- In 2016, EPA's final modeling for the 2008 Ozone NAAQS update to the CSAPR indicated that Travis County's O_3 design value would decrease an average of 1.0 ppb per year from 2011 to 2017 due to year-over-year reductions in NO_X emissions within this time frame, without consideration of the impact of the EGU NO_X emissions reductions attributable to the 2008 O_3 NAAQS CSAPR Update.[12]
- EPA's final regulatory impact analysis for the 2008 Ozone NAAQS update to the CSAPR indicated that the NO_X reductions from states subject to the new rule would result in an average decrease in the O_3 design values of the 19 final "receptors" analyzed was 0.28 ppb.[13]
- TCEQ's most recent "Trends" emissions inventories indicated that there were likely substantial decreases in NO_X emissions from mobile sources statewide between 2016 and 2017:
    - A statewide reduction of 151 tpd of OSD weekday NO_X from on-road sources from 2016 to 2017 (a 20% reduction)[14]
    - A statewide reduction of 29 tpd of OSD weekday NO_X from non-road sources (sources in EPA's NONROAD model) from 2016 to 2017 (a 9% reduction)[15]

[10] EPA. *Air Quality Modeling Technical Support Document: Proposed Tier 3 Emission Standards*. Air Quality Assessment Division, Office of Air Quality Planning and Standards. EPA-454/R-13-006. March 2013. Available online at: https://nepis.epa.gov/Exe/ZyPDF.cgi/P100GNLO.PDF?Dockey=P100GNLO.PDF

[11] EPA. *Air Quality Modeling Technical Support Document: Tier 3 Motor Vehicle Emission and Standards*. Air Quality Assessment Division, Office of Air Quality Planning and Standards. EPA-454/R-14-002. February 2014. Available online at: https://nepis.epa.gov/Exe/ZyPDF.cgi/P100HX23.PDF?Dockey=P100HX23.PDF

[12] EPA. *Data File with Ozone Design Values and Ozone Contributions*. August 2016. Available online at: https://www.epa.gov/sites/production/files/2017-05/final_csapr_update_ozone_design_values_contributions_all_sites.xlsx

[13] EPA. Regulatory Impact Analysis of the Cross-State Air Pollution Rule (CSAPR) Update for the 2008 National Ambient Air Quality Standards for Ground-Level Ozone. Health and Environmental Impacts Division, Office of Air Quality Planning and Standards. EPA-452/R-16-004. Available online at: https://www3.epa.gov/ttn/ecas/docs/ria/transport_ria_final-csapr-update_2016-09.pdf.

[14] TTI. *August 2015. On-Road, Mobile Source Emissions Inventories for All Counties in Texas for 1999 – 2050*. Prepared for the TCEQ. August 2015. Available online at: ftp://amdaftp.tceq.texas.gov/pub/EI/onroad/mvs14_trends/reports/mvs14_trends_final_report_aug_2015.pdf.

[15] ERG. *Development of Texas Statewide 2014 AERR Inventory and Trends Data for NONROAD Model Category Mobile Sources. Prepared for the TCEQ*. September 21, 2015.

- A statewide reduction of 2 tpd of OSD NO_X from commercial marine vessels from 2016 to 2017 (a 3% reduction)[16]
- A statewide reduction of 2 tpd of OSD NO_X from locomotives from 2016 to 2017 (a 2% reduction)[17]

There are some potential other anthropogenic NO_X-related causes for higher O_3 levels in the region between 2016 and 2017:

- A 6% increase in crude oil production (although this could have been offset by a 7% reduction in natural gas production)[18]

A 2% increase in ozone season industrial and commercial natural gas consumption statewide[19]

8 Conclusion

This report provides an update to the "state of the knowledge" regarding the influence of emissions, meteorology, transport, and other processes on O_3 pollution within the region that was gained in the 2010-2015 Conceptual Model completed in 2016.

Overall, 2017 meteorological data trends were consistent with the relationship between MDA8 O_3 and weather conditions observed in 2010-2015. Although the downward trend in the region's O_3 design value did not continue in 2017, increasing from 66 ppb in 2016 to 69 ppb in 2017, this mainly had to do with the low O_3 levels observed in 2014 dropping out of the three-year average for 2015-2017.

This report shows that 2017 had diurnal temperature differences that were consistent with what was observed in 2010-2015, while these temperature differences were much smaller in 2016. The report also shows that low humidity – another factor strongly associated with high O_3 – was substantially more common in 2017 than in 2016, but less common than what was observed from 2010-2015. Another major meteorological factor associated with high O_3 – solar radiation – actually appears to have been less common in 2017 than either in 2016 or from 2010-2015. These analyses suggest that the area's O_3 levels in 2017 would likely have been higher in 2017 if its humidity and solar radiation levels had been more consistent with what had been observed from 2010-2015.

While the significant statistical positive correlations between 24-hour MDA8 O_3 concentrations in 2017 was consistent with what was observed in 2010-2015 and 2016, the analysis of maximum daily 1-hour NO_2 and SO_2 produced different results. The long-run trend in reduced NO_X emissions and the trends in SO_2 emissions at the Sandow Power plant, along with the smaller number of high O_3 data points for 2017 compared to 2010-2015, can help explain these differences.

Other significant findings included:

[16] ERG. *2014 Texas Statewide Commercial Marine Vessel Emissions Inventory and 2008 through 2040 Trend Inventories*. Prepared for TCEQ. August 26, 2015. Available online at: https://www.tceq.texas.gov/assets/public/implementation/air/am/contracts/reports/ei/582155149301FY15-20150826-erg-commercial_marine_vessel_2014aerr_inventory_trends_2008to2040.pdf.

[17] ERG. *2014 Texas Statewide Locomotive Emissions Inventory and 2008 through 2040 Trend Inventories*. Prepared for TCEQ. August 26, 2015. Available online at: https://www.tceq.texas.gov/assets/public/implementation/air/am/contracts/reports/ei/582155153802FY15-20150826-erg-locomotive_2014aerr_inventory_trends_2008to2040.pdf.

[18] http://www.rrc.state.tx.us/oil-gas/research-and-statistics/production-data/historical-production-data/

[19] https://www.eia.gov/dnav/ng/hist/n3035tx2m.htm

- The 2017 data continued the 2016 trend of February having substantially more days with MDA8 $O_3 \geq 55$ ppb than was measured from 2010-2015. This may suggest that initiating non-regulatory O_3 monitoring earlier in the O3 may provide additional valuable information.
- The general relationships between meteorology and high MDA8 O_3 in 2017 were broadly consistent with what the relationships observed 2010-2015 and 2016.
- Background MDA8 O_3 levels were slightly, but significantly statistically higher in 2017 and 2016 than what was typical for 2010-2015.
- Local contributions to MDA8 O_3 levels were substantially and significantly statistically lower in 2017 and 2016 than what was typical for 2010-2015.
- While there was no reported increase in statewide NO_X emission from EGUs in 2016 compared to 2017, there was an increase in the reported NO_X emissions from local and surrounding counties EGUs. This may explain the increase in days with MDA8 O3 days >70 ppb, however, the impact from this NO_X increase is likely less significant than meteorological factors.

Appendix A: Monitor-by-Monitor Meteorological Data

This section includes monitor-by-monitor data for some of the key meteorological factors analyzed. This includes monitors that were not as extensively analyzed in the body of this report.

Wind Speed

Table A 1. Avg. wind speed 12-4pm statistics for CAMS 3

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. WS (mph)	2010-2015 Avg. WS St. Dev. (mph)	2017 Count	2017 Avg. WS. (mph)	2017 Avg. WS. St. Dev. (mph)
>70 ppb	36	5.93	1.42	3	4.83	1.29
55-70 ppb	260	6.76	2.26	31	7.74	2.11
<55 ppb	1801	7.53	2.60	325	7.61	2.58

Table A 2. Avg. wind speed 12-4pm statistics for CAMS 38

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. WS (mph)	2010-2015 Avg. WS St. Dev. (mph)	2017 Count	2017 Avg. WS. (mph)	2017 Avg. WS. St. Dev. (mph)
>70 ppb	25	5.22	1.06	1	4.50	n/a
55-70 ppb	276	6.41	2.03	32	7.63	2.29
<55 ppb	1802	7.00	2.27	318	7.03	2.20

Table A 3. Avg. wind speed 12-4pm statistics for CAMS 601

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. WS (mph)	2010-2015 Avg. WS St. Dev. (mph)	2017 Count	2017 Avg. WS. (mph)	2017 Avg. WS. St. Dev. (mph)
>70 ppb	17	6.72	1.72	0	n/a	n/a
55-70 ppb	184	8.01	3.06	33	9.17	3.51
<55 ppb	1044	9.59	3.59	217	9.80	3.64

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

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. WS (mph)	2010-2015 Avg. WS St. Dev. (mph)	2017 Count	2017 Avg. WS. (mph)	2017 Avg. WS. St. Dev. (mph)
>70 ppb	24	6.98	1.49	233	6.70	n/a
55-70 ppb	218	8.24	2.68	25	9.12	3.11
<55 ppb	987	9.26	2.81	1	9.01	3.06

Table A 5. Avg. wind speed 12-4pm statistics for CAMS 684

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. WS (mph)	2010-2015 Avg. WS St. Dev. (mph)	2017 Count	2017 Avg. WS. (mph)	2017 Avg. WS. St. Dev. (mph)
>70 ppb	5	4.38	0.77	0	n/a	n/a
55-70 ppb	106	4.51	1.69	8	4.10	0.99
<55 ppb	858	5.02	1.96	254	5.35	1.92

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

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. WS (mph)	2010-2015 Avg. WS St. Dev. (mph)	2017 Count	2017 Avg. WS. (mph)	2017 Avg. WS. St. Dev. (mph)
>70 ppb	28	3.76	1.51	3	6.45	0.91
55-70 ppb	224	4.30	1.91	40	10.25	3.54
<55 ppb	887	6.35	3.39	219	9.74	3.49

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

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. WS (mph)	2010-2015 Avg. WS St. Dev. (mph)	2017 Count	2017 Avg. WS. (mph)	2017 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	23	15	8.18
<55 ppb	358	6.01	3.10	239	244	9.15

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

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. WS (mph)	2010-2015 Avg. WS St. Dev. (mph)	2017 Count	2017 Avg. WS. (mph)	2017 Avg. WS. St. Dev. (mph)
>70 ppb	0	n/a	n/a	2	87.04	4.26
55-70 ppb	52	3.16	2.28	34	84.75	6.64
<55 ppb	380	5.32	3.34	219	82.79	11.57

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

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. WS (mph)	2010-2015 Avg. WS St. Dev. (mph)	2017 Count	2017 Avg. WS. (mph)	2017 Avg. WS. St. Dev. (mph)
>70 ppb	14	3.35	1.43	0	n/a	n/a
55-70 ppb	142	3.16	2.21	23	10.44	3.68
<55 ppb	752	5.53	3.85	224	11.48	4.58

Table A 10. Avg. wind speed 12-4pm statistics for CAMS 6602

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. WS (mph)	2010-2015 Avg. WS St. Dev. (mph)	2017 Count	2017 Avg. WS. (mph)	2017 Avg. WS. St. Dev. (mph)
>70 ppb	18	2.31	1.48	0	n/a	n/a
55-70 ppb	142	2.52	1.73	27	6.67	1.74
<55 ppb	621	3.92	2.22	211	7.16	2.33

Temperature

Table A 11. Avg. temp. 12-4pm 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)	2017 Count	2017 Avg. Temp. (deg. F)	2017 St. Dev. Avg. Temp. (deg. F)
>70 ppb	36	92.8	6.2	3	85.16	2.66
55-70 ppb	260	85.3	7.7	31	83.10	4.69
<55 ppb	1810	73.5	16.2	316	75.43	13.44

Table A 12. Avg. temp. 12-4pm 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)	2017 Count	2017 Avg. Temp. (deg. F)	2017 St. Dev. Avg. Temp. (deg. F)
>70 ppb	25	90.9	7.4	1	86.48	n/a
55-70 ppb	276	86.1	7.4	32	83.37	4.82
<55 ppb	1818	73.3	16.4	311	74.60	13.65

Table A 13. Avg. temp. 12-4pm statistics for CAMS 601

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. Temp. (deg. F)	2010-2015 St. Dev. Avg. Temp. (deg. F)	2017 Count	2017 Avg. Temp. (deg. F)	2017 St. Dev. Avg. Temp. (deg. F)
>70 ppb	6	89.6	6.5	0	n/a	n/a
55-70 ppb	114	84.9	8.2	33	84.62	6.15
<55 ppb	715	83.5	9.5	217	84.20	9.18

Table A 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)	2017 Count	2017 Avg. Temp. (deg. F)	2017 St. Dev. Avg. Temp. (deg. F)
>70 ppb	24	92.0	7.5	1	93.05	n/a
55-70 ppb	214	85.8	7.3	25	83.18	5.76
<55 ppb	967	83.9	9.6	233	79.59	10.19

Table A 15. Avg. temp. 12-4pm statistics for CAMS 684

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. Temp. (deg. F)	2010-2015 St. Dev. Avg. Temp. (deg. F)	2017 Count	2017 Avg. Temp. (deg. F)	2017 St. Dev. Avg. Temp. (deg. F)
>70 ppb	1	92.4	n/a	0	n/a	n/a
55-70 ppb	32	86.2	7.2	8	87.38	4.95
<55 ppb	328	81.6	12.7	254	81.94	10.57

Table A 16. Avg. temp. 12-4pm 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)	2017 Count	2017 Avg. Temp. (deg. F)	2017 St. Dev. Avg. Temp. (deg. F)
>70 ppb	28	90.0	8.4	3	83.60	1.67
55-70 ppb	232	87.2	8.4	40	83.35	5.11
<55 ppb	977	84.2	10.6	219	79.86	10.52

Table A 17. Avg. temp. 12-4pm 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)	2017 Count	2017 Avg. Temp. (deg. F)	2017 St. Dev. Avg. Temp. (deg. F)
>70 ppb	6	88.6	8.4	0	n/a	n/a
55-70 ppb	45	86.9	7.0	15	85.08	5.66
<55 ppb	234	78.0	12.3	244	81.11	9.33

Table A 18. Avg. temp. 12-4pm 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)	2017 Count	2017 Avg. Temp. (deg. F)	2017 St. Dev. Avg. Temp. (deg. F)
>70 ppb	0	n/a	n/a	2	87.04	4.26
55-70 ppb	39	86.03	6.70	34	84.71	6.69
<55 ppb	312	82.14	12.60	219	82.69	4.26

Table A 19. Avg. temp. 12-4pm 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)	2017 Count	2017 Avg. Temp. (deg. F)	2017 St. Dev. Avg. Temp. (deg. F)
>70 ppb	3	93.9	4.2	0	n/a	n/a
55-70 ppb	46	82.9	9.7	23	80.93	4.16
<55 ppb	311	80.6	11.9	224	79.36	9.33

Table A 20. Avg. temp. 12-4pm 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)	2017 Count	2017 Avg. Temp. (deg. F)	2017 St. Dev. Avg. Temp. (deg. F)
>70 ppb	4	84.0	7.3	0	n/a	n/a
55-70 ppb	34	86.9	6.1	27	81.67	5.17
<55 ppb	164	83.4	8.7	211	80.37	9.66

Diurnal Temperature Change

Table A 21. 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)	2017 Count	2017 Avg. Temp Chg. (deg. F)	2017 Avg. Temp. Chg. St. Dev. (deg. F)
>70 ppb	36	23.1	4.8	3	19.37	4.40
55-70 ppb	254	21.3	4.3	31	21.25	5.08
<55 ppb	1776	17.2	6.0	306	17.23	5.54

Table A 22. 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)	2017 Count	2017 Avg. Temp Chg. (deg. F)	2017 Avg. Temp. Chg. St. Dev. (deg. F)
>70 ppb	25	23.1	2.9	1	17.60	n/a
55-70 ppb	270	22.2	22.2	32	23.05	4.51
<55 ppb	1791	18.1	6.1	317	18.20	5.64

Table A 23. Diurnal temp. change statistics for CAMS 601

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. Temp Chg. (deg. F)	2010-2015 Avg. Temp. Chg. St. Dev. (deg. F)	2017 Count	2017 Avg. Temp Chg. (deg. F)	2017 Avg. Temp. Chg. St. Dev. (deg. F)
>70 ppb	6	26.3	4.0	0	n/a	n/a
55-70 ppb	114	22.2	3.9	33	25.07	4.48
<55 ppb	709	16.7	4.9	217	18.49	5.10

Table A 24. 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)	2017 Count	2017 Avg. Temp Chg. (deg. F)	2017 Avg. Temp. Chg. St. Dev. (deg. F)
>70 ppb	24	25.0	3.8	1	29.20	n/a
55-70 ppb	211	24.6	4.6	25	27.99	4.18
<55 ppb	951	18.8	5.4	233	20.56	6.30

Table A 25. Diurnal temp. change statistics for CAMS 684

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. Temp Chg. (deg. F)	2010-2015 Avg. Temp. Chg. St. Dev. (deg. F)	2017 Count	2017 Avg. Temp Chg. (deg. F)	2017 Avg. Temp. Chg. St. Dev. (deg. F)
>70 ppb	1	37.1	n/a	0	n/a	n/a
55-70 ppb	32	33.2	5.1	8	30.53	6.66
<55 ppb	325	23.1	7.9	252	23.03	7.56

Table A 26. 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)	2017 Count	2017 Avg. Temp Chg. (deg. F)	2017 Avg. Temp. Chg. St. Dev. (deg. F)
>70 ppb	28	26.8	2.9	3	28.33	6.31
55-70 ppb	230	24.6	4.5	40	24.89	4.62
<55 ppb	961	19.2	5.3	217	19.56	6.01

Table A 27. 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)	2017 Count	2017 Avg. Temp Chg. (deg. F)	2017 Avg. Temp. Chg. St. Dev. (deg. F)
>70 ppb	6	23.9	1.9	0	n/a	n/a
55-70 ppb	45	24.7	4.0	15	24.55	3.61
<55 ppb	231	17.5	5.9	244	19.15	5.97

Table A 28. 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)	2017 Count	2017 Avg. Temp Chg. (deg. F)	2017 Avg. Temp. Chg. St. Dev. (deg. F)
>70 ppb	0	n/a	n/a	2	28.75	3.04
55-70 ppb	39	26.8	3.4	34	28.71	6.00
<55 ppb	310	20.6	6.5	216	22.11	6.63

Table A 29. 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)	2017 Count	2017 Avg. Temp Chg. (deg. F)	2017 Avg. Temp. Chg. St. Dev. (deg. F)
>70 ppb	3	23.9	1.6	0	n/a	n/a
55-70 ppb	46	23.3	4.4	23	25.86	5.69
<55 ppb	310	18.0	5.6	223	19.28	5.70

Table A 30. 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)	2017 Count	2017 Avg. Temp Chg. (deg. F)	2017 Avg. Temp. Chg. St. Dev. (deg. F)
>70 ppb	4	26.7	3.8	0	n/a	n/a
55-70 ppb	34	24.8	3.4	27	25.66	4.73
<55 ppb	164	19.2	5.6	211	20.00	5.28

Relative Humidity

Table A 31. Avg. relative humidity 12-4pm statistics for CAMS 3

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	4	26.7	3.8	2	38.31	13.21
55-70 ppb	34	24.8	3.4	26	38.47	8.02
<55 ppb	164	19.2	5.6	286	50.86	18.48

Table A 32. Avg. relative humidity 12-4pm statistics for CAMS 38

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	23	25.0	8.2	2	38.31	13.21
55-70 ppb	275	31.7	9.8	26	38.47	8.02
<55 ppb	1787	48.5	19.2	310	51.55	17.09

Table A 33. Avg. relative humidity 12-4pm statistics for CAMS 614

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	5	25.2	2.0	1	27.70	n/a
55-70 ppb	60	28.6	7.6	25	33.19	5.19
<55 ppb	292	47.2	17.7	233	48.91	17.23

Table A 34. Avg. relative humidity 12-4pm statistics for CAMS 684

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	10	22.2	7.6	0	n/a	n/a
55-70 ppb	177	32.0	9.2	8	34.37	5.47
<55 ppb	1090	47.9	16.1	254	44.76	15.75

Table A 35. Avg. relative humidity 12-4pm statistics for CAMS 690

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	5	24.5	2.9	3	25.85	8.97
55-70 ppb	53	26.0	8.0	40	27.79	7.78
<55 ppb	298	41.7	17.6	219	40.44	16.46

Table A 36. Avg. relative humidity 12-4pm statistics for CAMS 1603

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	6	28.5	3.2	0	n/a	n/a
55-70 ppb	45	27.8	6.6	15	30.06	6.26
<55 ppb	234	51.5	20.1	244	43.25	16.70

Table A 37. Avg. relative humidity 12-4pm 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	12	36.91	6.24
<55 ppb	312	47.6	17.2	295	51.63	17.23

Table A 38. Avg. relative humidity 12-4pm statistics for CAMS 1675

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	3	30.2	2.9	0	n/a	n/a
55-70 ppb	46	31.1	7.8	23	36.43	6.52
<55 ppb	319	49.2	17.2	224	48.23	15.21

Table A 39. Avg. relative humidity 12-4pm statistics for CAMS 6602

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	4	28.9	3.7	0	n/a	n/a
55-70 ppb	32	30.2	6.3	43	44.88	14.36
<55 ppb	162	46.5	17.4	211	47.68	14.73

Solar Radiation

Table A 40. 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)	2017 Count	2017 Avg. (langleys / min)	2017 Avg. SR. St. Dev. (langleys / min)
>70 ppb	25	1.18	0.11	3	1.065667	0.184485
55-70 ppb	276	1.11	0.17	31	1.097153	0.151929
<55 ppb	1,819	0.81	0.35	285	0.75723	0.32393