Analysis of 2016 Monitoring Data

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Executive Summary

The purpose of this project is to compare ambient air monitoring data collected in 2016 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;
- Fine particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) data collected at CAMS 3.

Some of the key findings from this analysis are:

- The O_3 "design value" for the Austin-Round Rock Metropolitan Statistical Area (MSA) decreased from 68 parts per billion (ppb) for 2013-2015 to 66 ppb for 2014-2016 at both of the regulatory O_3 monitoring stations in region, meaning that the region's O_3 levels remained in attainment of the 2015 National Ambient Air Quality Standard (NAAQS) of 70 ppb for O_3.
- Maximum daily 8-hour average (MDA8) O_3 monitoring data collected at CAPCOG's non-regulatory O_3 monitoring stations strongly suggest that 2014-2016 O_3 levels across the region were also in attainment of the 2015 O_3 NAAQS.
- The 4th-highest MDA8 O_3 values in 2016 ranged from 58 ppb to 64 ppb within the region, lower than the three-year averages for 2014-2016 at all sites by at least 2 ppb and up to 7 ppb.
- St. Edward's University's non-regulatory O_3 monitor also collected O_3 data in 2016, but CAPCOG and St. Edward's University observed that the O_3 data in 2016 was systematically lower than what was expected, and should not necessarily be considered a reliable indication of ground-level O_3 concentrations in the general vicinity of the university.
- There was one day in 2016 when one monitor recorded O_3 levels were considered "unhealthy for sensitive groups" (>70 ppb) compared to 12 such days in 2015, and an average of 11 days each year that were "unhealthy for sensitive groups" or worse between 2010-2015.
- There were only 49 days when the highest O_3 levels recorded in the region were "moderate" or worse in 2016 based on the 2015 O_3 NAAQS Air Quality Index (AQI), compared to an average of 71 for each year 2010-2015, and matching the lowest of all of those years (2010).
- While the region's official O_3 monitoring season is March 1 – November 30, MDA8 O_3 values recorded in early February that were among the 4 highest MDA8 values at both of the region's regulatory monitors, two months' sooner than the earliest date that had been among the 4-

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

highest values at these two monitoring stations between 2010-2015, and the region again recorded "Moderate" O_3 levels (MDA8 concentrations between 55 ppb and 70 ppb) in February.

- The monthly frequency of days when MDA8 O_3 values were 55 ppb or higher in 2016 was statistically significantly different than what was typical for 2010-2015, with statistically significantly more days 55 ppb or higher in February and statistically significantly fewer days <55 ppb in August.
- The monthly frequency of days when MDA8 O_3 values were 55 ppb or higher in 2016 was also statistically significantly different from the March and September frequencies for 2010-2012 and statistically significantly different from the April frequency for 2013-2015.
- The day-of-week distribution of days when MDA8 O_3 values were 55 ppb or higher in 2016 were not statistically significantly different from the day-of-week distribution for such days between 2010 and 2015.
- Except for CAMS 1603, there was no statistically significant difference in the distribution of start hours for the MDA8 O_3 when the MDA8 ≥ 55 ppb.
- While the meteorology for typical for "moderate" O_3 days (MDA8 values of 55-70 ppb) in 2016 was statistically significantly different in 2016 compared to what was typical for 2010-2015, the general patterns showing the following relationships continued to be seen in the 2016 data:
    - Mid-day wind speeds (WS) when MDA8 O_3 values were 55-70 ppb were statistically significantly slower than when MDA8 O_3 values were <55 ppb
    - Mid-day temperatures (Temp.) when MDA8 O_3 values were 55-70 ppb were statistically significantly higher than when MDA8 O_3 values were <55 ppb
    - Diurnal temperature changes when MDA8 O_3 values were 55-70 ppb were statistically significantly larger than when MDA8 O_3 values were <55 ppb
    - Mid-day relative humidity (RH) averages when MDA8 O_3 values of 55-70 ppb were statistically significantly higher than when MDA8 O_3 values were <55 ppb
    - Mid-day solar radiation (SR) averages when MDA8 O_3 values were 55-70 ppb were statistically significantly lower than when MDA8 O_3 values were <55 ppb
- All of these meteorological factors other than wind speed were statistically less likely to occur in 2016 than what would have been expected based on 2010-2015 data.
- Wind direction patterns in 2016 were consistent with wind direction patterns observed in 2010-2015.
- MDA8 O_3 values in 2016 continued to show positive correlations with 24-hour $PM_{2.5}$ concentrations, maximum daily 1-hour average (MDA1) NO_2 concentrations, and SO_2 concentrations, with MDA8 O_3 values of 55-70 ppb coinciding with statistically significantly higher levels of all three pollutants than MDA8 values of <55 ppb.
- "Background" MDA8 O_3 levels were 30.3 ppb when the region's peak MDA8 O_3 value was <55 ppb, 46.5 ppb when the peak MDA8 O_3 level was 55-70 ppb and 58.0 ppb on the single day when peak MDA8 O_3 levels exceeded 70 ppb
- The typical background O_3 for days with peak MDA8 O_3 <55 ppb and 55-70 ppb values were slightly, but statistically significantly higher than the background typical for these ranges from 2010-2015.

- The local contribution to peak MDA8 O_3 levels averaged 10.9 ppb for days with peak MDA8 O_3 <55 ppb, 13.3 ppb for days with peak MDA8 O_3 55-70 ppb, and 14.0 ppb on the single day when peak MDA8 O_3 exceeded 70 ppb.
- These local contributions were statistically significantly lower (2-3 ppb less) than what was typical for 2010-2015, which is what would have been expected based on downward trends in emissions of nitrogen oxides (NO_X) in the region.

This report includes:

- General summaries of O_3 data in the region from in 2016 compared to 2010-2015 (Section 3);
- Analysis of the temporal profiles and features of O_3 pollution in the region in 2016 compared to 2010-2015 (Section 4);
- Investigations of potential relationships between meteorology and O_3 pollution in 2016 compared to 2010-2015 (Section 5);
- Analysis of correlations between O_3 pollution and ambient fine particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2), and sulfur dioxide (SO_2) concentrations in 2016 compared to 2010-2015 (Section 6); and
- Analysis of spatial patterns in regional O_3 pollution, and investigation of relationships between emissions and ambient O_3 concentrations in the region in 2016 compared to 2010-2015 (Section 7).

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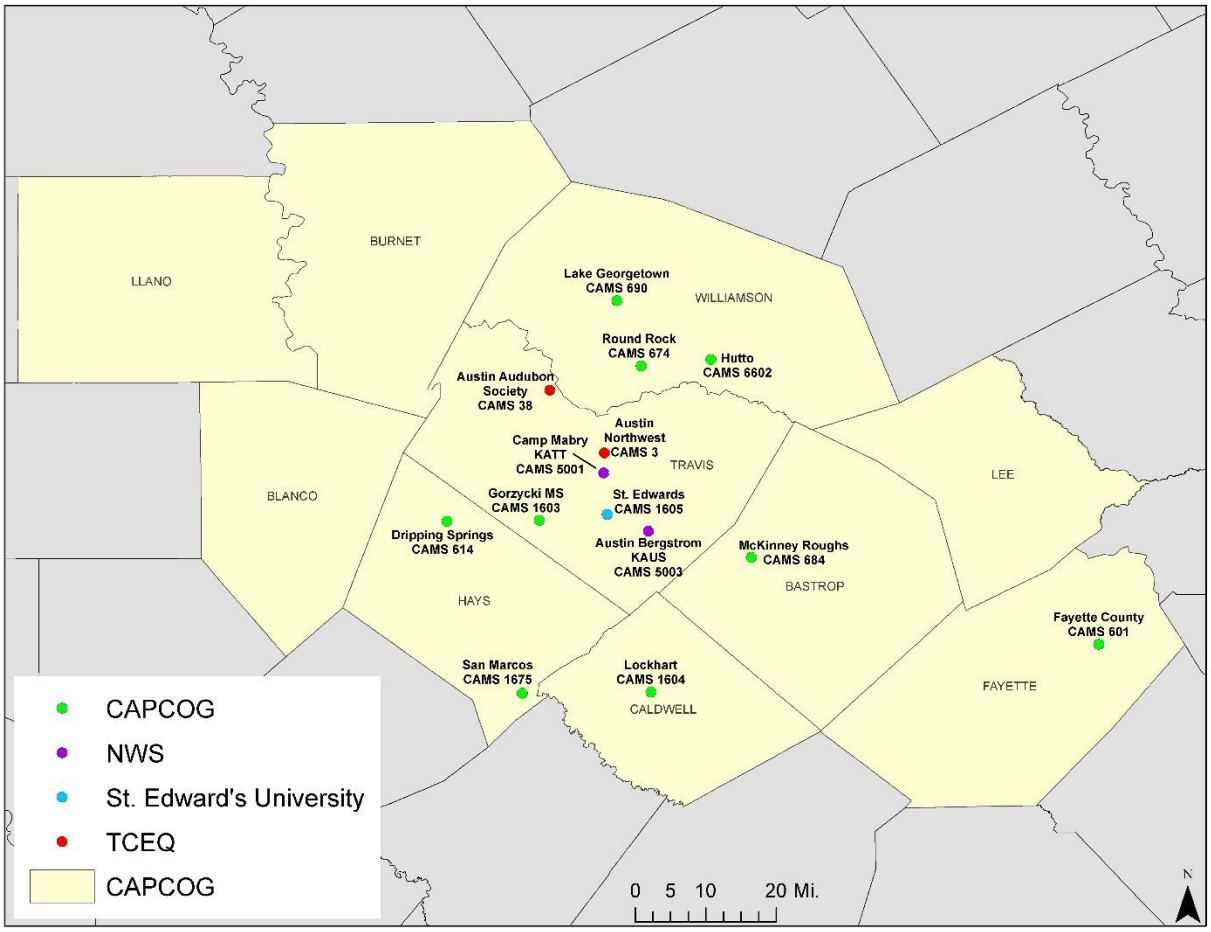
1 Introduction

The purpose of this project is to compare 2016 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 2016 air pollution and meteorological data to the 2010-2015 data used for the most recent conceptual model.

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 2016, green circles are CAPCOG stations that collected O_3 and meteorological data for at least some time between 2010 and 2016, the purple circles are National Weather System (NWS) monitoring stations that collected meteorological data used in this project, and the blue circle is a St. Edward's University station that collected O_3 and meteorological data in 2016.

Figure 1-1. CAPCOG region and CAMS used for 2016 Conceptual Model and 2016 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 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 and the NWS website. The following table provides identifying information on each of the monitoring stations CAPCOG used for this analysis.

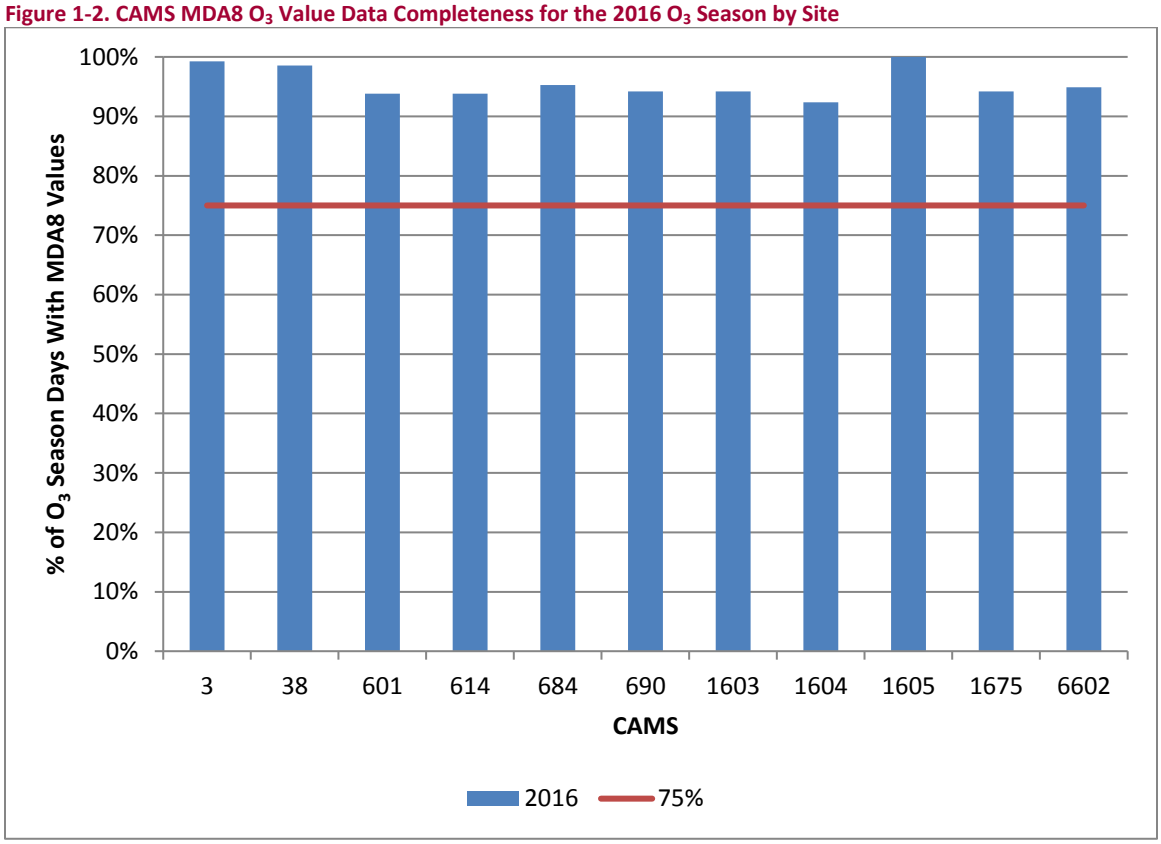
Table 1-1. Ambient air monitoring stations used in 2010-2015 Conceptual Model and 2016 Data Analysis

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
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
5001	Camp Mabry KATT	Travis	30.3136111	-97.7613889	NWS
5003	Austin Bergstrom KAUS	Travis	30.1944444	-97.6700000	NWS
6602	CAPCOG Hutto College Street	Williamson	30.5457060	-97.5417940	CAPCOG

1.3 Availability of O_3 Data by Monitoring Station

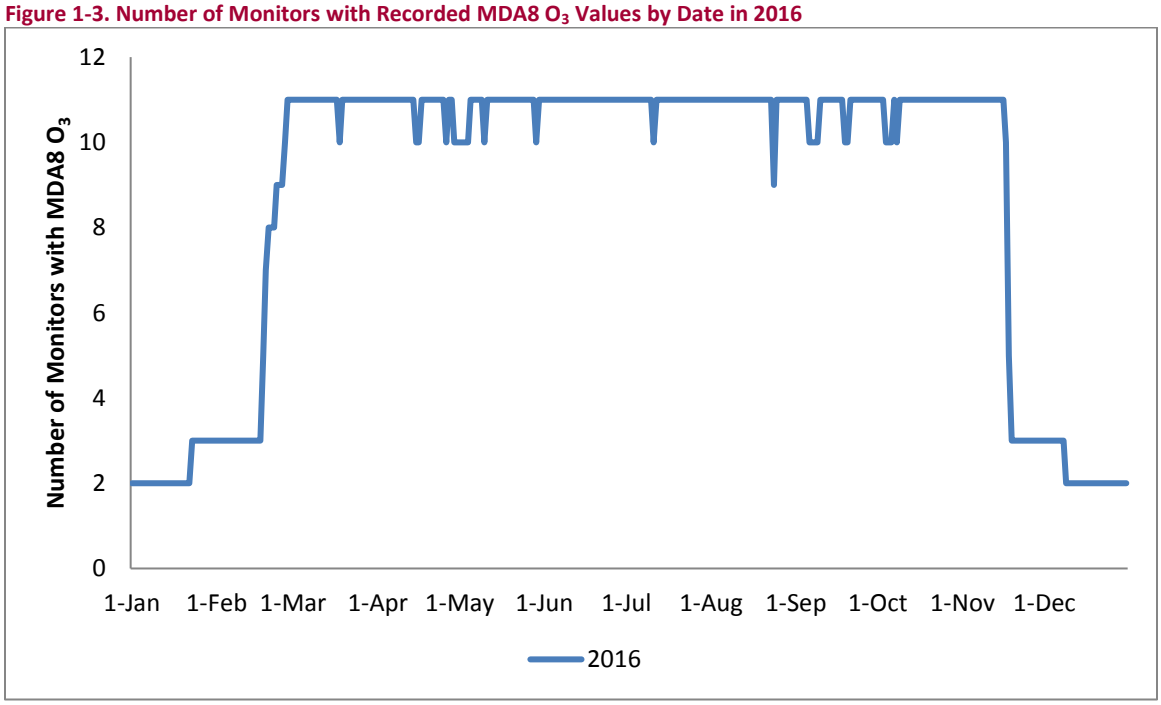
In order to provide perspective on the overall availability of MDA8 O_3 values for analysis, the following figure shows the percentage of O_3 season MDA8 values available for each monitoring station in 2016. TCEQ's two O_3 monitors collected data year-round, while the eight CAPCOG CAMS and one St. Edwards University CAMS collected data from mid-February to mid-November. For regulatory purposes, the Environmental Protection Agency (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 now March 1 – November 30, so the figure below represents the percentage of total possible MDA8 values available each year during these 275 days.

Figure 1-2. CAMS MDA8 O_3 Value Data Completeness for the 2016 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 2016.

Figure 1-3. Number of Monitors with Recorded MDA8 O_3 Values by Date in 2016



1.4 Attainment Status

The two FRM monitors in the region have official 3-year O_3 design values of 0.066 parts per million (ppm), meaning that they that are attaining the 2015 O_3 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 690 had the highest 3-year average of its 4th highest MDA8 in the region (0.067 ppm), although this value was still well below the 2015 O_3 NAAQS. All counties in the CAPCOG region are designated "unclassifiable/attainment" for the 2008 O_3 NAAQS. The Governor recommended to the EPA that Travis County be designated "attainment" for the 2015 O_3 NAAQS and that the remaining 9 counties in the CAPCOG region without FRM monitors be designated "unclassifiable/attainment." The EPA is expected to make initial designation determination in early October 2017.

1.5 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.

1.6 Key Questions for this Analysis

Some of the key questions for this analysis are:

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

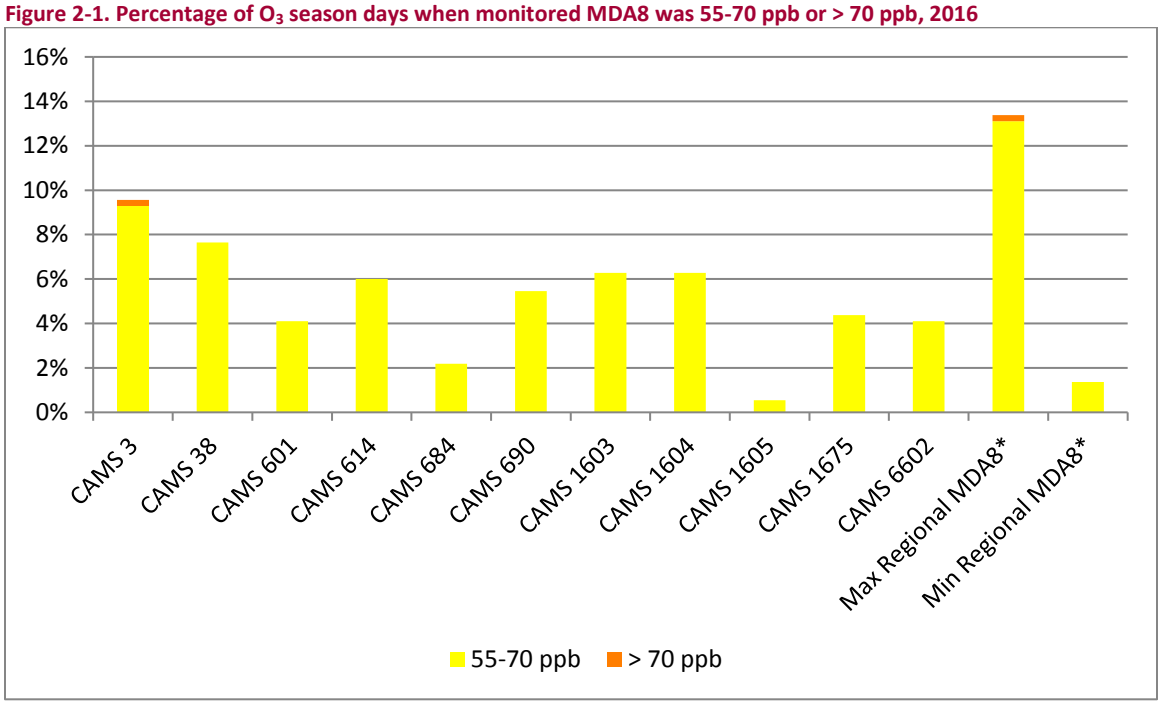
2 Analysis of General O_3 Data

This section provides general data on the MDA8 levels measured in the region in 2016. This includes analysis of days when MDA8 levels were >70 ppb, 55-70 ppb, and <55 ppb, which corresponds generally 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 2016 (March-November). There was one day in 2016 with MDA8 levels measured above 70 ppb and just above 16% of days in ozone season when MDA8 measured above 55 ppb. The regional maximum and minimum value analyses excluded CAMS 1605 due to data quality concerns, which are documented in an appendix to this report.

Figure 2-1. Percentage of O_3 season days when monitored MDA8 was 55-70 ppb or > 70 ppb, 2016



*Excluding CAMS 1605

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 2010-2016. 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	Total
3	8	13	6	1	0	8	1	37
38	3	6	6	3	0	7	0	25
601	1	10	1	2	1	2	0	17
614	4	9	6	0	0	5	0	24
675	2	8	0	0	0	0	0	10
684	0	5	4	0	0	1	0	10
690	1	6	8	9	0	5	0	29
1603	n/a	n/a	n/a	n/a	0	6	0	6
1604	n/a	n/a	n/a	n/a	0	0	0	0
1605	n/a	n/a	n/a	n/a	n/a	n/a	0	0
1675	n/a	2	6	3	0	3	0	14
6602	n/a	13	0	1	0	4	0	18
Region-Wide	**12**	**21**	**12**	**10**	**1**	**12**	**1**	**69**

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

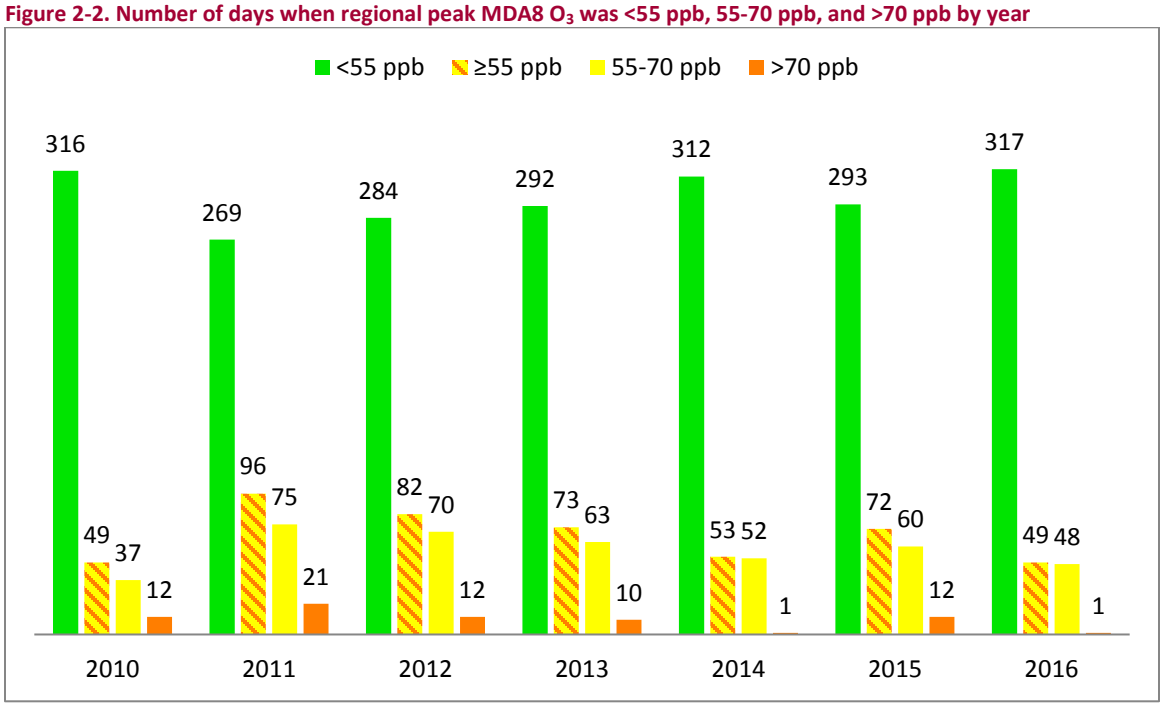
CAMS	2010	2011	2012	2013	2014	2015	2016	Total
3	32	57	45	49	28	49	34	294
38	30	65	54	44	36	47	28	304
601	24	50	25	28	28	33	15	203
614	26	69	38	19	24	45	22	243
684	23	54	42	24	2	32	8	185
690	17	64	43	45	29	40	20	258
1603	n/a	n/a	n/a	n/a	8	44	23	75
1604	n/a	n/a	n/a	n/a	21	31	23	75
1605	n/a	n/a	n/a	n/a	n/a	n/a	2	2
1675	n/a	16	41	28	17	41	16	159
6602	n/a	41	31	38	0	34	15	159
Region-Wide	**37**	**75**	**70**	**63**	**52**	**60**	**48**	**405**

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

CAMS	2010	2011	2012	2013	2014	2015	2016	Total
3	316	267	298	310	329	302	329	2,151
38	326	286	297	300	315	296	334	2,154
601	180	161	159	179	172	209	315	1,375
614	152	138	164	178	170	188	243	1,233
684	169	149	166	191	198	219	266	1,358
690	179	136	145	158	177	198	250	1,243
1603	n/a	n/a	n/a	n/a	155	204	239	598
1604	n/a	n/a	n/a	n/a	163	217	240	620
1605	n/a	n/a	n/a	n/a	n/a	n/a	318	318
1675	n/a	26	168	184	176	205	250	1,009
6602	n/a	117	168	174	0	164	257	880
Total	**316**	**269**	**284**	**292**	**312**	**293**	**317**	**2,083**

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



As the figure shows, 2016 had the smallest number of days when MDA8 O_3 levels were 55 ppb or higher since 2010. In order to determine if the distribution of days in 2016 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 2016 compared to what would be expected for 2010-2015, 2010-2012, and 2013-2015. The following table summarizes the results.

Table 2-4. P-values of chi-square tests comparing 2016 O_3 AQI days to 2010-2015 AQI days

Years	<55 ppb, 55-70 ppb, >70 ppb	<55 ppb, ≥ 55 ppb
2010	***0.001283***	0.983578
2011	***0.000000***	***0.000000***
2012	***0.000031***	***0.000036***
2013	***0.001022***	***0.001565***
2014	0.825295	0.538547
2015	***0.000744***	***0.002310***
2010-2012	***0.000109***	***0.000545***
2013-2015	***0.013006***	***0.019627***
2010-2015	***0.001257***	***0.003642***

This analysis shows that the distribution of days into these Air Quality Index (AQI) ranges in 2016 was statistically significantly different from what was typical of 2010-2015 at a significance level of less than 0.01, as well as the two three-year periods that span 2010-2015 with significance levels of less than 0.02. The 2016 distribution was also statistically significantly different from individual year's distributions for 2011, 2012, 2013, and 2015 for both sets of distributions at significance levels of <0.01. The distribution into the <55 ppb, 55-70 ppb, and >70 ppb ranges in 2016 was also statistically significantly different than the distribution in 2010 at a significance level of <0.01, but the distribution

into <55 ppb and ≥55 ppb ranges in 2016 was not statistically significantly different than the distribution into those ranges in 2010 at a 0.05 significance level. The distributions in 2016 were not statistically significantly different from the distributions in 2014.

2.2 Average of 4th Highest MDA8 O_3 in 2016

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 wither the 2016 values were lower than, higher than, or within the 95% confidence intervals for 2010-2012 and 2013-2015.

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

Rank	2010	2011	2012	2013	2014	2015	2016	2016 in C.I. for 2010-2012	2016 in C.I. for 2013-2015
1	77	82	94	79	69	85	72	Low	Yes
2	76	79	87	70	65	83	67	Low	Yes
3	75	78	80	69	63	82	66	Low	Yes
4	74	75	74	69	62	73	64	Low	Yes
5	73	75	73	68	62	73	64	Low	Yes
6	72	74	71	68	62	73	63	Low	Yes
7	72	74	68	67	61	72	63	Low	Yes
8	71	74	68	67	61	71	62	Low	Yes
9	69	73	67	66	61	70	62	Low	Yes
10	68	73	67	65	60	69	61	Low	Yes
Avg. Top 4	75.5	78.5	83.8	71.8	64.8	80.8	67.25	Low	Yes
Avg. Top 10	72.7	75.7	74.9	68.8	62.6	75.1	64.4	Low	Yes

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

Rank	2010	2011	2012	2013	2014	2015	2016	2016 in C.I. for 2010-2012	2016 in C.I. for 2013-2015
1	76	78	80	74	68	82	69	Low	Yes
2	72	76	78	73	63	81	65	Low	Yes
3	71	73	78	72	63	80	64	Low	Yes
4	70	73	76	70	63	73	62	Low	Low
5	69	71	74	68	63	71	61	Low	Low
6	68	71	72	68	62	71	61	Low	Low
7	66	69	70	68	62	71	61	Low	Low
8	65	69	70	68	62	69	60	Low	Low
9	65	68	69	67	61	68	60	Low	Low
10	64	68	69	66	61	67	60	Low	Low
Avg. Top 4	72.3	75.0	78.0	72.3	64.3	79.0	65	Low	Yes
Avg. Top 10	68.6	71.6	73.6	69.4	62.8	73.3	62.3	Low	Low

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

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

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

Rank	2010	2011	2012	2013	2014	2015	2016	2016 in C.I. for 2010-2012	2016 in C.I. for 2013-2015
1	80	86	77	69	70	79	66	Low	Low
2	78	83	76	69	64	76	66	Low	Yes
3	73	79	73	68	63	72	66	Low	Yes
4	72	77	73	67	63	71	65	Low	Yes
5	70	77	73	64	62	71	64	Low	Yes
6	70	76	71	64	61	70	63	Low	Yes
7	69	74	70	62	61	70	61	Low	Yes
8	67	71	70	62	61	69	61	Low	Yes
9	66	71	68	62	61	69	61	Low	Yes
10	64	70	68	59	61	68	59	Low	Yes
Avg. Top 4	75.8	81.3	74.8	68.3	65.0	74.5	65.75	Low	Yes
Avg. Top 10	70.9	76.4	71.9	64.6	62.7	71.5	63.2	Low	Yes

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

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

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

Rank	2010	2011	2012	2013	2014	2015	2016	2016 in C.I. for 2010-2012	2016 in C.I. for 2013-2015
1	71	79	81	89	70	83	70	Low	Yes
2	70	79	81	79	69	79	68	Low	Low
3	66	77	78	78	66	78	66	Low	Low
4	65	73	73	75	66	75	61	Low	Low
5	65	71	73	74	65	73	60	Low	Low
6	65	71	71	73	63	67	60	Low	Low
7	64	70	71	72	62	66	60	Low	Low
8	62	70	71	71	62	65	59	Low	Low
9	61	69	69	71	62	65	58	Low	Low
10	59	69	69	70	61	64	58	Low	Low
Avg. Top 4	68.0	77.0	78.3	80.3	67.8	78.8	66.25	Low	Low
Avg. Top 10	64.8	72.8	73.7	75.2	64.6	71.5	62	Low	Low

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

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

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

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

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

Rank	2016
1	56
2	56
3	53
4	52
5	52
6	51
7	51
8	51
9	51
10	50
Avg. Top 4	54.25
Avg. Top 10	52.3

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

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

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

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

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, 2014, 2015, and 2016. Consistent with the data-handling conventions for the 2015 O_3 NAAQS, values beyond the units' digit are truncated.

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

Table 2-16. Average of 4th-highest MDA8 values, 2014-2016 (ppb)

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

As the table shows, 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 from 2014 – 2016 dropped the value back below 70 ppb.

2.4 Measurement Uncertainty in MDA8 O_3 Data

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 performs 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 2016 and used the same data acceptance principles as it used for CAPCOG's own stations.

In 2016, TCEQ was using 90 ppb O_3 as its precision check level from January 1 – April 30, and changed to 70 ppb starting May 1. CAPCOG used 70 ppb as the precision check point for all of its calibrations.

The following table summarizes the statistics for TCEQ's precision checks at CAMS 3 and 38 for 2016 through the end of October.

Table 2-17. Summary of CAMS 3 and 38 Precision Calibration Checks, January 1, 2016 - October 31, 2016

Statistic	CAMS 3	CAMS 38
Number of Precision Checks, Including Five-Point Calibrations	46	49
Number of Five-Point Calibrations	14	16
Avg. Bias (ppb)	-0.09	-0.05
St. Deviation Bias (ppb)	1.53	3.45
Min. Bias Value (ppb)	-2.35	-2.40
Max. Bias Value (ppb)	3.00	21.50
Avg. Error (ppb)	1.34	1.81
St. Deviation Error (ppb)	0.72	2.93
Min. Error Value (ppb)	0.15	0.25
Max. Error Value (ppb)	3.00	21.50

There was only one precision check for both stations that had values outside of what is considered acceptable: a three-point span check on 10/1/2016 at CAMS 38 reported 91.5 ppb at the 70 ppb reference level. The next-highest deviation above the reference point for CAMS 38 was 2.6 ppb, which is largely consistent with the data for CAMS 3. On 10/3/2016, the instrument at CAMS 38 did not pass its SpanZ check either. CAMS 3 had one SpanZ check, on 6/12/2016, that had a 0 ppb check that triggered a warning, reporting a – 8 ppb value.

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 2-18. Summary of Deviations from 70 ppb Calibration Checks at CAPCOG and St. Edwards CAMS in 2016 (ppb)

Month	CAMS 601	CAMS 614	CAMS 684	CAMS 690	CAMS 1603	CAMS 1604	CAMS 1605	CAMS 1675	CAMS 6602
Feb.	1.8	-0.4	1.5	1.5	1.0	5.7	n/a	2.2	1.1
Mar.	1.4	0.9	0.4	0.2	0.1	2.9	-0.3	-0.3	2.7
Apr.	0.0	0.3	0.5	0.9	0.4	1.9	-0.4	1.2	1.0
May	1.7	2.7	1.0	1.2	1.0	1.6	0.1	1.5	1.3
Jun.	2.3	0.9	1.5	1.7	1.1	0.9	n/a	1.6	1.3
Jul.	2.4	1.6	1.9	1.1	1.7	1.9	n/a	1.9	1.6
Aug.	1.6	0.6	2.4	1.1	1.3	0.5	n/a	1.0	1.7
Sep.	2.0	0.2	0.5	1.5	1.5	0.2	n/a	1.9	1.5
Oct.	1.8	1.3	1.2	1.4	1.5	0.6	1.0	2.0	1.3
Nov.	0.8	1.5	0.6	1.0	0.3	-0.1	n/a	0.2	1.2
Avg.	1.6	1.0	1.2	1.2	1.0	1.6	0.1	1.3	1.5
St.Dev.	0.7	0.9	0.7	0.4	0.6	1.7	0.6	0.8	0.5
Min.	0.0	-0.4	0.4	0.2	0.1	-0.1	-0.4	-0.3	1.0
Max.	2.4	2.7	2.4	1.7	1.7	5.7	1.0	2.2	2.7

Since all of CAPCOG's monitoring stations tended to show a slight positive bias in reported O_3 concentrations at the 70 ppb mark, CAPCOG believes that "adjusted" MDA8 values recorded at these stations that used the types of adjustment that are applied to TCEQ's data would result in MDA8 O_3 values about 1.0 – 1.6 ppb higher lower or less than what is recorded in LEADS.

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 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;
- W126 seasonal O_3 exposure estimates.

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

3.1 Earliest and Latest Dates for High O_3 in 2016

One of the key issues for CAPCOG to understand is when 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 O3 value recorded in the region was ≥ 55 ppb
- Days when the highest MDA8 O3 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 and for 2016.

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
Regional Peak ≥ 55 ppb	2/10/2015	11/8/2012	2/11/2016	10/27/2016
Regional Peak > 70 ppb	3/25/2012	10/17/2015	10/3/2016	10/3/2016
CAMS 3 Top 4	4/13/2011	10/24/2014	2/12/2016	10/3/2016
CAMS 3 Top 10	3/13/2013	10/25/2014	2/12/2016	10/3/2016
CAMS 38 Top 4	5/2/2015	10/24/2014	2/12/2016	10/2/2016
CAMS 38 Top 10	3/13/2013	10/26/2014	2/12/2016	10/2/2016

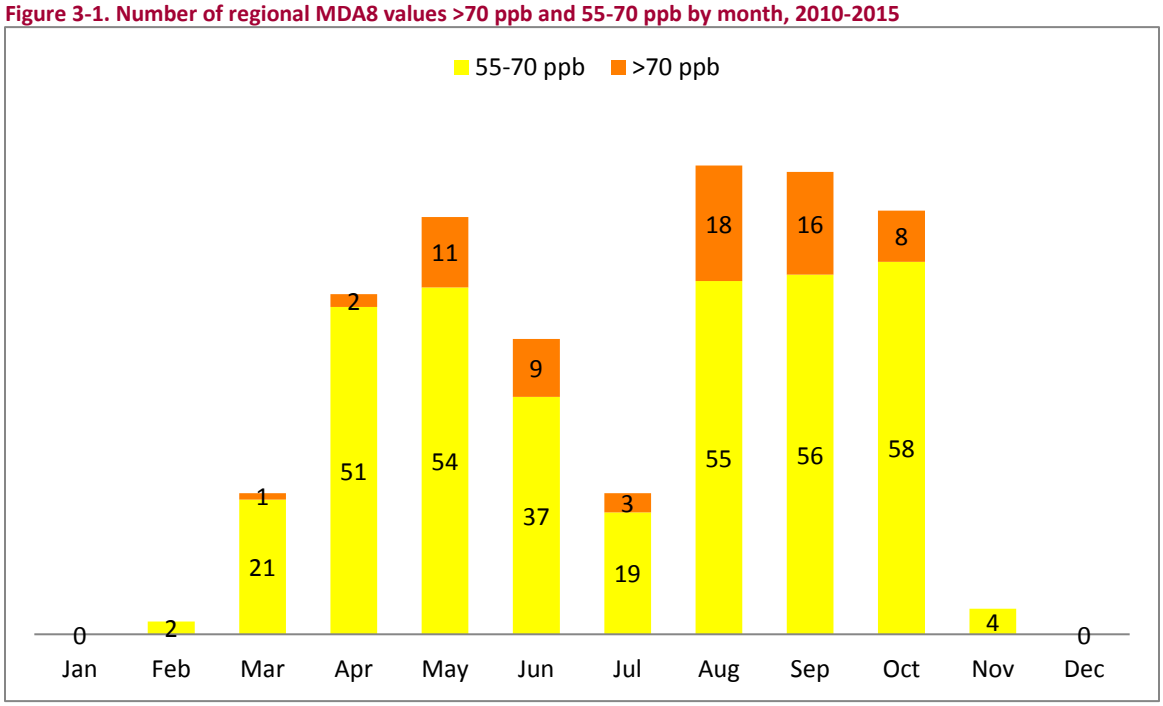
This table shows that MDA8 O_3 values in the region reached "moderate" and "unhealthy for sensitive groups" AQI levels in 2016 within the range of times observed from 2010-2015, although the inclusion of an observed MDA8 O_3 value among the 4-highest MDA8 values for both CAMS 3 and 38 in 2016 is notable, as this is a full 2 months earlier than observed for CAMS 3 from 2010-2015 and nearly three months earlier than observed for CAMS 38 during those six years. It is also earlier than the March 1 start

date for the region's official O_3 monitoring season. This suggests that there may be a need to start monitoring activities earlier in future years. When EPA established the official O_3 monitoring seasons for the 2015 O3 NAAQS, it considered whether there were any MDA8 O_3 values ≥ 60 ppb in that month from 2010-2013 to determine whether to include that month in the official O_3 monitoring season.[3] If EPA were to re-do that analysis and included the 2016 data, it would have included the month of February in the CAPCOG region's official monitoring season. Since TCEQ's monitors operate year-round this is more relevant for public outreach/messaging and CAPCOG's monitoring activities than it is for any formal regulatory purpose. For CAMS 3, it should be noted, there was actually another date with the same MDA8 O_3 value as was observed on 2/12/2016 (10/2/2017 also had an MDA8 O_3 value of 64 ppb). However, even if the 2/12/2016 was excluded from the analysis for CAMS 3 above, the earliest date for an observed MDA8 O_3 value that was among CAMS 3's top 4 would be 3/13/2016.

3.2 High O_3 Days by Month

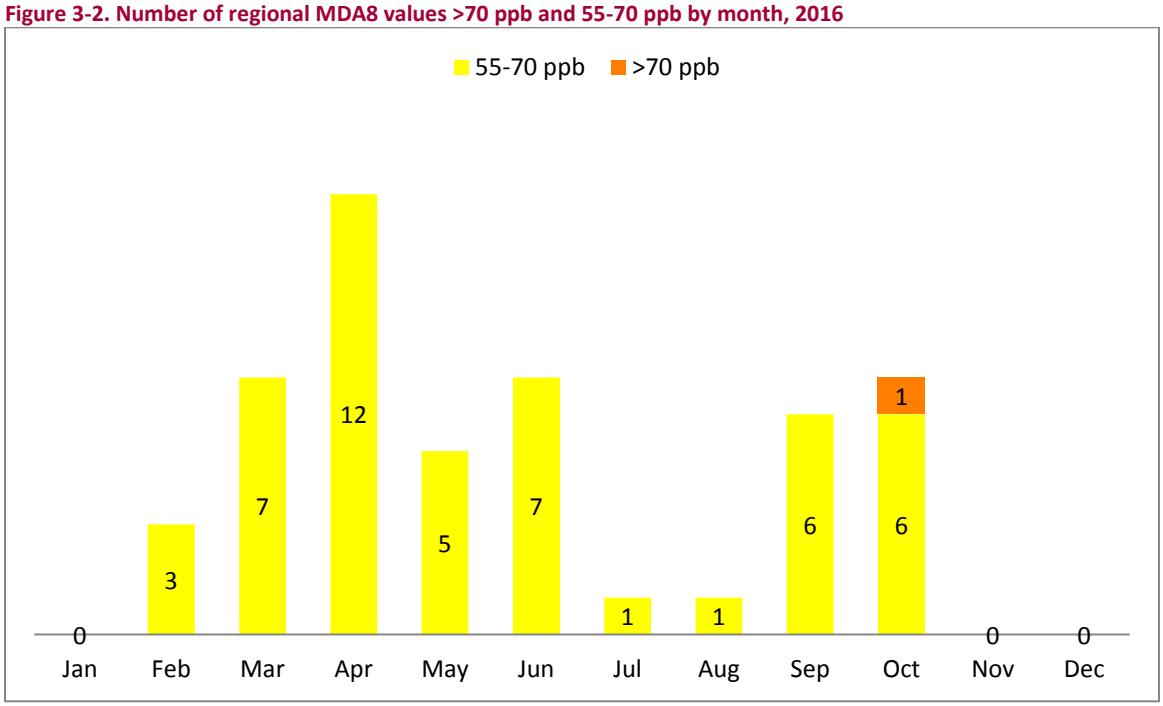
The following tables shows the number of days when MDA8 values were 55-70 ppb and >70 ppb by month between 2010 and 2015 and in 2016.

Figure 3-1. Number of regional MDA8 values >70 ppb and 55-70 ppb by month, 2010-2015



[3] Rice, Joann. *Ozone Monitoring Season Analysis: Memorandum to the Ozone NAAQS Review Docket, EPA-HQ-OAR-2008-0699*. U.S. Environmental Protection Agency, November 19, 2014. Available online at: https://www.regulations.gov/document?D=EPA-HQ-OAR-2008-0699-0383.

Figure 3-2. Number of regional MDA8 values >70 ppb and 55-70 ppb by month, 2016



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 was highly unusual for there to be three such days in 2016. Similarly, while there had been an average of 12 days a year when O_3 levels were 55 ppb or greater in August between 2010-2015, there was only one in 2016. For a significance level of 0.05, the critical chi-squared value is 3.841. As the table below shows, this value was exceeded for February and August when comparing 2016 data to 2010-2015 data, as well as for 2010-2012 and 2013-2015 data. In addition to February and August, 2016 frequencies were also statistically significantly different from 2010-2012 data in March (statistically significantly higher in 2016) and September (statistically significantly lower in 2016), and were also statistically significantly different from 2013-2015 data for April (significantly higher in 2016).

Table 3-2. Chi-squared values for comparison of 2016 monthly frequency of MDA8 values ≥ 55 ppb to 2010-2015

Month	Chi-Squared Value for 2010-2012 Comparison	Chi-Squared Value for 2013-2015 Comparison	Chi-Squared Value for 2010-2015 Comparison
January	n/a	n/a	n/a
February	***21.285***	***21.260***	***21.273***
March	***4.013***	2.227	3.008
April	0.087	4.226	1.118
May	3.827	2.521	3.160
June	0.326	0.062	0.061
July	1.338	2.893	1.947
August	***10.769***	***10.116***	***10.276***
September	***4.867***	1.836	3.021
October	2.322	1.091	1.470
November	1.336	n/a	0.668
December	n/a	n/a	n/a
TOTAL	**50.168**	**46.232**	**24.730**

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 at any of the sites in the region, region-wide, or MSA-wide. 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. At a significance level of 0.10, MDA8 values >70 ppb were also statistically significantly less likely region-wide and MSA-wide on Sundays, while they were statistically significantly more likely to occur on Saturdays at CAMS 601.

Figure 3-3. Distribution of high O_3 by day of the week, 2010 - 2015

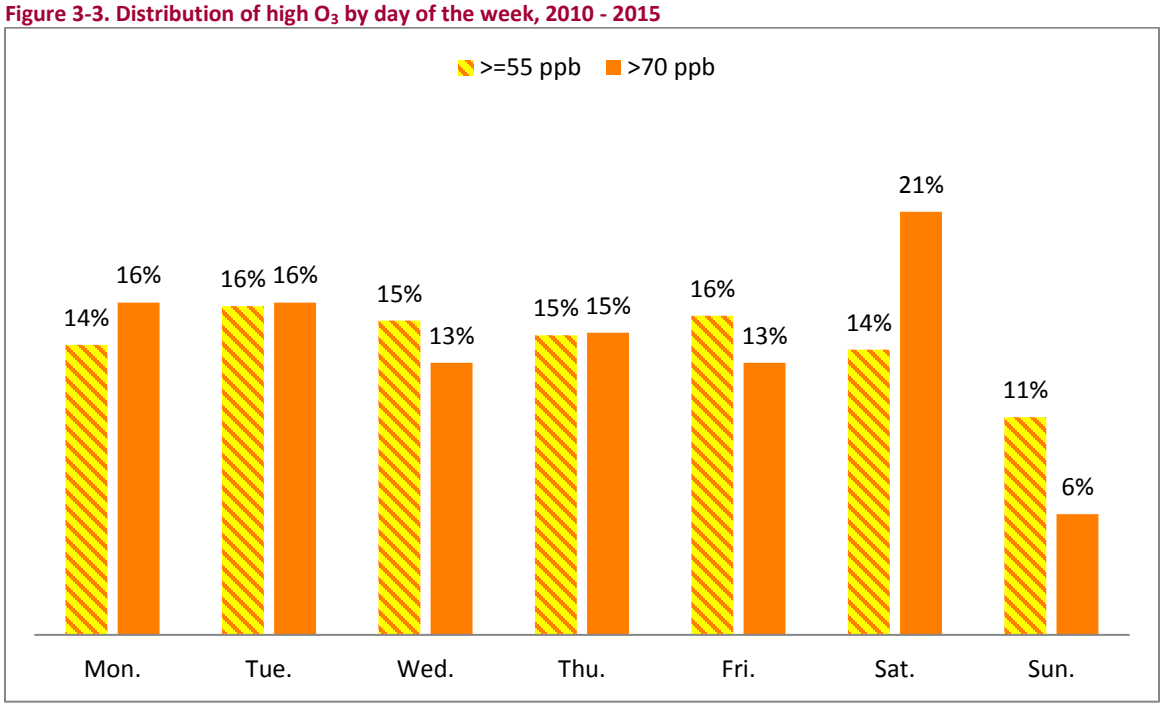
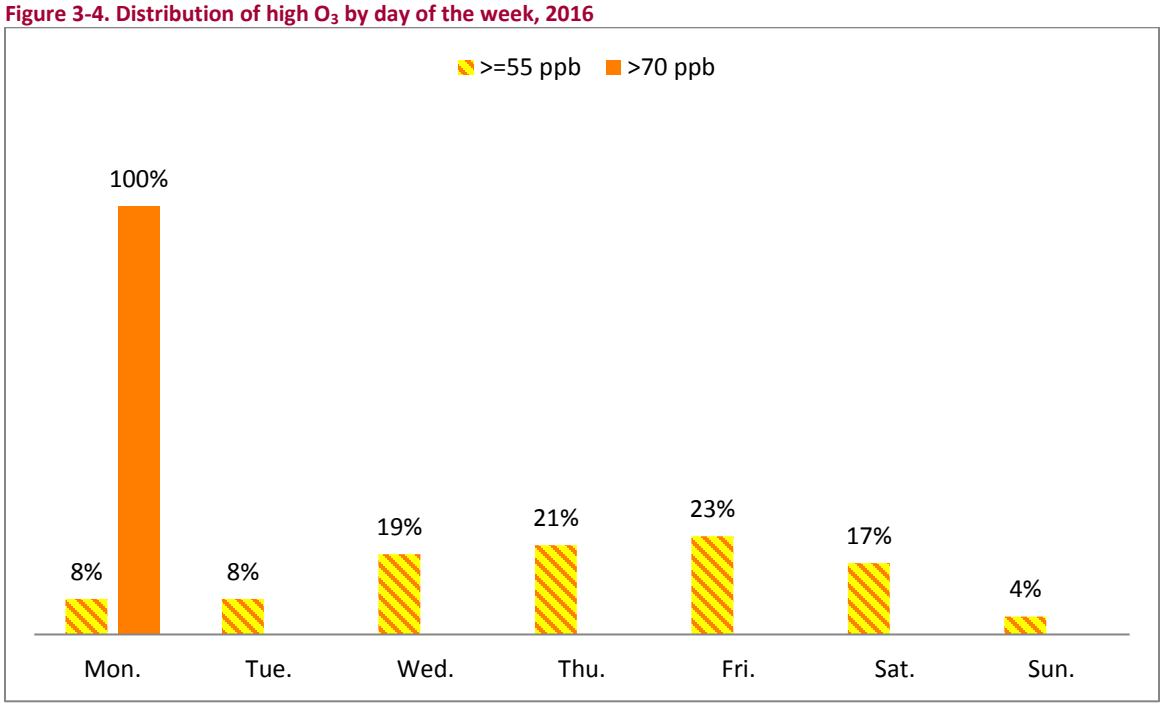


Figure 3-4. Distribution of high O_3 by day of the week, 2016

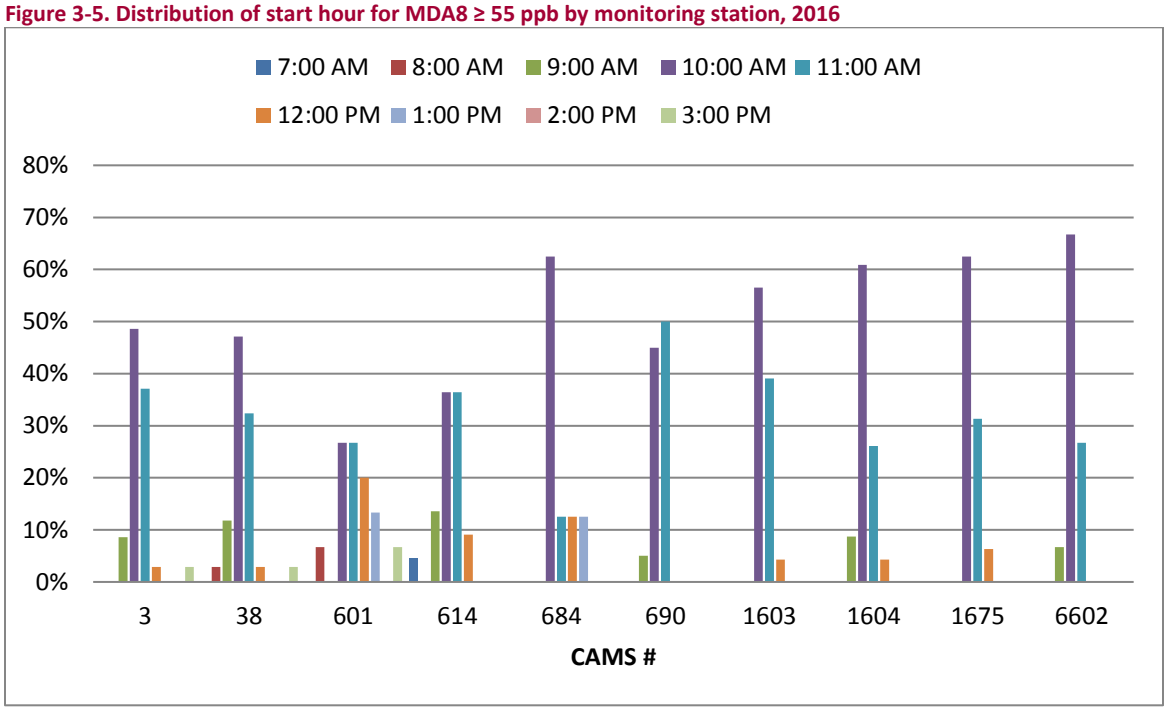


Since there was only one day in 2016 with MDA8 O_3 level above 70 ppb, CAPCOG only performed statistical analyses based on days with MDA8 O_3 ≥55 ppb. There were not statistically significant differences between the 2016 day-of-week distribution and the 2010-2015 distributions at either the 0.05 or 0.10 levels at any of the monitoring stations, region-wide, or MSA-wide.

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 2016. As the figure shows, 10 am and 11 am were the most common start hour for MDA8 O_3 values ≥ 55 ppb (these were the start hours for 53% - 96% of these MDA8 O_3 values, depending on the monitoring station), and started as early as 7 am and as late as 3 pm.

Figure 3-5. Distribution of start hour for MDA8 ≥ 55 ppb by monitoring station, 2016



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

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

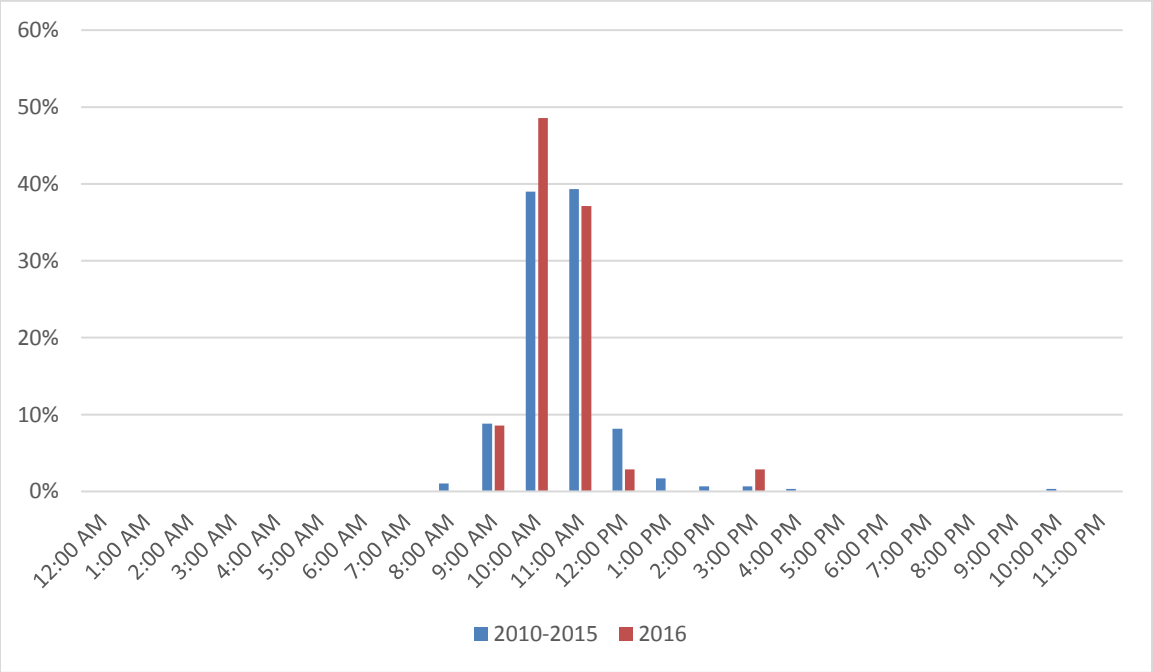


Figure 3-7. Start hour for MDA8 O_3 ≥55 ppb at CAMS 38, 2010-2015 and 2016

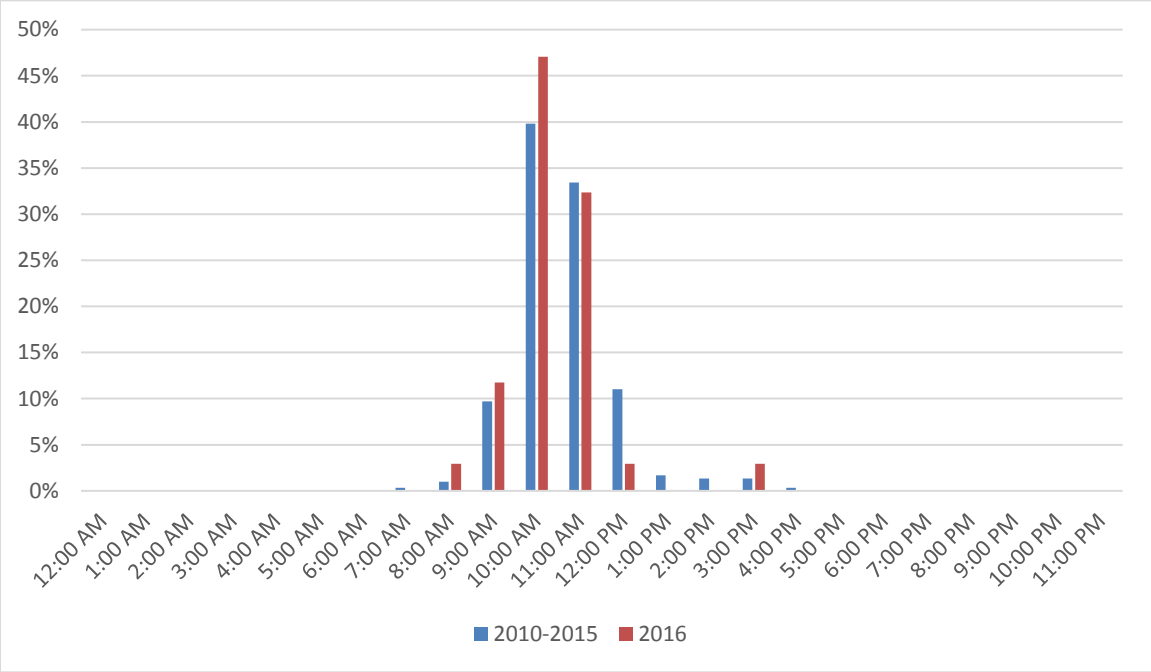


Figure 3-8. Start hour for MDA8 O_3 ≥55 ppb at CAMS 601, 2010-2015 and 2016

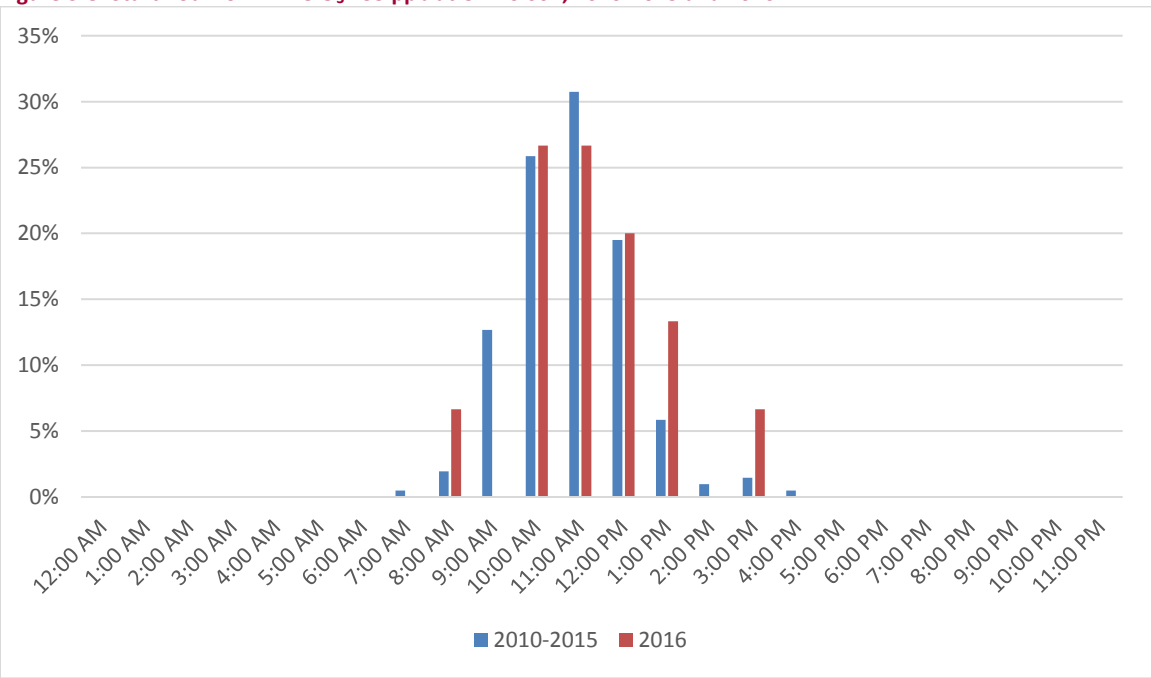


Figure 3-9. Start hour for MDA8 O_3 ≥55 ppb at CAMS 614, 2010-2015 and 2016

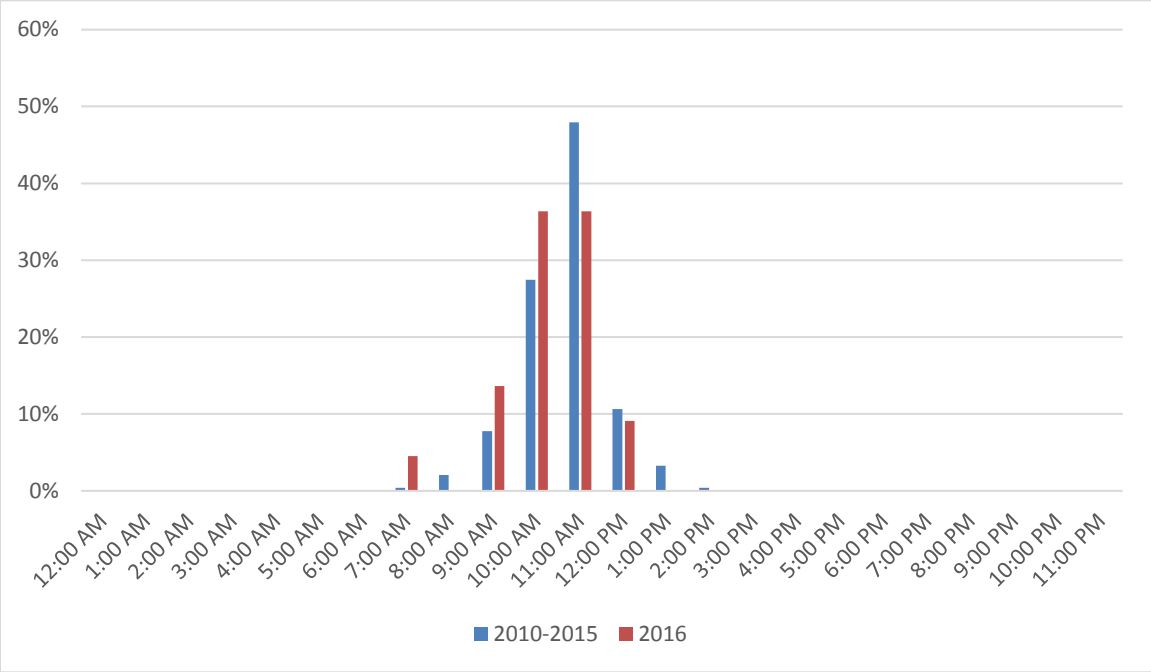


Figure 3-10. Start hour for MDA8 O_3 ≥55 ppb at CAMS 684, 2010-2015 and 2016

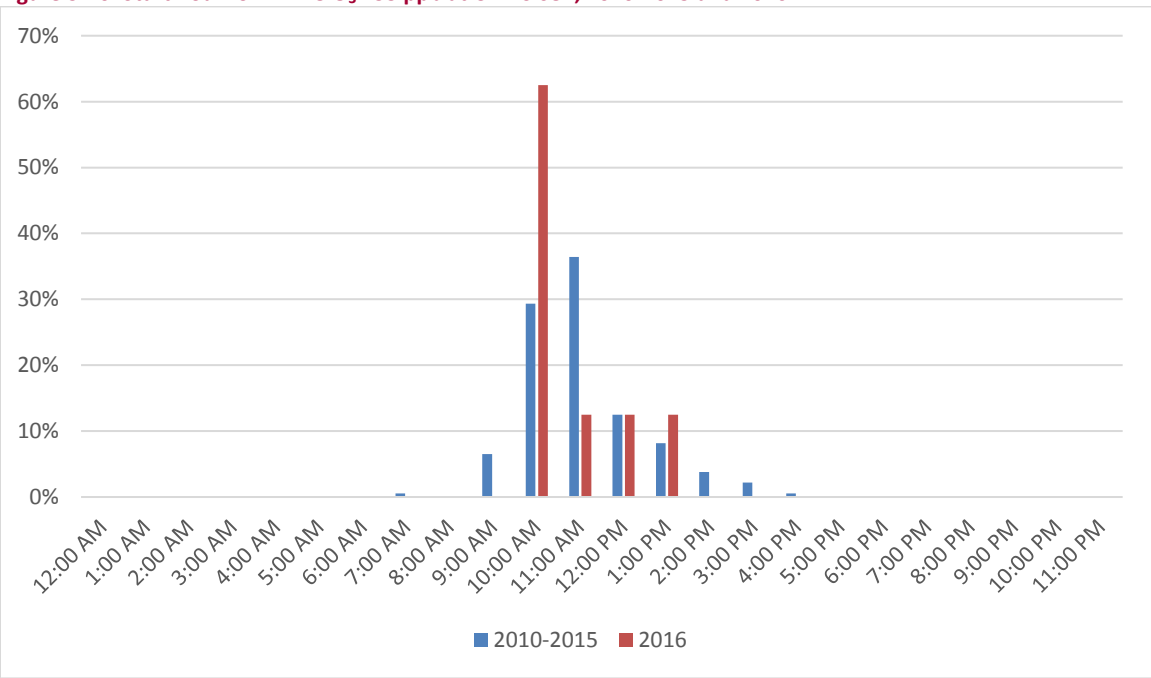


Figure 3-11. Start hour for MDA8 O_3 ≥55 ppb at CAMS 690, 2010-2015 and 2016

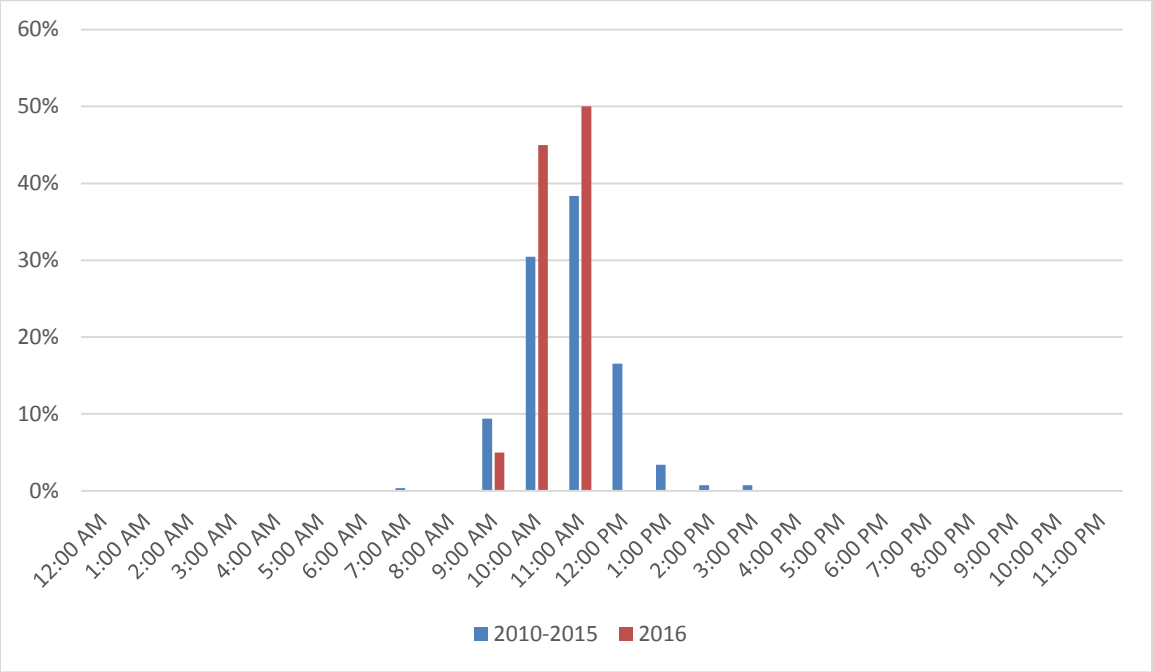


Figure 3-12. Start hour for MDA8 O_3 ≥55 ppb at CAMS 1603, 2010-2015 and 2016

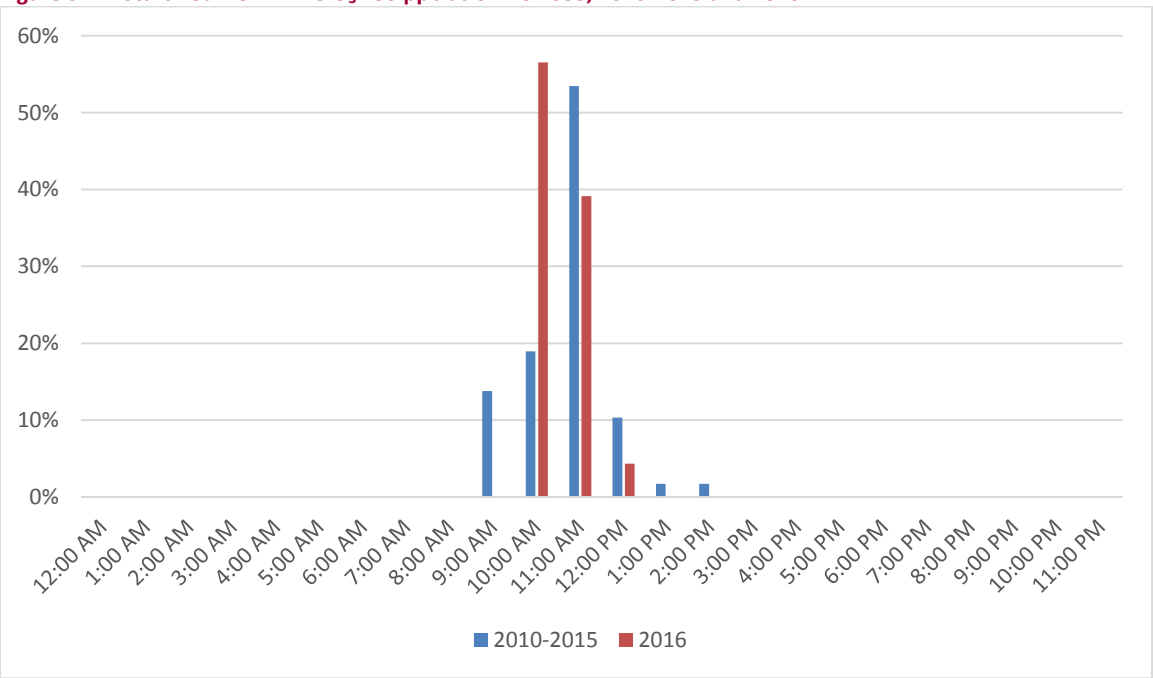


Figure 3-13. Start hour for MDA8 O_3 ≥55 ppb at CAMS 1604, 2010-2015 and 2016

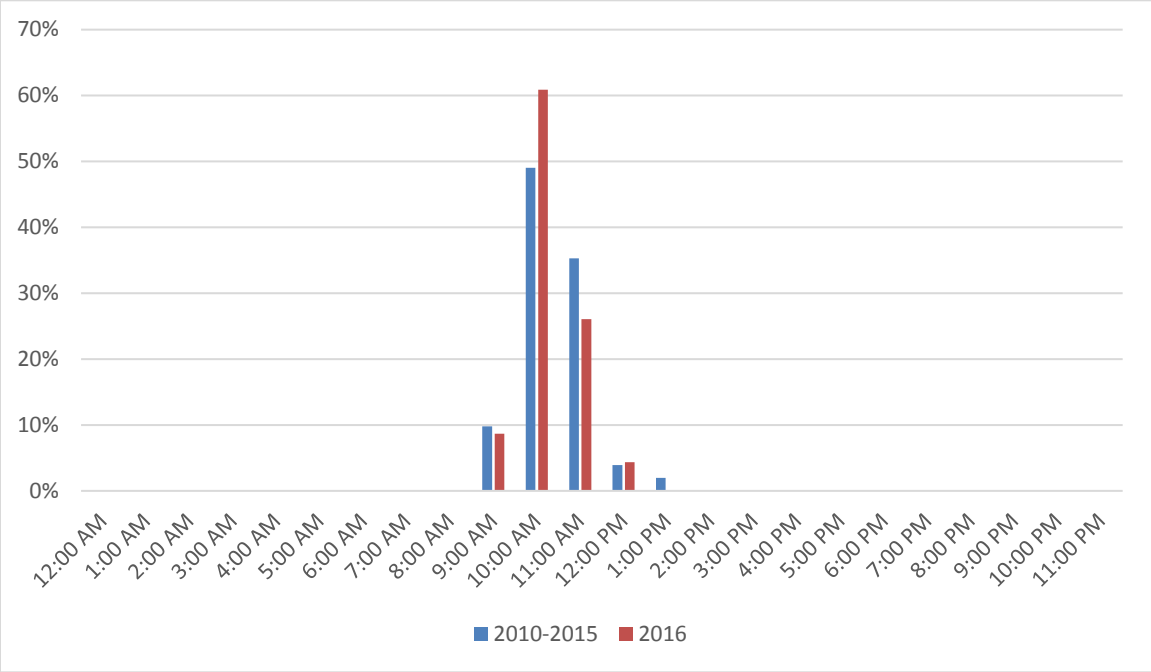


Figure 3-14. Start hour for MDA8 O_3 ≥55 ppb at CAMS 1675, 2010-2015 and 2016

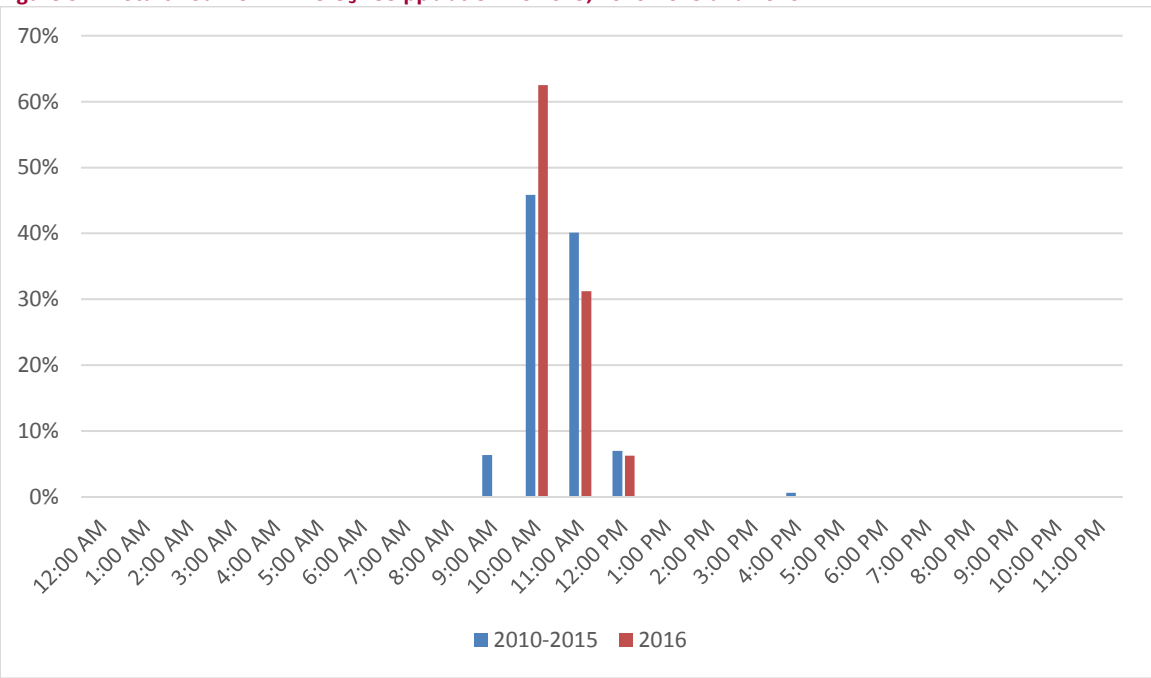
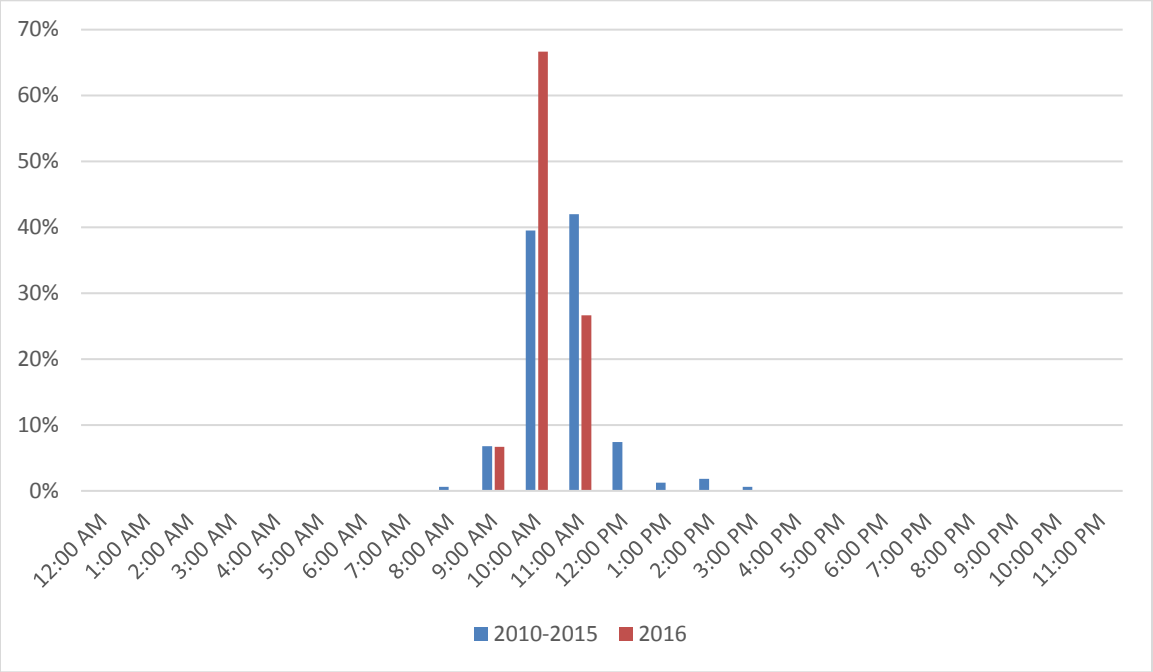


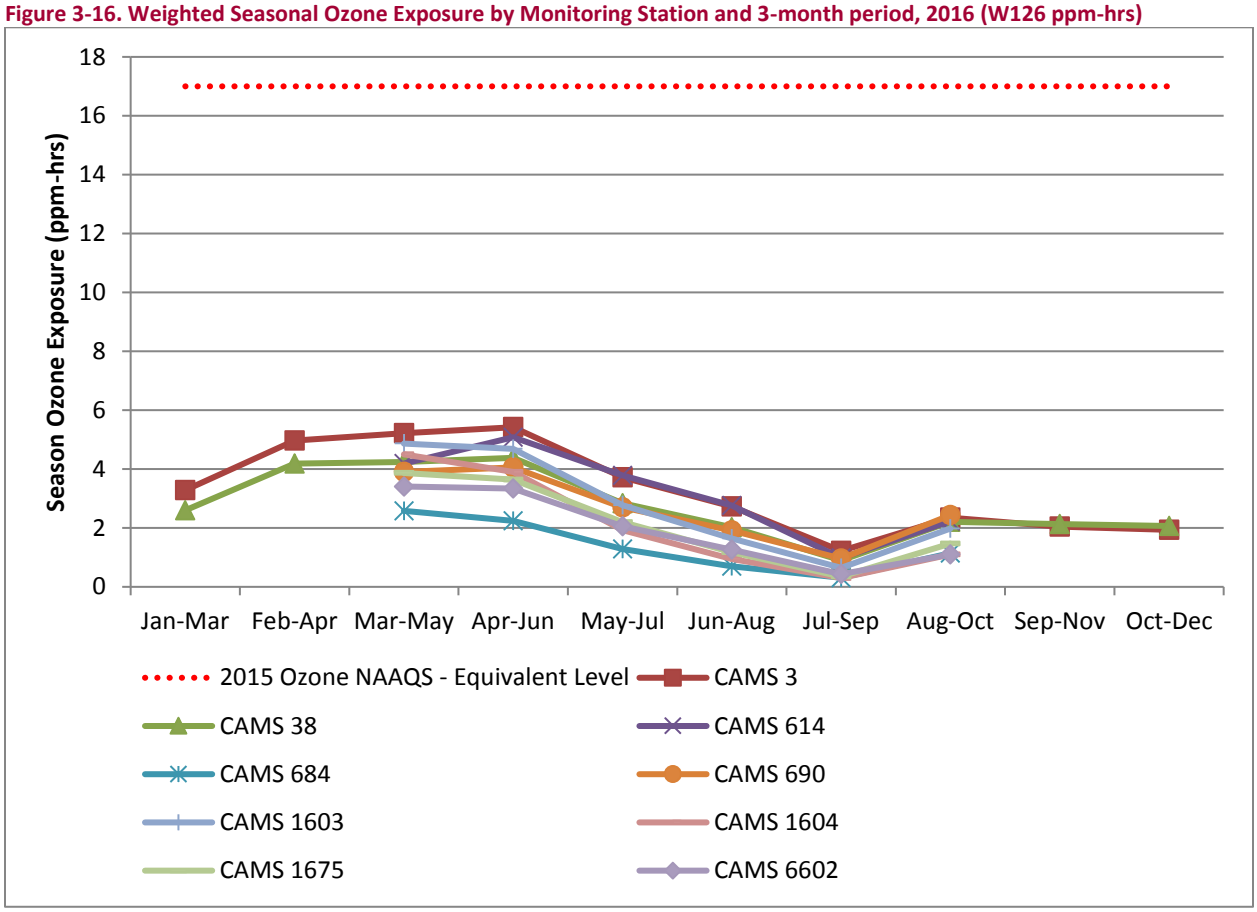
Figure 3-15. Start hour for MDA8 O_3 ≥55 ppb at CAMS 6602, 2010-2015 and 2016



3.5 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 68-85% below the 17 ppm-hr 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 3-16. Weighted Seasonal Ozone Exposure by Monitoring Station and 3-month period, 2016 (W126 ppm-hrs)



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
- Resultant Wind direction (WD) from 8 am – 12 pm and 12 pm – 4 pm.

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.

For resultant WD, CAPCOG used the 1-hour resultant WS and WD data in order to calculate 4-hour WS and WD vectors and assigned them to compass directions as shown in the following table.

Table 4-1. Wind direction definitions

WD	Abbreviation	Assigned Values (degrees)
North	N	348.75 ≥ x ≥ 360 and 0 ≥ x > 11.25
North-Northeast	NNE	11.25 ≥ x > 33.75
Northeast	NE	33.75 ≥ x > 56.25
East-Northeast	ENE	56.25 ≥ x > 78.75
East	E	78.75 ≥ x > 101.25
East-Southeast	ESE	101.25 ≥ x > 123.75
Southeast	SE	123.75 ≥ x > 146.25
South-Southeast	SSE	146.25 ≥ x > 168.75
South	S	168.75 ≥ x > 191.25
South-Southwest	SSW	191.25 ≥ x > 213.75
Southwest	SW	213.75 ≥ x > 236.25
West-Southwest	SSW	236.25 ≥ x > 258.75
West	W	258.75 ≥ x > 281.25
West-Northwest	WNW	281.25 ≥ x > 303.75
Northwest	NW	303.75 ≥ x > 326.25
North-Northwest	NNW	326.25 ≥ x > 348.75

In CAPCOG's most recent conceptual model, CAPCOG used groupings of >70 ppb, 55-70 ppb, and <55 ppb. Since there was only one MDA8 O_3 value of >70 ppb at one monitoring station in 2016, CAPCOG instead used a threshold of ≥ 55 ppb for many of the analyses in this section. 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
- solar radiation data at CAMS 38

4.1 Wind Speed

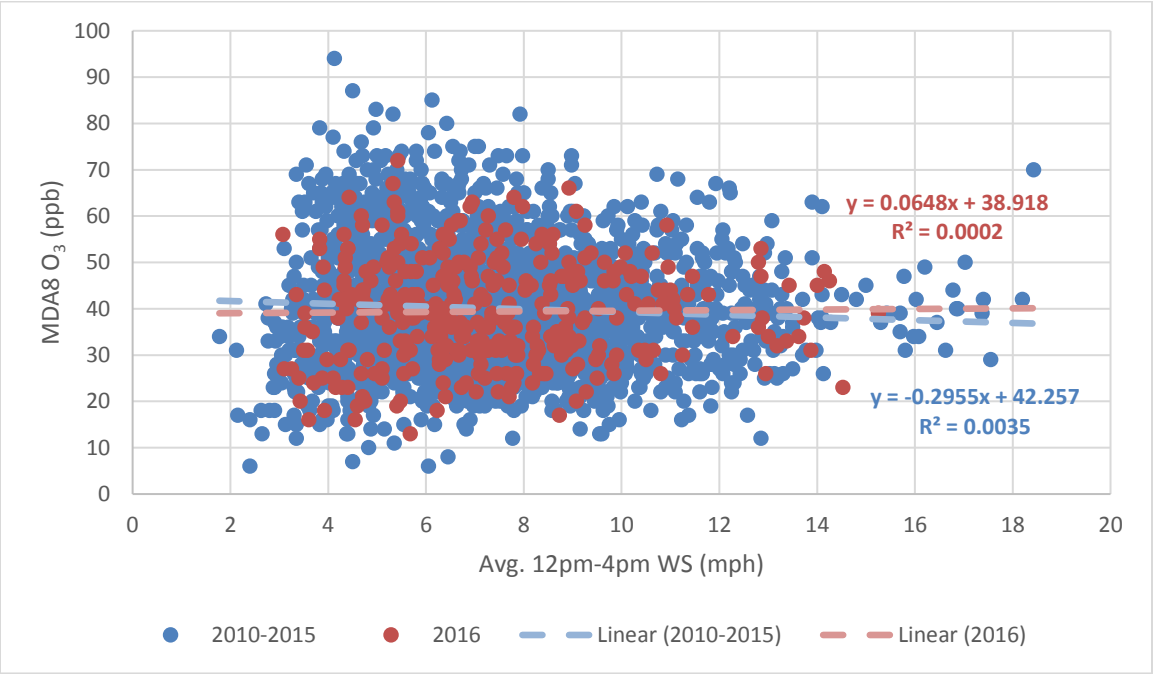
CAPCOG's most recent O_3 conceptual model showed that average wind speeds between 12 pm-4 pm had a statistically significant negative correlation with MDA8 O_3. In CAPCOG's 2010-2015 Conceptual Model, CAPCOG analyzed the data for 12-4 pm in order to limit the analysis to just the hours that typically 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 2016 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 2016 to 2010-2015

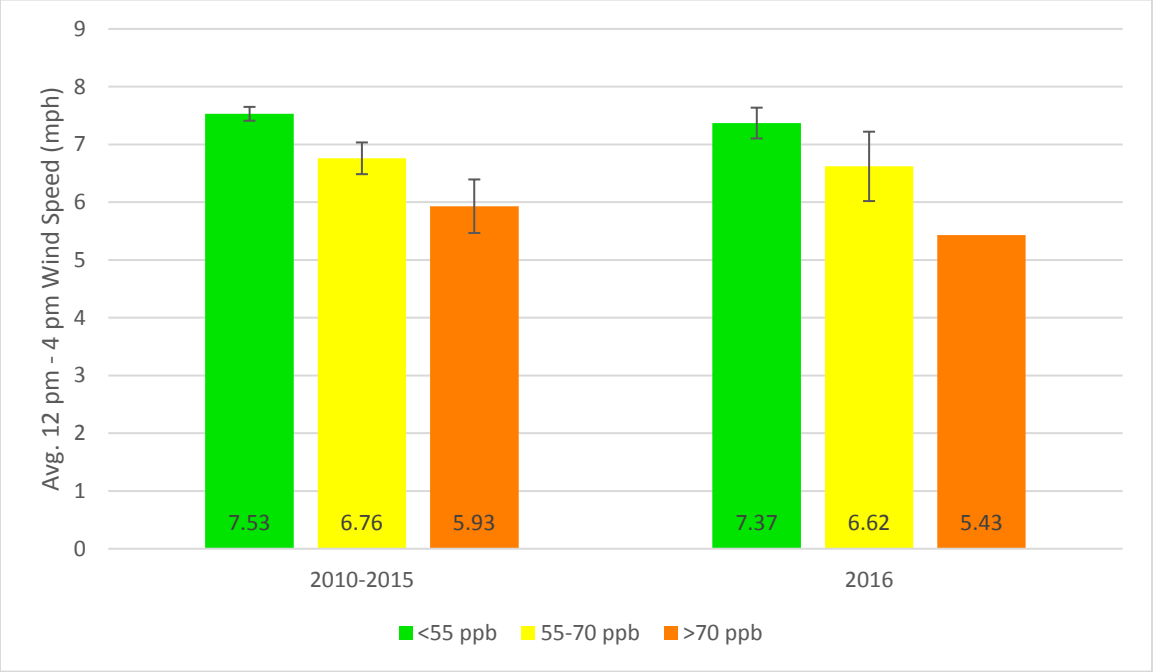
The figure below a scatter plot of MDA8 O_3 values compared to average wind speed between 12 pm and 4pm at CAMS 3 for 2010-2015 and 2016. The very small R^2 value for the data suggests that this is not a very good predictor for MDA8 O_3 values, however. There was a slightly negative correlation for the 2010-2015 data and a slightly positive correlation for the 2016 data, but both sets of data 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 and 2016



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 2016 compared to 2010-2015.

Figure 4-2. 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 and 2016

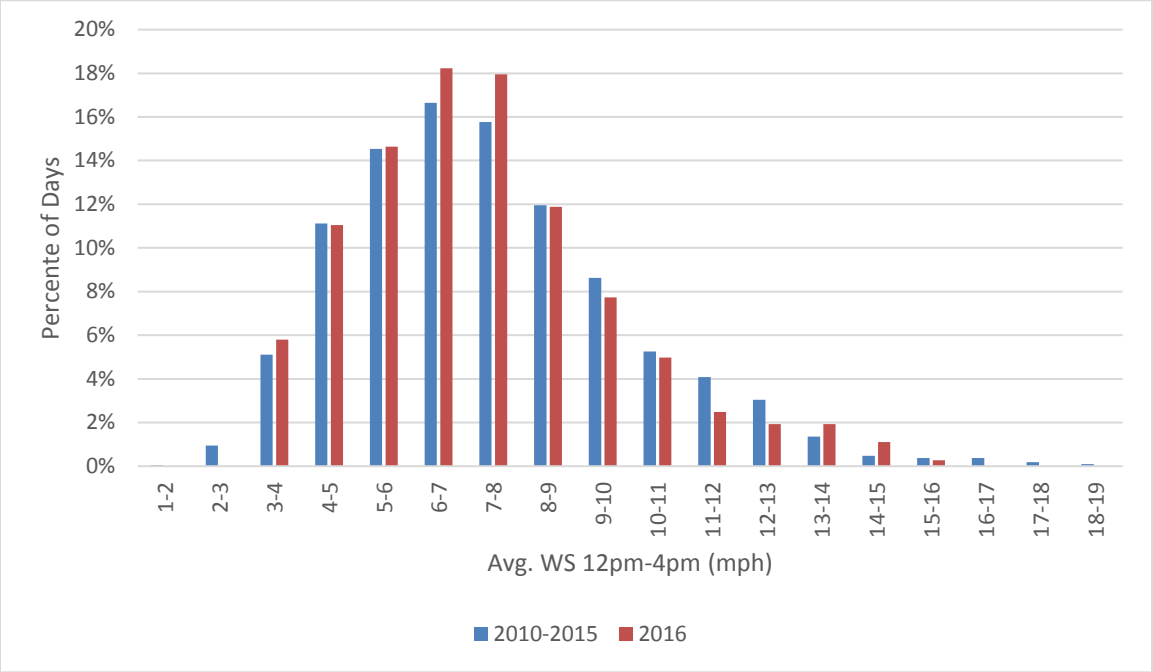


Typical 12 pm – 4 pm wind speeds were statistically significantly lower in 2016 for the <55 ppb range at a 0.05 significance level, and the single MDA8 O_3 value >70 ppb was below the lower end of the 95% confidence interval for the typical >70 ppb wind speed for 2010-2015. However, average wind speeds for days 55-70 ppb in 2016 were not statistically significantly different from wind speeds 2010-2015 at a 0.05 significance level. As the graph shows, there were still clear statistical differences between the wind speeds typical for <55 ppb days and 55-70 ppb days in 2016, consistent with what the 2010-2015 data showed.

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

Based on CAPCOG's review of wind speed data at CAMS 3 from 2010-2015 and 2016, CAPCOG was able to determine that there was not statistically different average 12 pm – 4pm wind speeds in 2016 compared to 2010-2015 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.

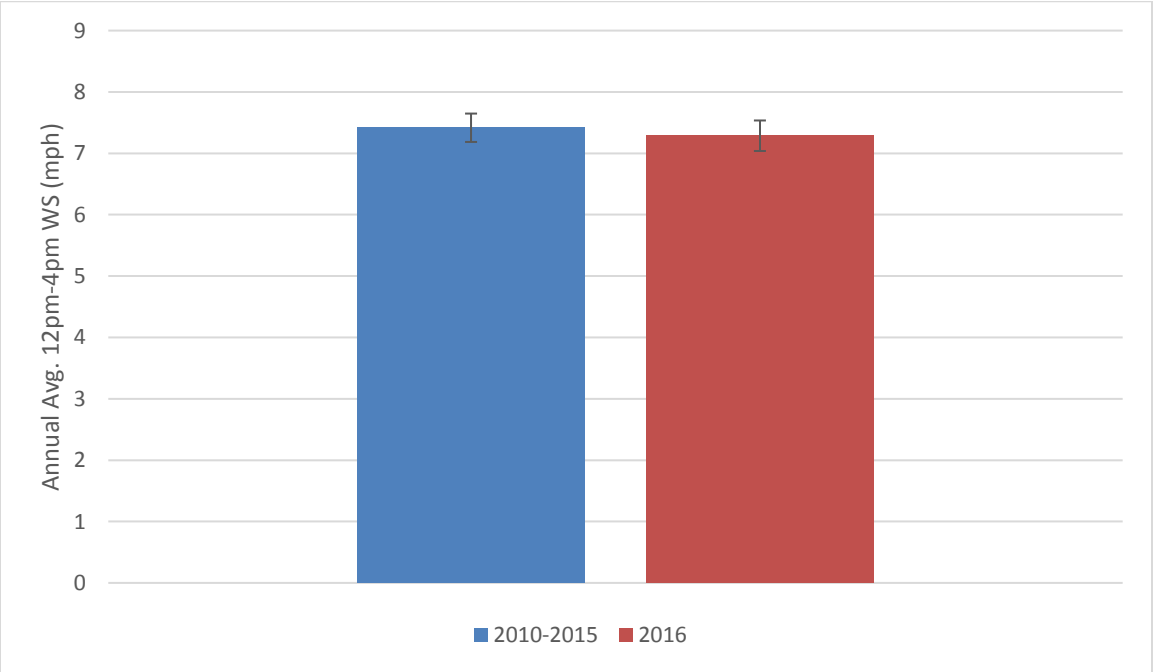
Figure 4-3. Histogram of 12 pm – 4 pm Wind Speeds at CAMS 3, 2010-2015 and 2016



CAPCOG performed a chi-squared test of independence on 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 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 4-4. Annual Avg. 12 pm-4 pm Wind Speed at CAMS 3, 2010-2015 and 2016



As the figure above shows, the annual average 12 pm-4 pm wind speed in 2016 was 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

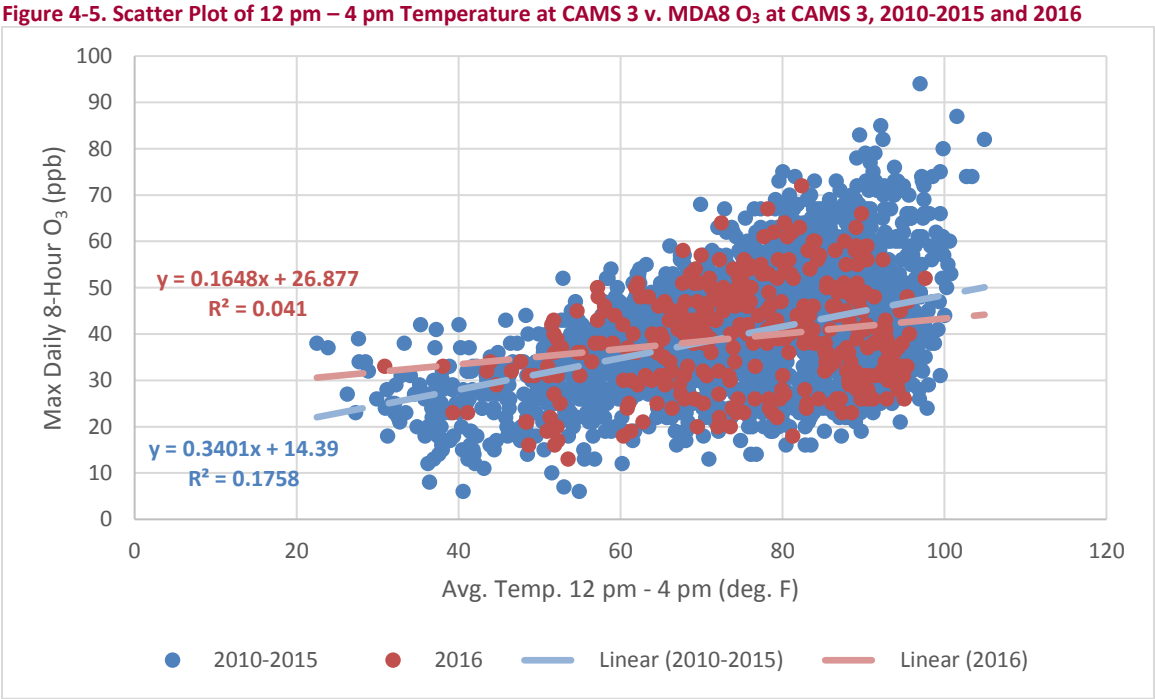
CAPCOG's most recent O_3 conceptual model showed that average temperatures between 12 pm-4 pm had a statistically significantly positive correlation with MDA8 O_3. In CAPCOG's 2010-2015 Conceptual Model, CAPCOG analyzed the data for 12-4 pm in order to limit the analysis to just the hours that typically 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/degree F at CAMS 3 and +0.19 ppb/degree F at CAMS 38.

Given this relationship, CAPCOG conducted a variety of statistical analyses to evaluate whether 2016 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 2016 to 2010-2015

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

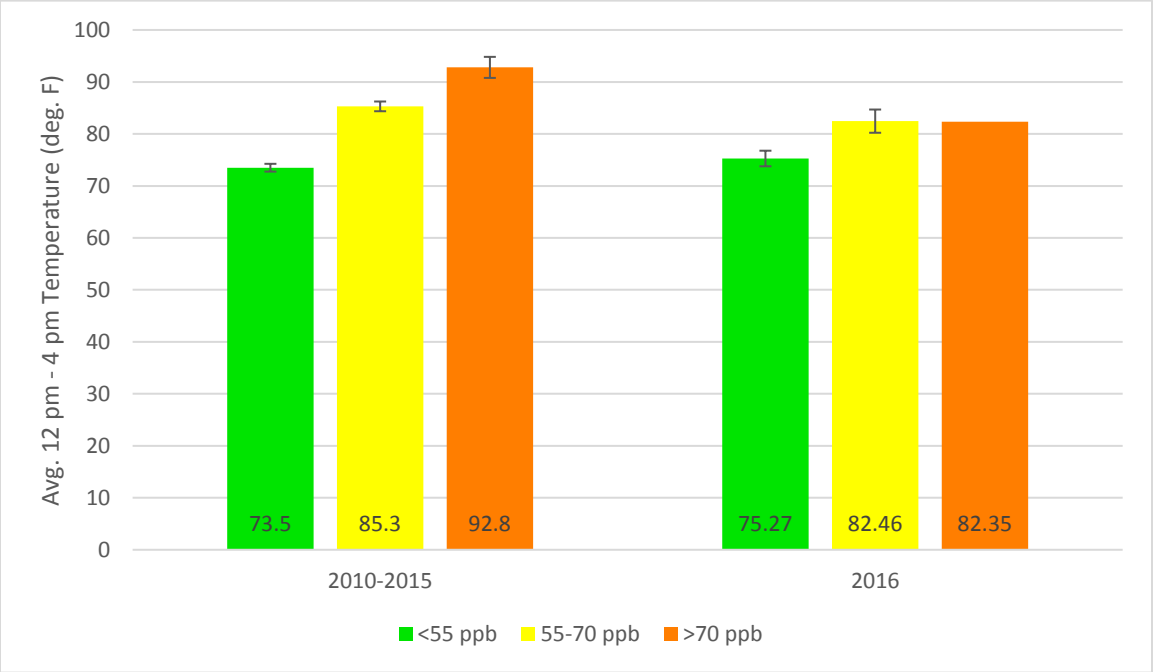
Figure 4-5. Scatter Plot of 12 pm – 4 pm Temperature at CAMS 3 v. MDA8 O_3 at CAMS 3, 2010-2015 and 2016



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 2016 relative to 2010-2015. The temperatures typical for days with

MDA8 O_3 days < 55 ppb in 2016 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 2016 were statistically significantly lower than what was typical for 2010-2015. However, the 2016 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.

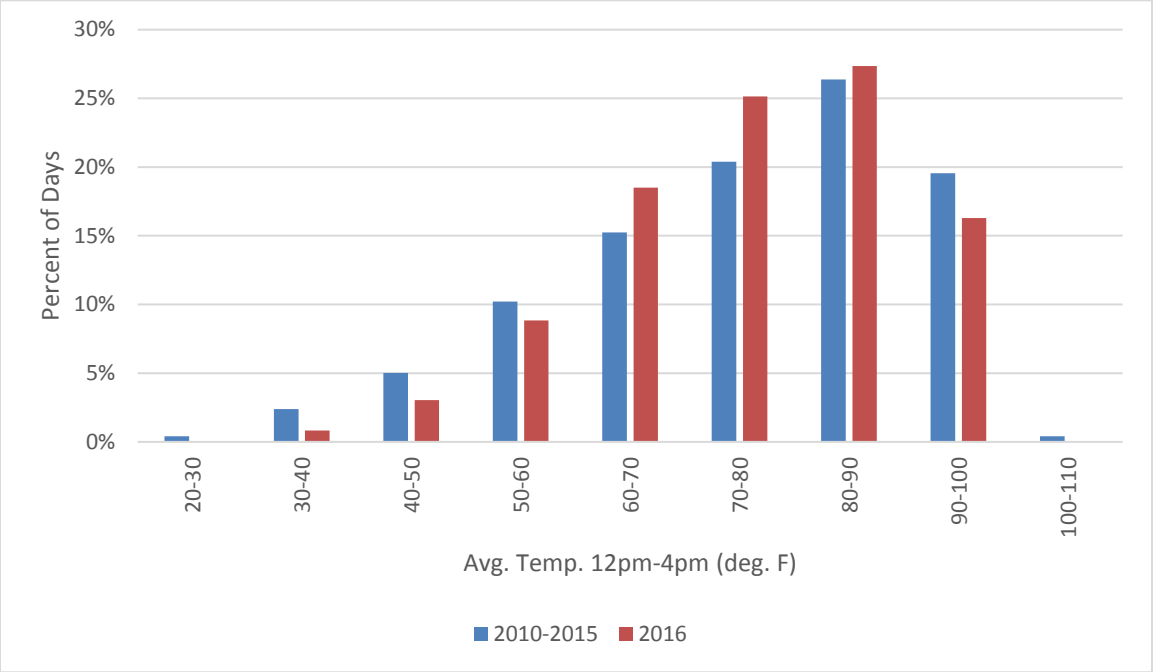
Figure 4-6. Typical Temperature 12 pm – 4pm at CAMS 3 on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 3, 2010-2015 and 2016



4.2.2 Comparison of 2016 Temperatures to 2010-2015 Temperatures

Based on CAPCOG's review of the meteorological data in 2010-2015 and in 2016, CAPCOG was able to determine that there was statistically significant difference in 12 pm – 4 pm temperatures in 2016 compared to 2010-2015. The figure below shows a histogram of the distribution of daily average wind temperatures between 12 pm and 4 pm at CAMS 3.

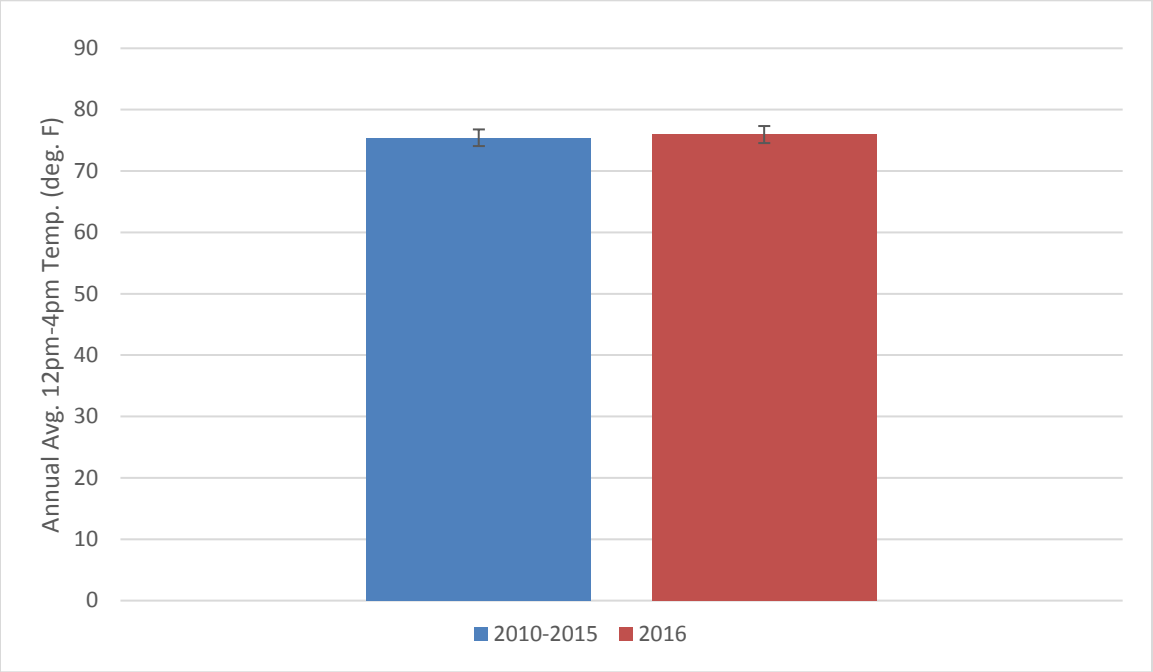
Figure 4-7. Histogram of 12 pm – 4 pm Temperatures at CAMS 3, 2010-2015 and 2016



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 degree F bins was statistically significantly different from the distribution in 2010-2015. CAPCOG found that there was a statistically significant difference in the distribution using this test at a 0.05 significance level.

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

Figure 4-8. Annual Avg. 12 pm-4 pm Temperature at CAMS 3, 2010-2015 and 2016



The figure above shows, the annual average 12pm-4pm temperature in 2016 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 2016 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

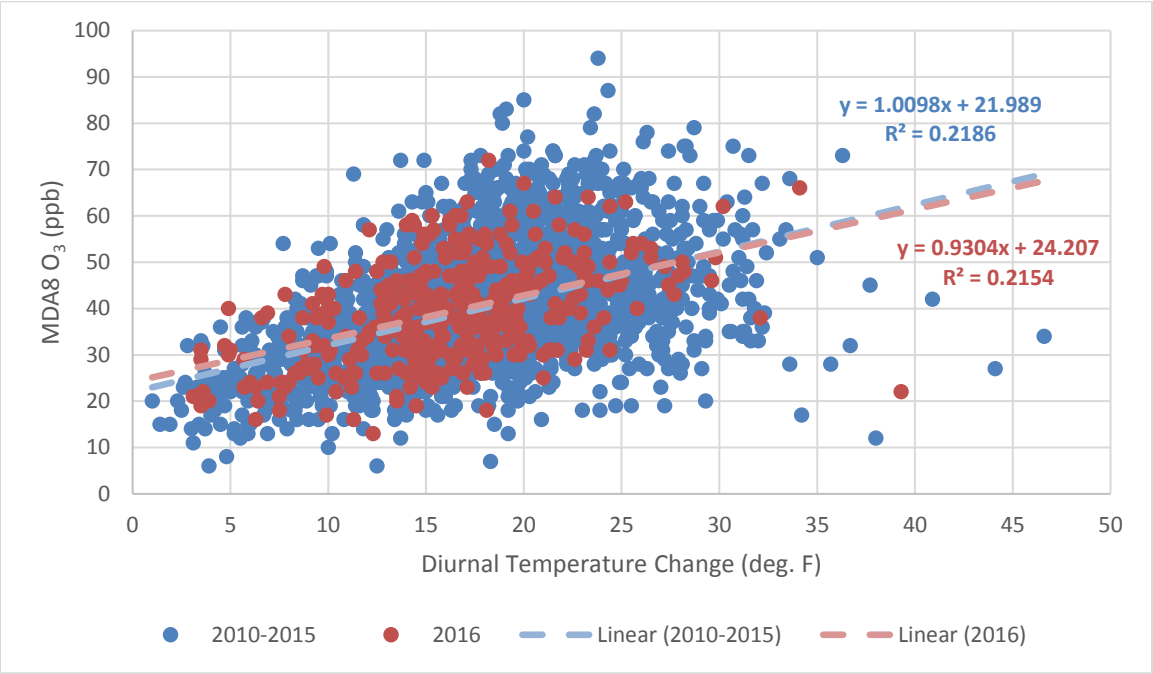
CAPCOG's most recent O_3 conceptual model showed that diurnal temperature change had a statistically significantly positive correlation with MDA8 O_3. In CAPCOG's 2010-2015 Conceptual Model, CAPCOG analyzed the data only for days when hourly averages were available for all 24 hours of the day in order 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 2016 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 2016 to 2010-2015

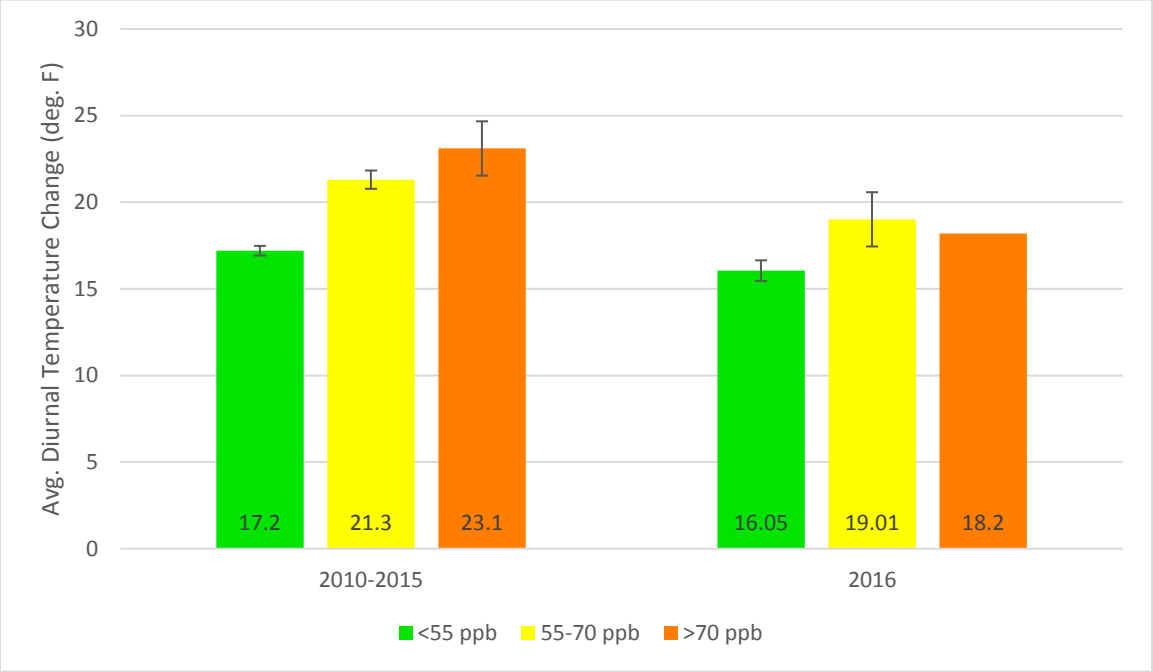
The figure below shows a scatter plot with MDA8 values and diurnal temperature changes at CAMS 3 for 2016 and 2010-2015. As the figure shows, the 2016 data was consistent in showing a positive correlation between these two factors. Notably, the trend line for this factor has a substantially larger R^2 value for both periods than the R^2 value of the trend lines for the average temperature scatter plot, indicating that it is a better predictor of MDA8 O_3 values.

Figure 4-9. Scatter Plot of Diurnal Temperature Change at CAMS 3 v. MDA8 O_3 at CAMS 3, 2010-2015 and 2016



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 temperatures 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 2016 data did continue to show statistically significant differences between temperature changes for days with MDA8 O_3 <55 ppb and days with MDA8 O_3 of 55-70 ppb.

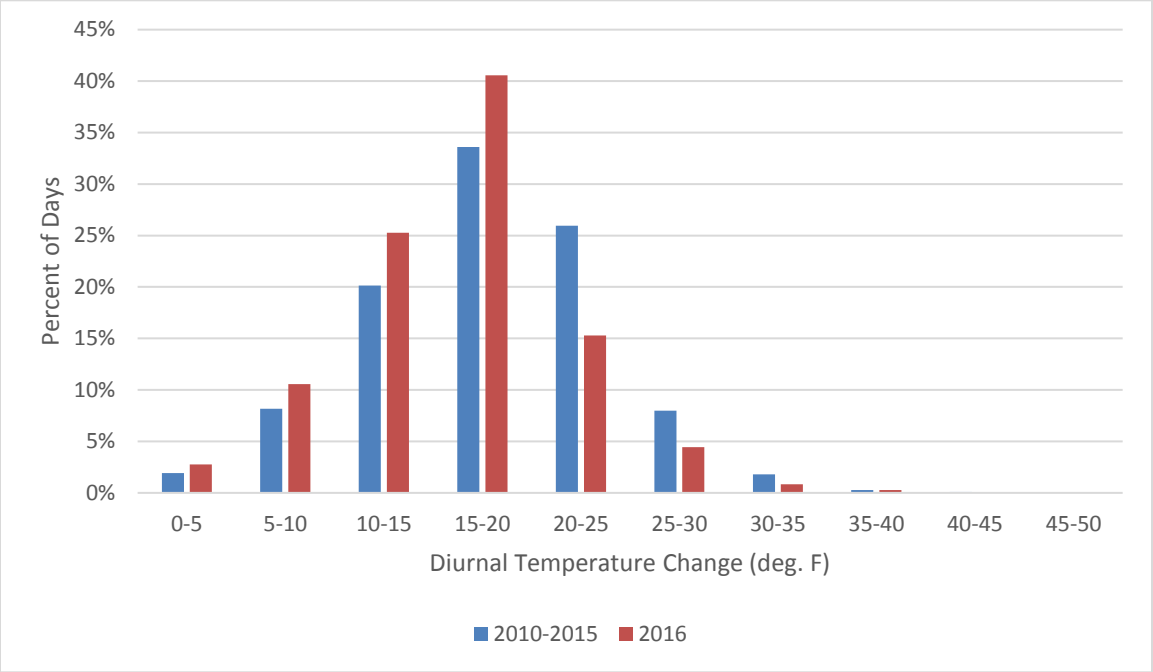
Figure 4-10. Figure 5 10. Typical Diurnal Temperature Change at CAMS 3 on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 3, 2010-2015 and 2016



4.3.2 Comparison of 2016 Diurnal Temperature Changes to 2010-2015 Diurnal Temperature Changes

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

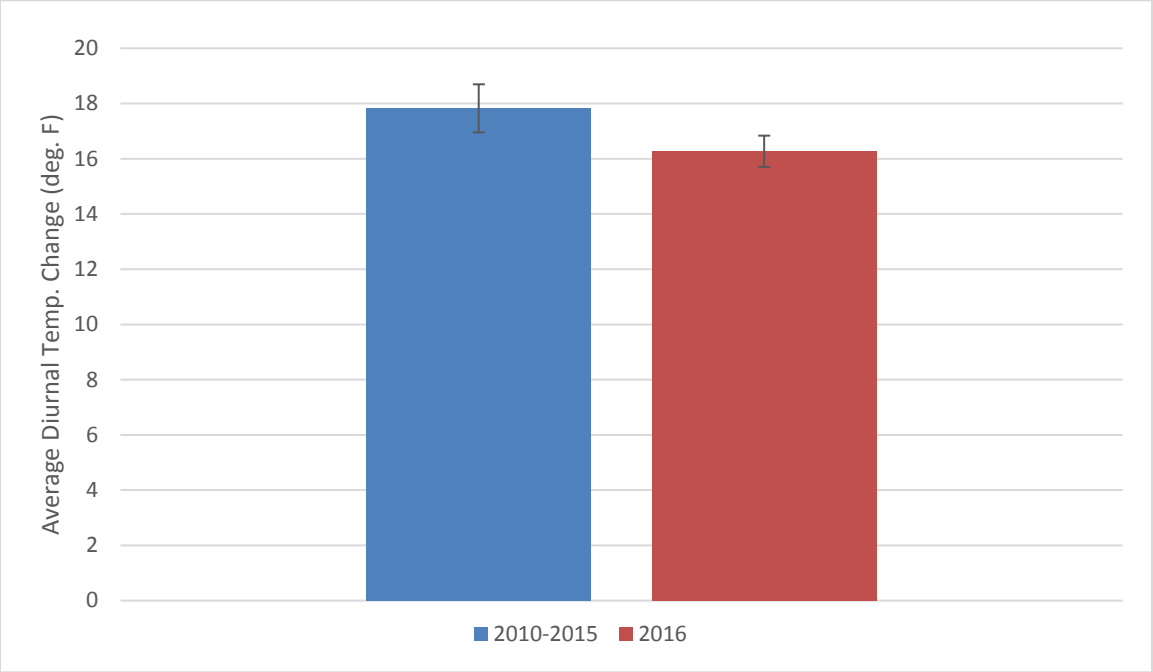
Figure 4-11. Histogram of Diurnal Temperature Changes at CAMS 3, 2010-2015 and 2016



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 data at a 0.05 significance level.

CAPCOG also performed a confidence interval analysis of the average annual daily diurnal temperature change. The average 16.27 degrees F diurnal change in 2016 was below the lower bound of the confidence interval for the 2010-2015 average.

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



4.4 Relative Humidity

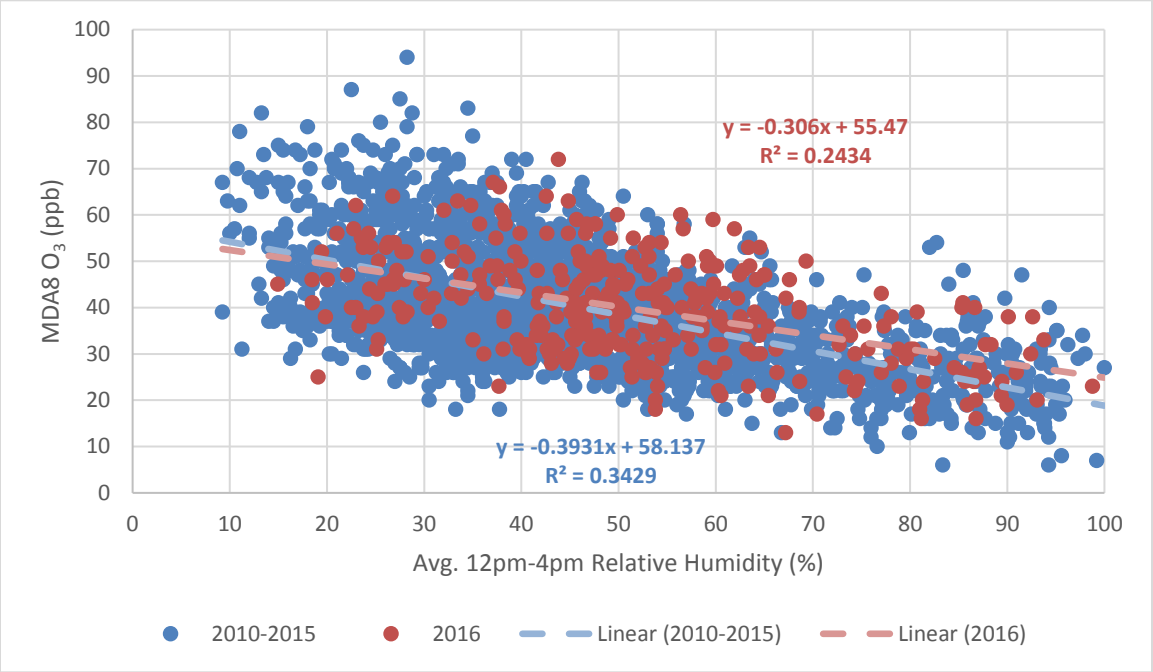
CAPCOG's most recent O_3 conceptual model showed that average relative humidity between 12 pm and 4 pm had a statistically significantly negative correlation with MDA8 O_3. The regression analyses CAPCOG conducted on the relationship between O_3, meteorological factors, day of week, and year at CAMS 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 5001 (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 2016 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 2016 to 2010-2015

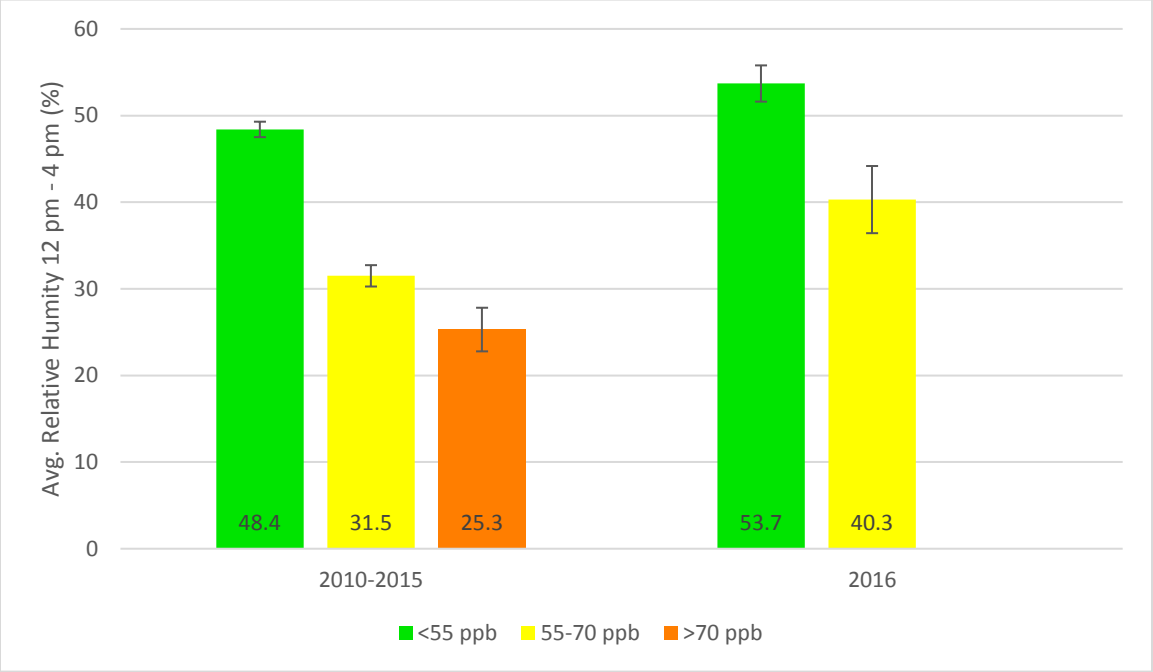
The figure below shows a scatter plot with MDA8 values at CAMS 3 and 12 pm – 4 pm relative humidity at CAMS 5001 (Camp Mabry) for 2016 and 2010-2015. As the figure shows, the 2016 data was consistent in showing a positive correlation between these two factors. This factor had the largest R^2 value for the trend lines for 2016 and the 2nd largest for 2010-2015 among the five factors analyzed in this section.

Figure 4-13. Scatter Plot of 12 pm – 4 pm Relative Humidity at Camp Mabry v. MDA8 O_3 at CAMS 3, 2010-2015 and 2016



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 2016 relative to 2010-2015. The relative humidity 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 2016 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 4-14. 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 and 2016

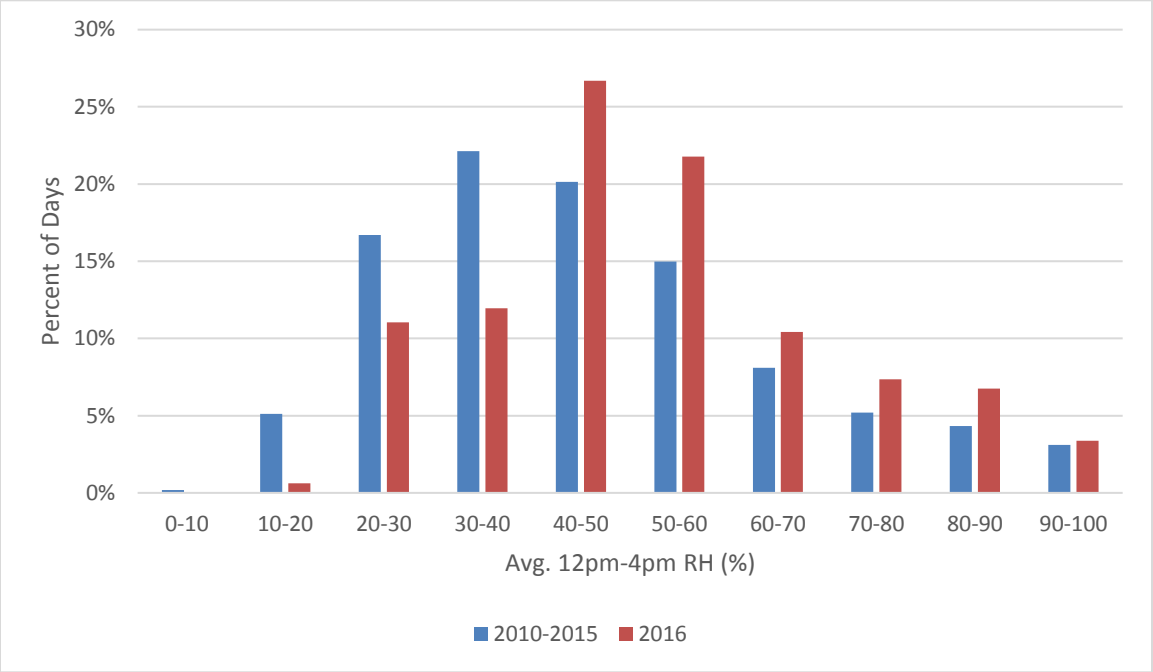


The data in the figure above show that relative humidity tended to be higher on both days that were < 55 ppb and days that were 55-70 ppb. The 2016 data continued to show statistically significantly lower relative humidity from 12 pm – 4 pm on days with MDA8 O_3 55-70 ppb than the relative humidity typical on days with MDA8 O_3 <55 ppb.

4.4.2 Comparison of 2016 Relative Humidity to 2010-2015 Relative Humidity

Based on CAPCOG's review of the meteorological data in 2010-2015 and in 2016, CAPCOG was able to determine that there were statistically significant differences in the 12 pm – 4 pm relative humidity at Camp Mabry in 2016 compared to 2010-2015. The distribution of days into 10 percentage points in the histogram below shows that 2016 had substantially fewer days with low relative humidity (below 40%) that are associated with high MDA8 O_3.

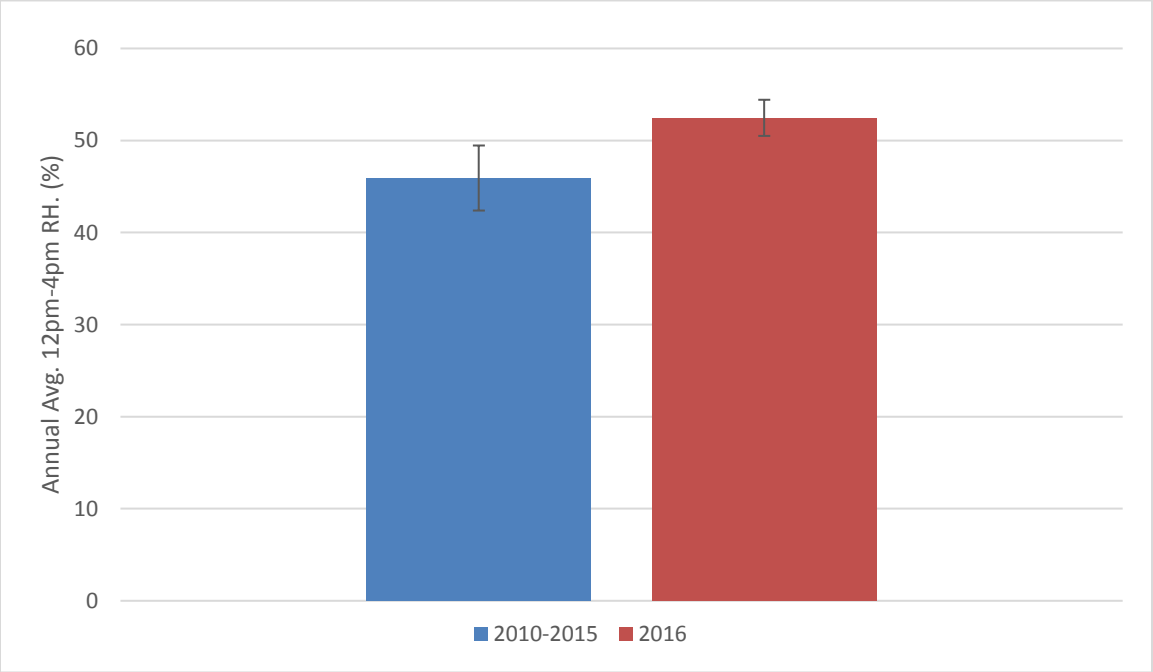
Figure 4-15. Histogram of 12 pm – 4 pm Relative Humidity at Camp Mabry, 2010-2015 and 2016



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 data at a 0.05 significance level.

CAPCOG also performed a confidence interval analysis of the average annual 12 pm – 4 pm relative humidity. The average 52.5% 12 pm – 4 pm relative humidity in 2016 was above the upper bound of the confidence interval for the 2010-2015 average.

Figure 4-16. Annual Avg. 12 pm-4 pm Relative Humidity at Camp Mabry, 2010-2015 and 2016



4.5 Solar Radiation

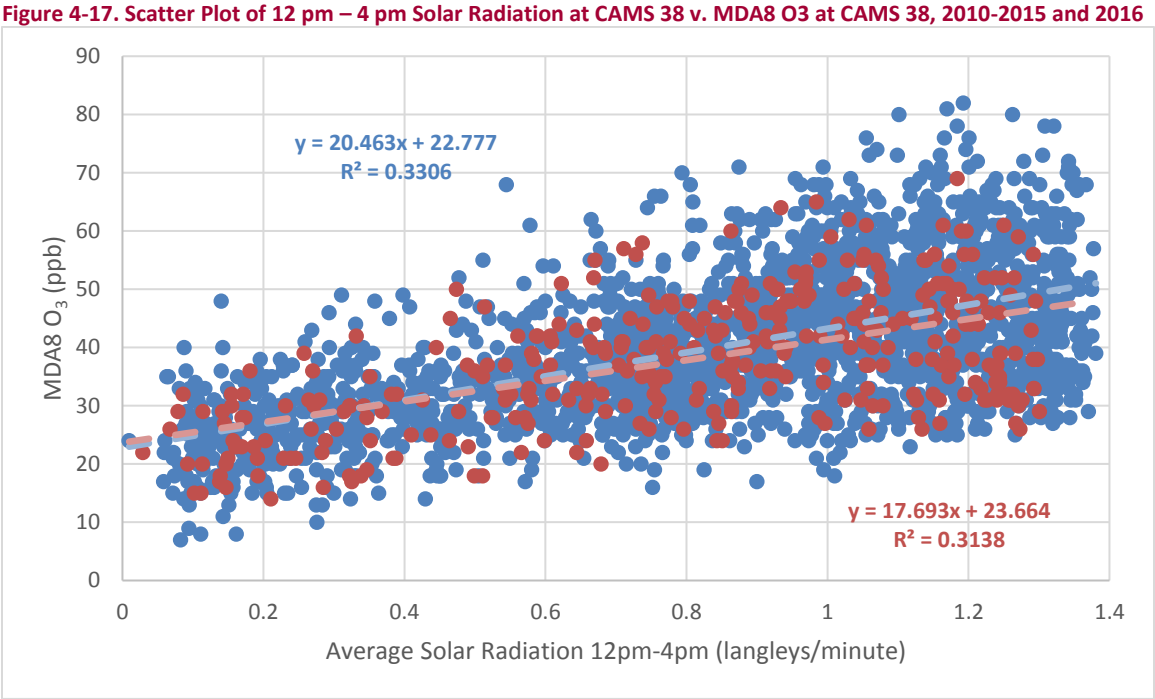
CAPCOG's most recent O_3 conceptual model showed that average solar radiation at CAMS 38 between 12 pm and 4 pm had a statistically significantly negative correlation with MDA8 O_3 at the same station The regression analyses CAPCOG conducted on the relationship between O_3, meteorological factors, day 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 2016 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 2016 to 2010-2015

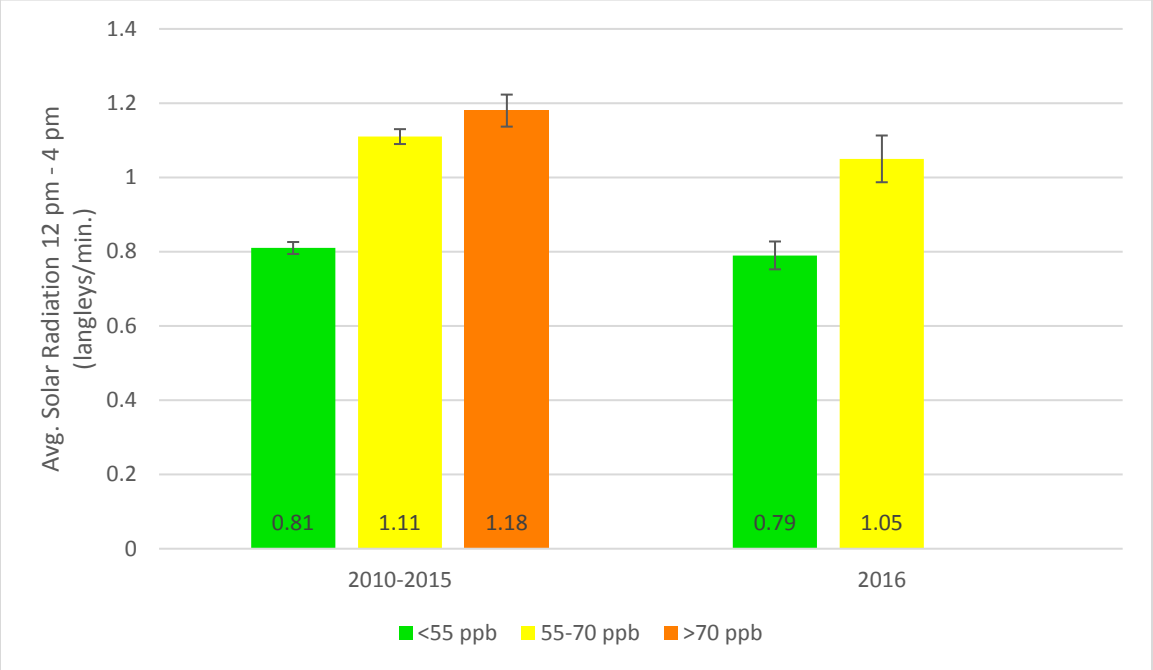
The figure below shows a scatter plot with MDA8 O_3 values at CAMS and 12 pm – 4 pm solar radiation at CAMS 38 for 2016 and 2010-2015. As the figure shows, the 2016 data was consistent in showing a positive correlation between these two factors. This factor had the 2nd-largest R^2 value for the trend lines for 2016 and the largest for 2010-2015.

Figure 4-17. Scatter Plot of 12 pm – 4 pm Solar Radiation at CAMS 38 v. MDA8 O3 at CAMS 38, 2010-2015 and 2016



The figure below shows a comparison of the typical solar radiation at CAMS 3 from 12 pm – 4 pm on days when MDA8 O_3 at CAMS 3 was <55 ppb, 55-70 ppb, and >70 ppb in 2016 relative to 2010-2015. The solar radiation 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 2016 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.

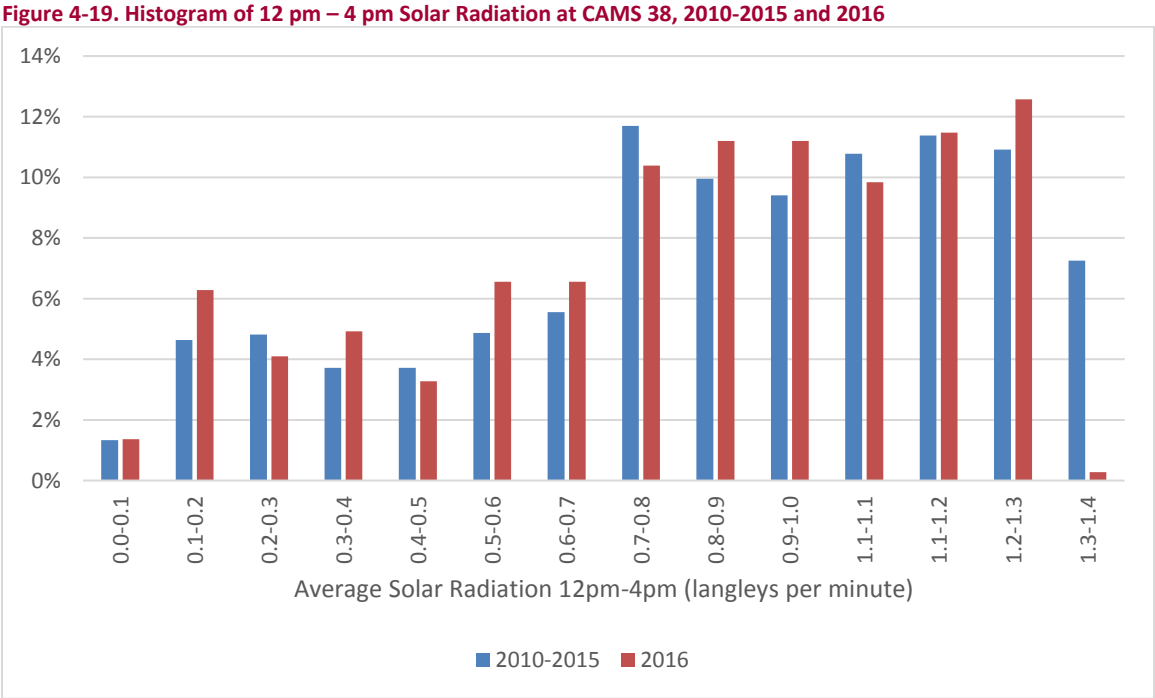
Figure 4-18. Typical Solar Radiation 12 pm – 4pm at CAMS 38 on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 38, 2010-2015 and 2016



4.5.2 Comparison of 2016 Solar Radiation to 2010-2015 Radiation

Based on CAPCOG's review of the meteorological data in 2010-2015 and in 2016, CAPCOG was able to determine that there were statistically significant differences in the 12 pm – 4 pm solar radiation at CAMS 38 in 2016 compared to 2010-2015. The distribution of days into 0.1 langley/minute bins in the histogram below shows that 2016 had substantially fewer days with the highest level of solar radiation (above 1.3 langleys/minute) that are associated with high MDA8 O_3.

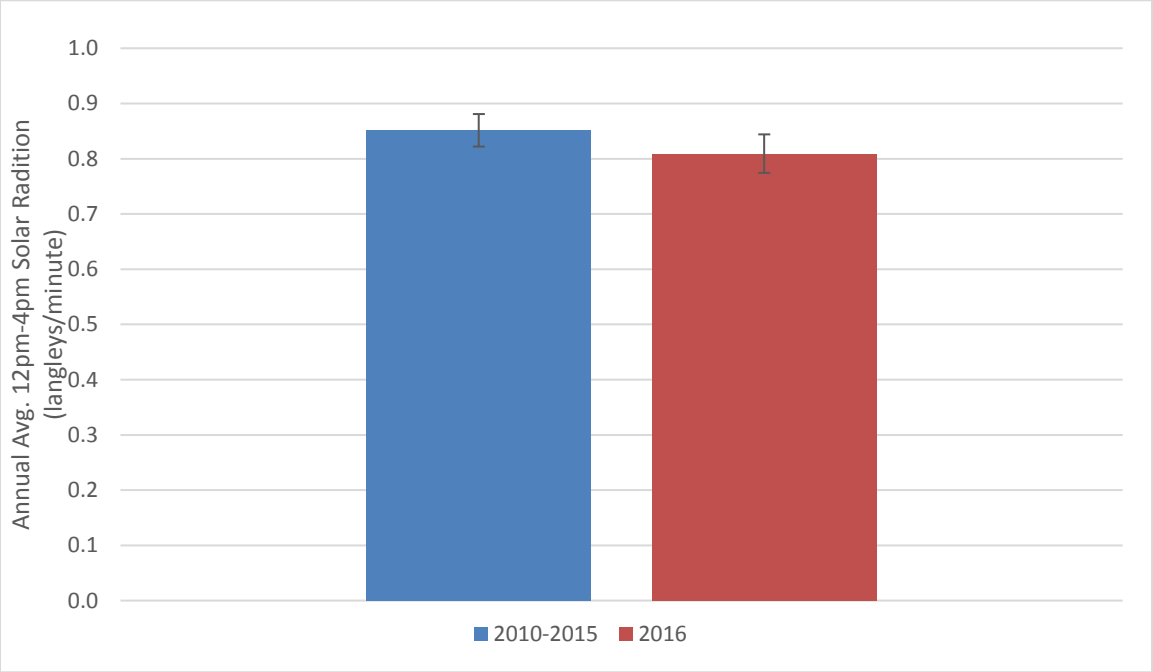
Figure 4-19. Histogram of 12 pm – 4 pm Solar Radiation at CAMS 38, 2010-2015 and 2016



A chi-square test of independence for these distributions showed them to be statistically significantly different at a 0.05 significance level.

CAPCOG also performed a confidence interval analysis of the average annual 12 pm – 4 pm solar radiation. The average 0.81 langley/minute average for 2016 below the lower limit of the 95% confidence interval for the average annual solar radiation values for 2010-2015.

Figure 4-20. Annual Avg. 12 pm-4 pm Solar Radiation at CAMS 38, 2010-2015 and 2016



4.6 Wind Direction

CAPCOG's wind direction analyses included calculating the distribution of resultant wind directions from 8 am – 12 pm and 12 pm to 4 pm on days when MDA8 O_3 was < 55 ppb, 55-70 ppb, and >70 ppb, as well as analysis of back-trajectories on some of the highest O_3 days.

4.6.1 Surface Wind Direction

CAPCOG calculated the resultant surface wind direction distributions for 8 am – 12 pm (which is typically when MDA8 values start) and 12 pm – 4 pm (when MDA8 values typically have their highest 1-hour O_3 concentrations) in order to evaluate whether there were statistically significant differences in these distributions in 2016 from the patterns observed 2010-2015. The following two histograms show these comparisons for these two time periods.

Figure 4-21. Histogram of CAMS 3 Resultant Wind Directions 8 am-12 pm, 2010-2015 and 2016

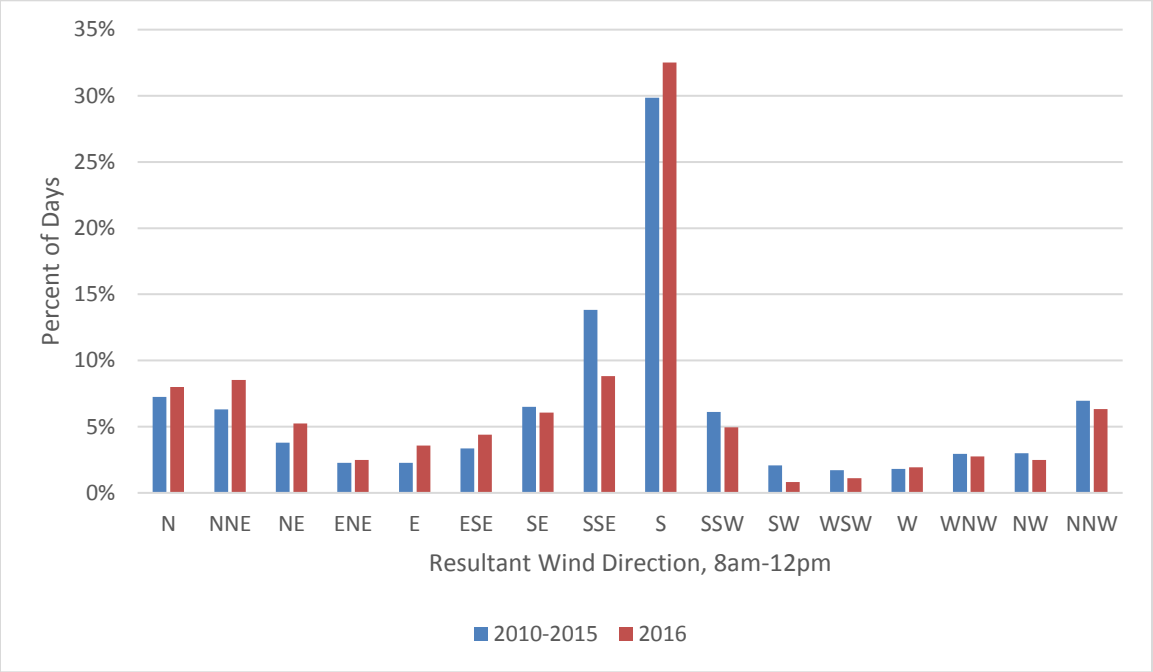
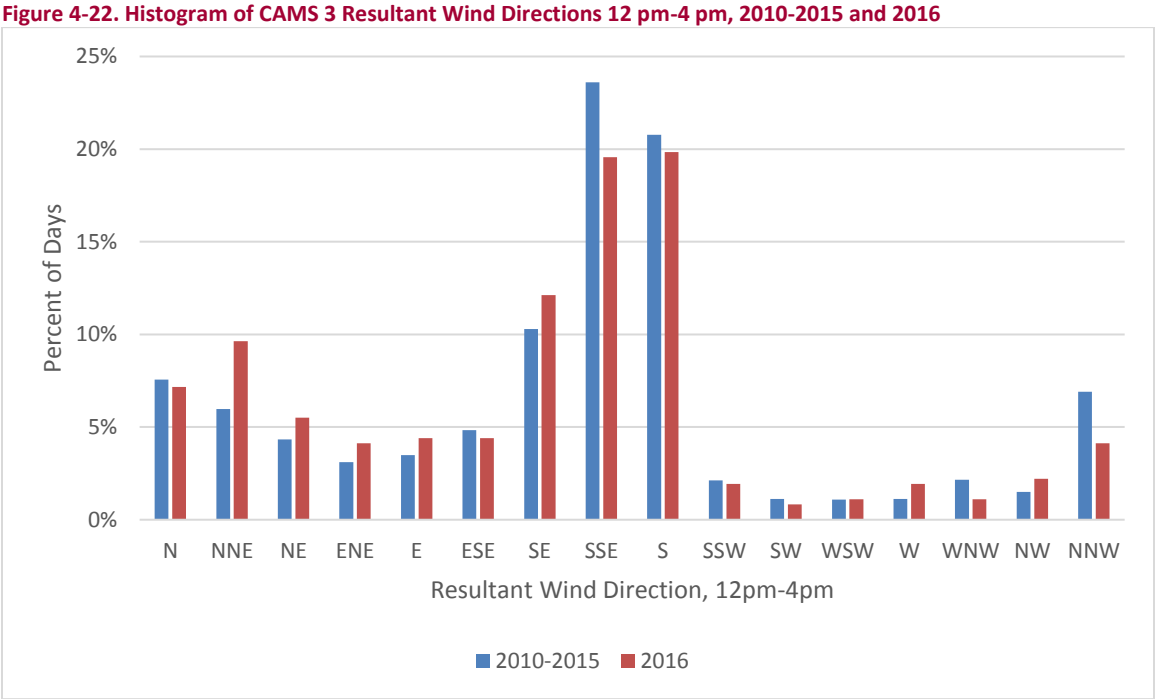


Figure 4-22. Histogram of CAMS 3 Resultant Wind Directions 12 pm-4 pm, 2010-2015 and 2016



CAPCOG performed a chi-squared test of independence for both of these sets of distributions and determined that there was not a statistically significant difference in the resultant wind directions at a 0.05 significance level.

4.6.2 Back-Trajectories

In CAPCOG's 2010-2015 Conceptual Model, CAPCOG developed HYSPLIT 24-hour back-trajectories for the peak 1-hour O_3 hour on days when MDA8 O_3 > 70 ppb at each monitoring station. Since there was only 1 day in 2016 when MDA8 O_3 > 70 ppb, CAPCOG developed back-trajectories for the days with the top four MDA8 O_3 values in 2016, since these days would be relevant to the region's design value. This resulted in CAPCOG modeling a total of five days since two days were tied for fourth at 64 ppb.

Otherwise, CAPCOG used the same model and approach for the 2016 data as was used for the 2010-2015 data:

- NAM 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 show the top 5 MDA8 O_3 levels measured at CAMS 3.

Table 4-2. CAMS 3 Top 5 MDA8 Days

Date	MDA8 Level
Monday, October 3, 2016	72
Saturday, April 23, 2016	67
Monday, March 14, 2016	66
Friday, February 12, 2016	64
Sunday, October 2, 2016	64

The figures below display the back-trajectories on each of the 5 days listed in Table 5-3.

Figure 4-23. CAMS 3 1st Highest MDA8 Day Back-Trajectory

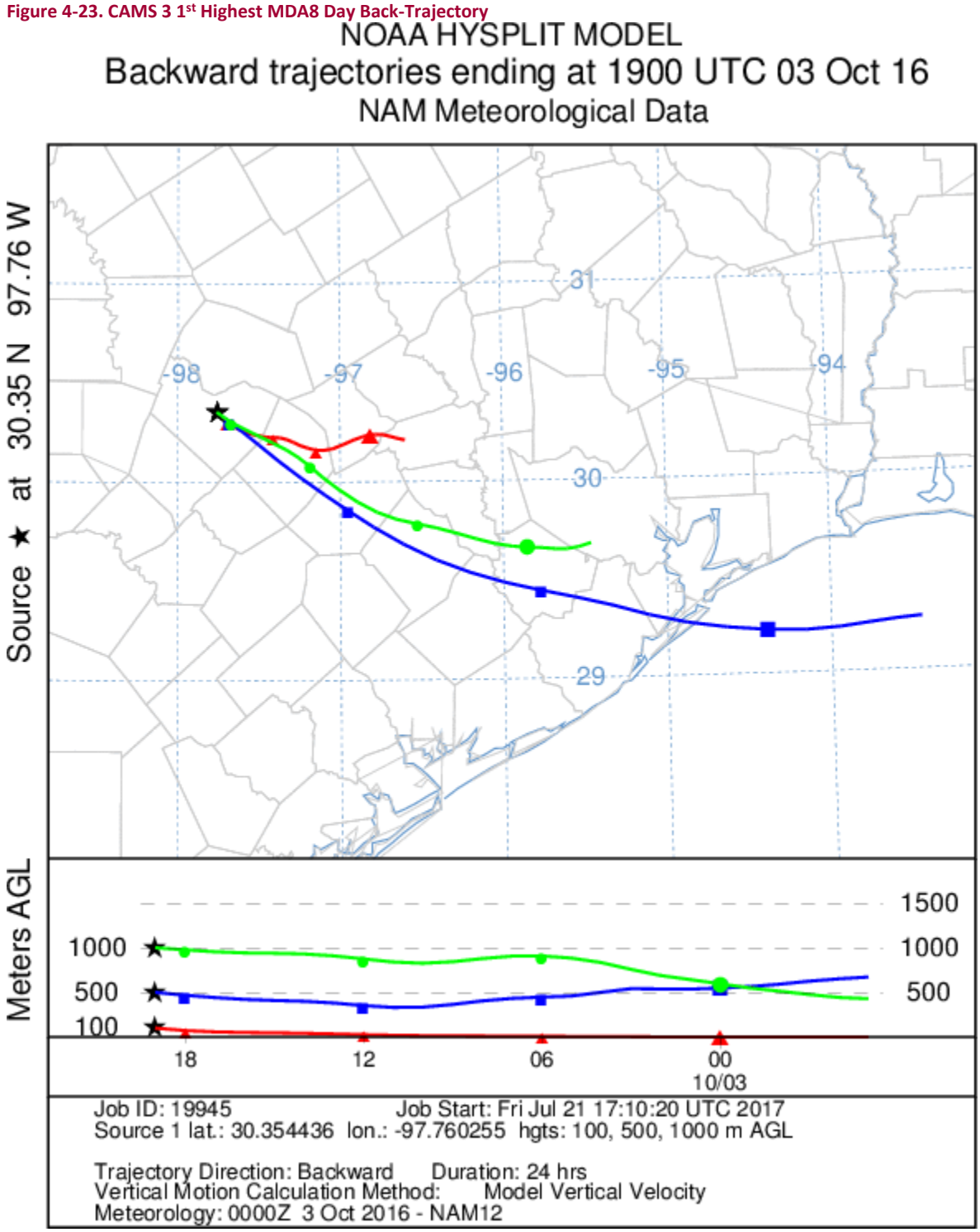


Figure 4-24. CAMS 3 2nd Highest MDA8 Day Back-Trajectory

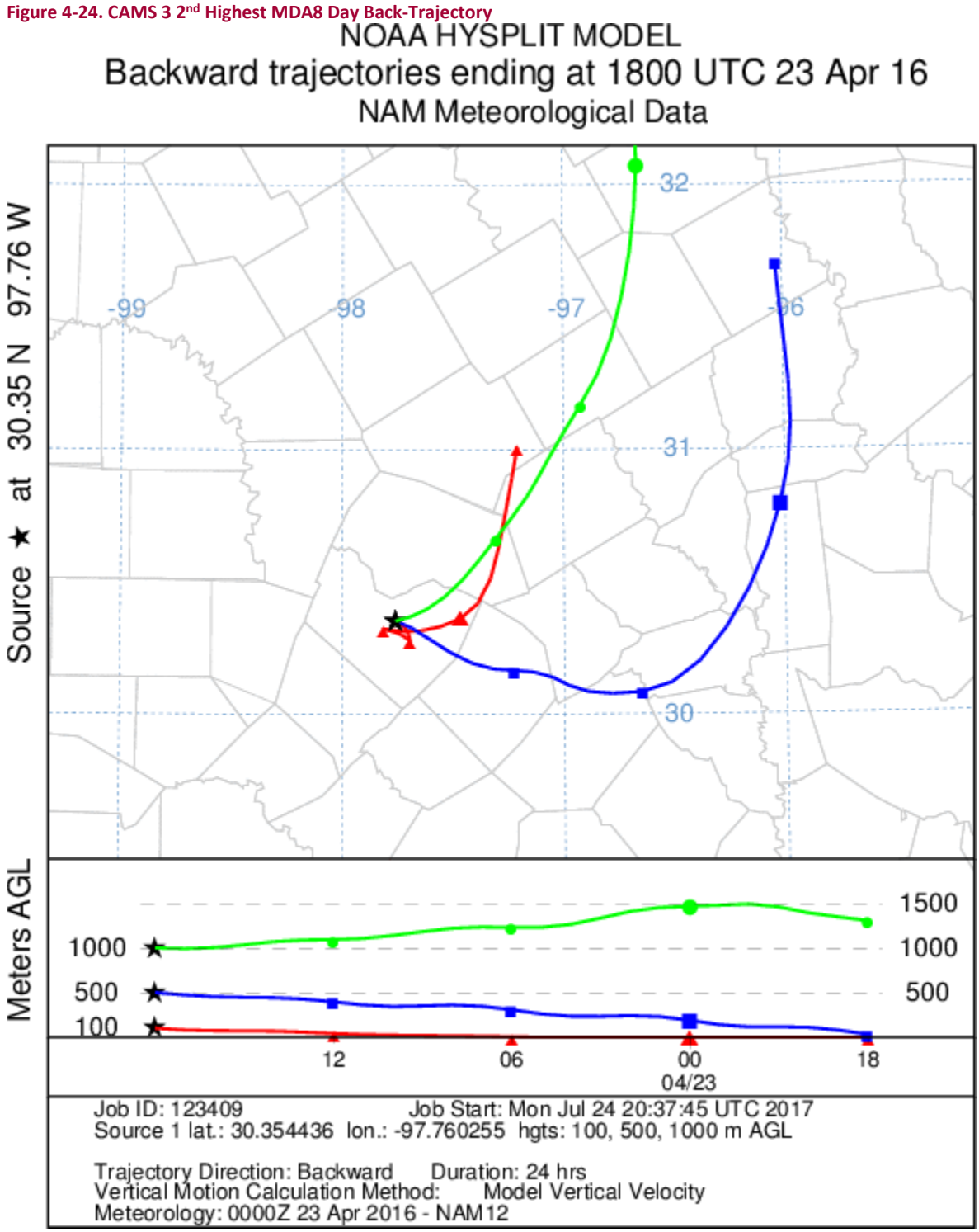


Figure 4-25. CAMS 3 3rd Highest MDA8 Day Back-Trajectory

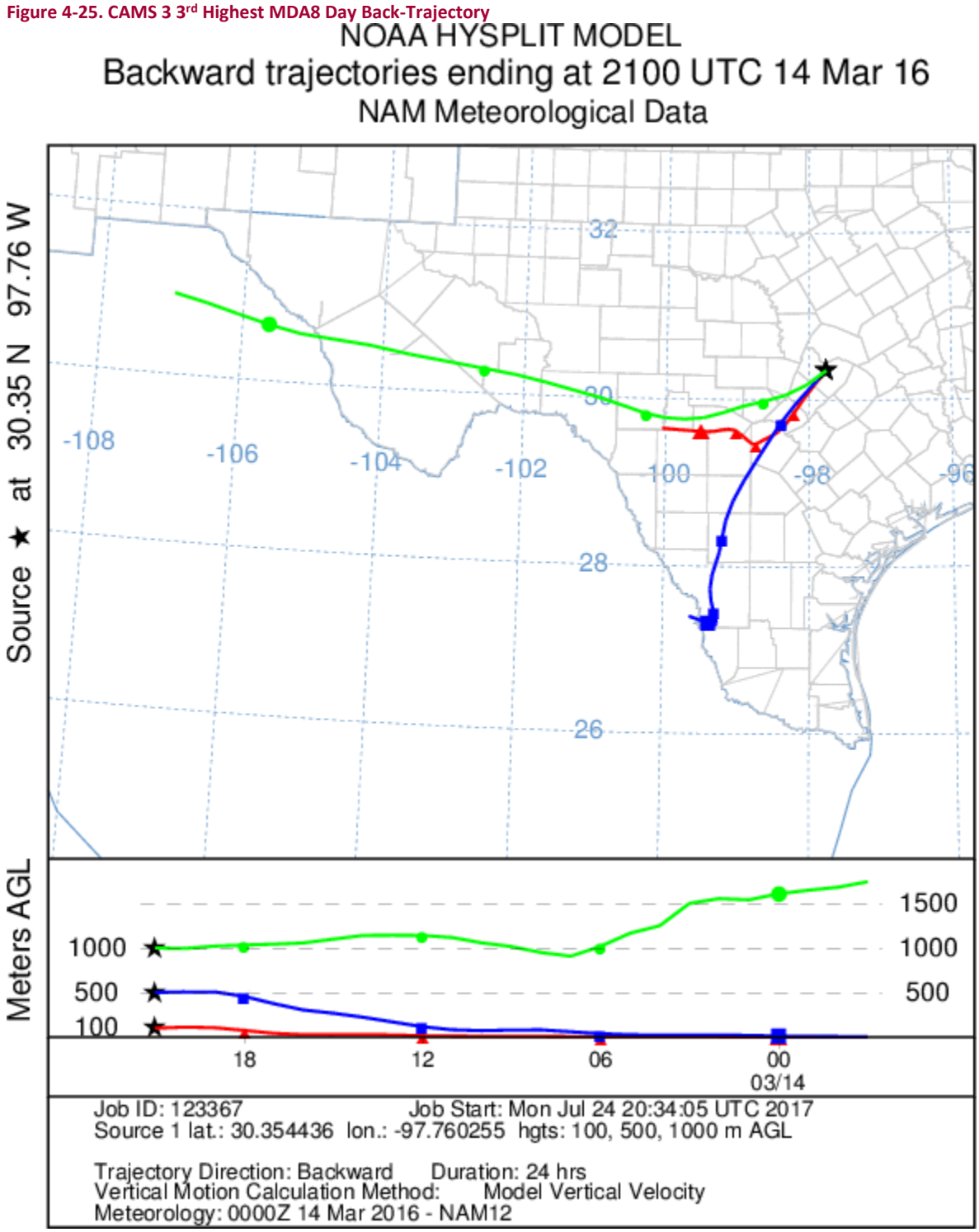


Figure 4-26. CAMS 3 4th Highest MDA8 Day Back-Trajectory

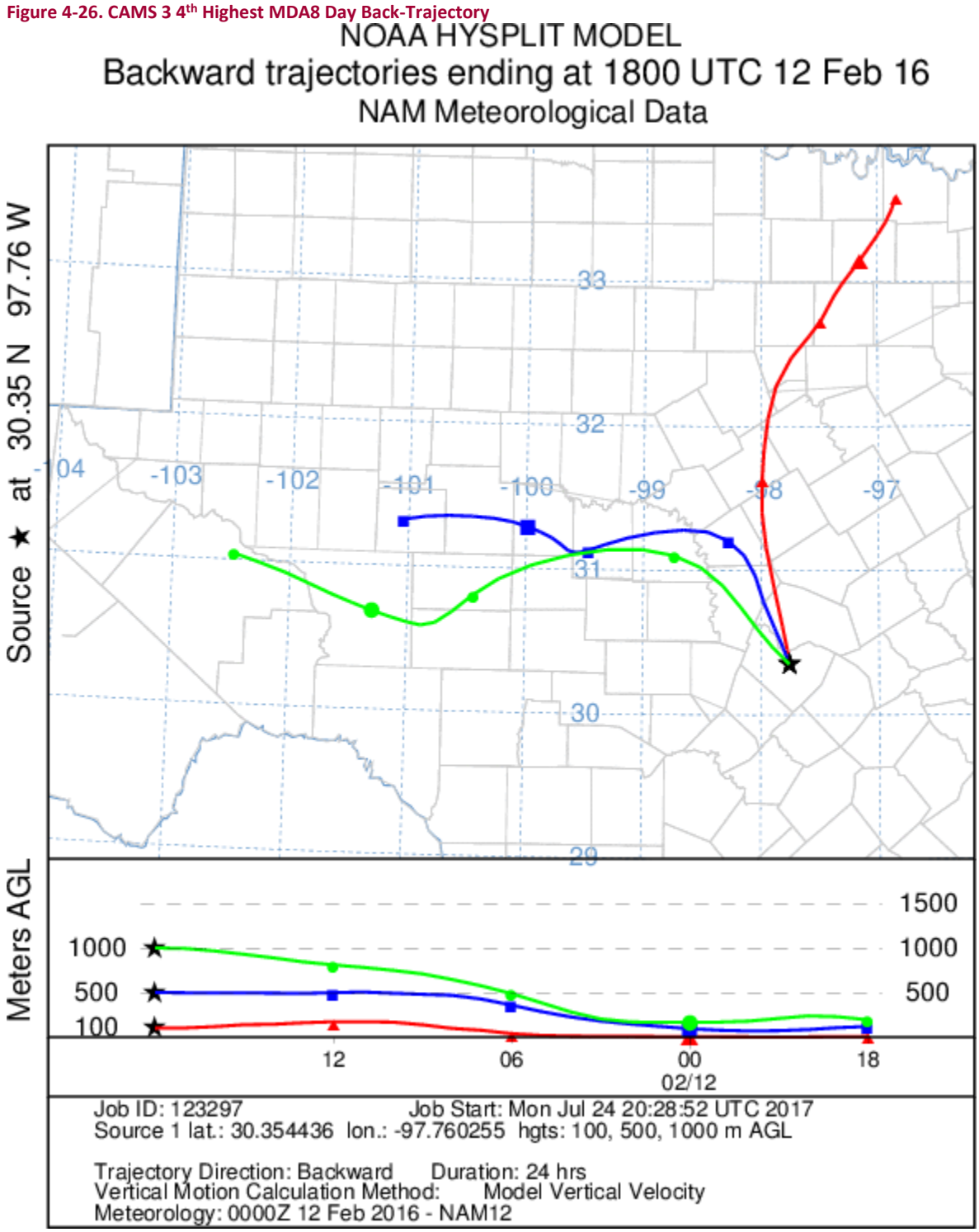
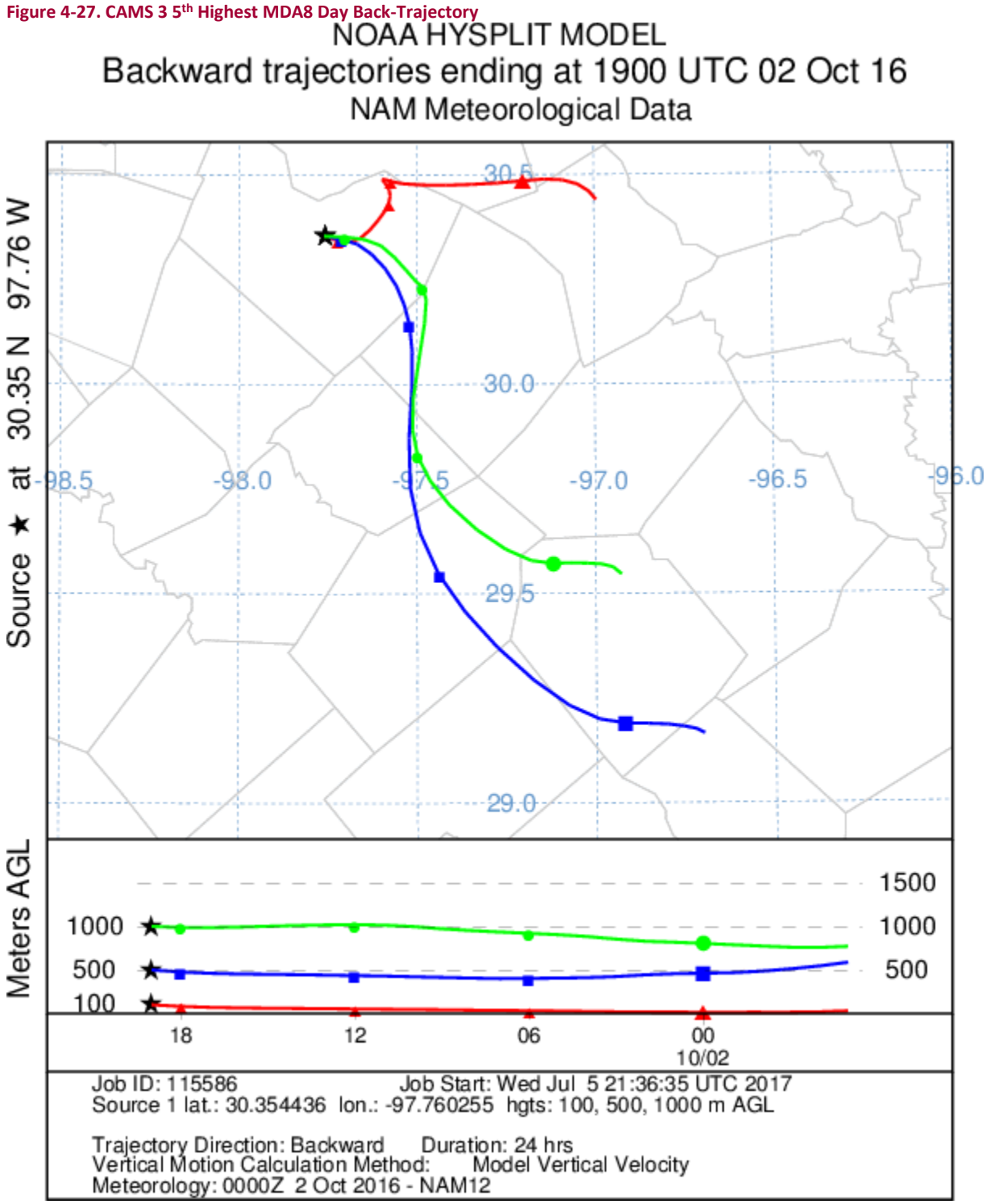


Figure 4-27. CAMS 3 5th Highest MDA8 Day Back-Trajectory



All of the back-trajectories for these days were generally consistent with the >70 ppb back-trajectories for 2010-2015, showing upwind areas ranging from north, with the Dallas-Fort Worth area upwind, clockwise to the southwest, with the San Antonio area upwind.

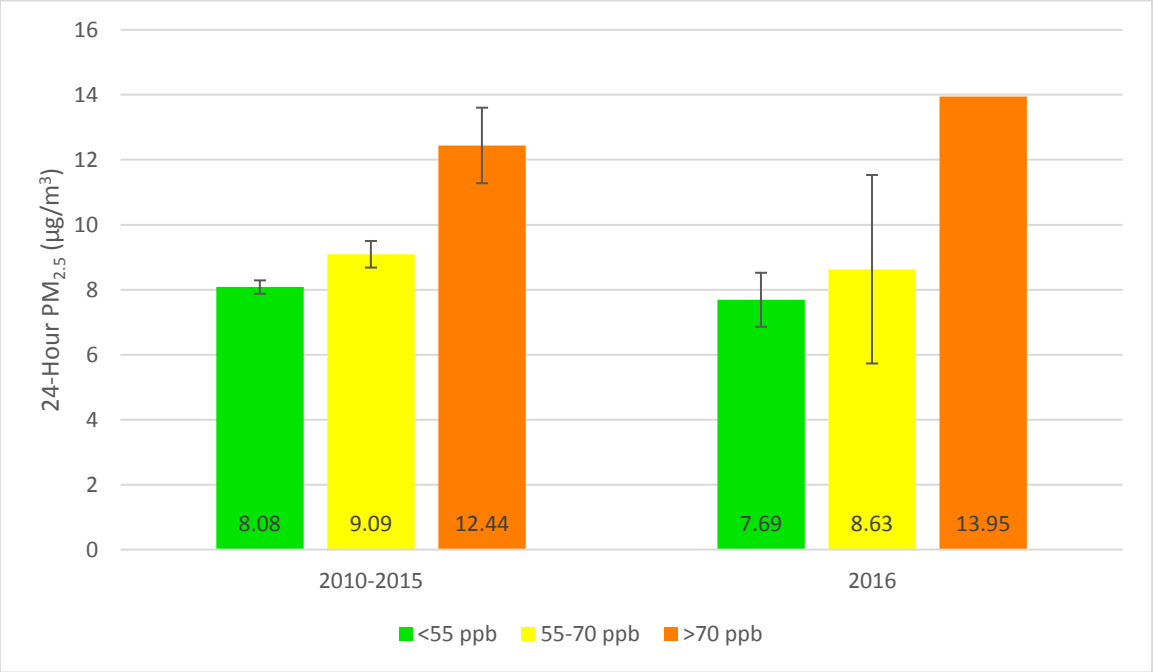
5 Correlation between MDA8 and Other Criteria Pollutants

CAPCOG's 2010-2015 conceptual model indicated that there were statistically significant 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. 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 and 2016

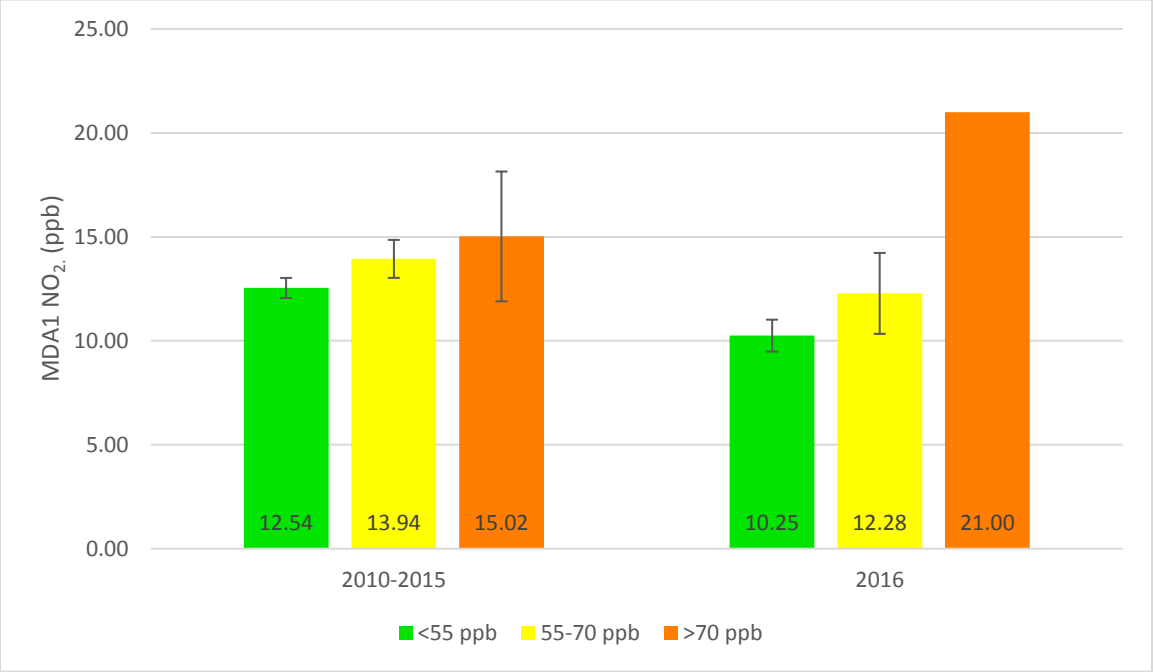


$PM_{2.5}$ concentrations were statistically significantly lower on days with MDA8 O_3 <55 ppb and 55-70 ppb in 2016 compared to 2010-2015, but there is still a statistically significantly higher 24-hour $PM_{2.5}$ concentration in the 55-70 ppb range than there was in the <55 ppb range. The single day in 2016 when MDA8 O_3 was >70 ppb did have a 24-hour $PM_{2.5}$ concentration that was higher than the 95% interval for the value typical for 2010-2015 on days with MDA8 O_3 > 70 ppb.

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 and 2016

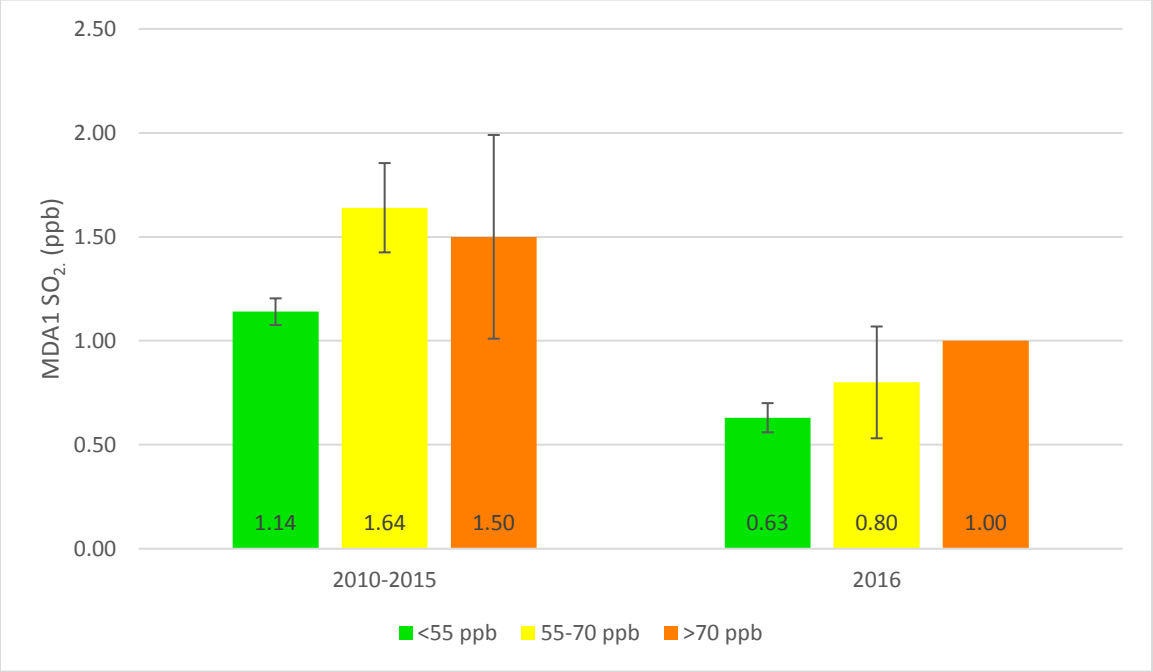


MDA1 NO_2 concentrations were statistically significantly lower on days with MDA8 O_3 <55 ppb and 55-70 ppb in 2016 compared to 2010-2015, but there is still a statistically significantly higher MDA1 NO_2 concentration in the 55-70 ppb range than there was in the <55 ppb range. The single day in 2016 when MDA8 O_3 was >70 ppb did have a MDA 1 NO_2 concentration that was higher than the 95% interval for the value typical for 2010-2015 on days with MDA8 O_3 > 70 ppb.

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 and 2016



MDA1 SO_2 concentrations were statistically significantly lower on days with MDA8 O_3 <55 ppb and 55-70 ppb in 2016 compared to 2010-2015. Additionally, the single day in 2016 when MDA8 O_3 was >70 ppb did have a MDA 1 SO_2 concentration that was lower than the 95% interval for the value typical for 2010-2015 on days with MDA8 O_3 > 70 ppb. There was still a statistically significantly higher MDA1 SO_2 concentration in the 55-70 ppb range than there was in the <55 ppb range.

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 2016. 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 and 2016.

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 and 2016

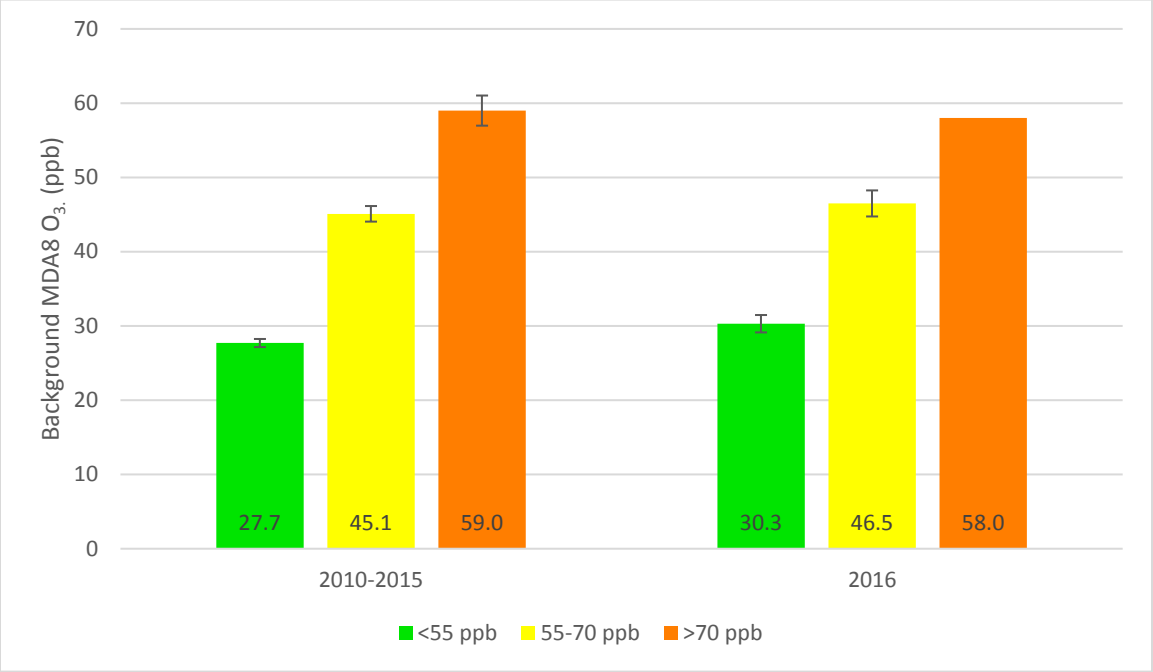
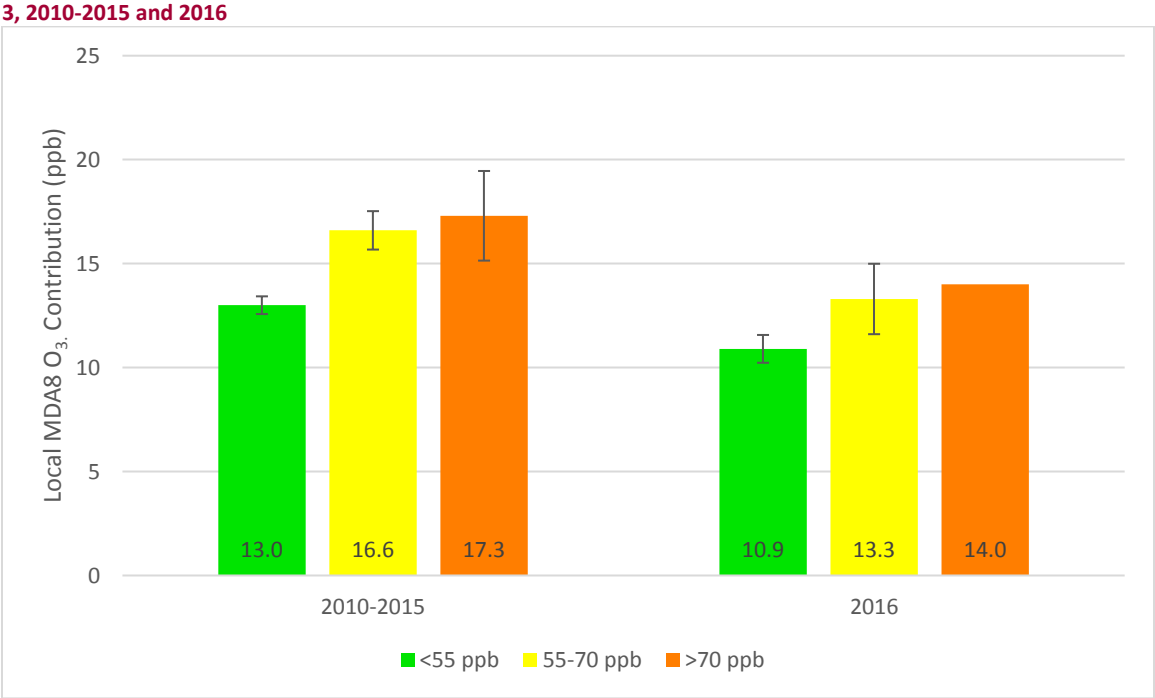


Figure 6-2. Comparison of Local Contribution to MDA8 O_3 on Days with MDA8 O_3 <55 ppb, 55-70 ppb, and >70 ppb at CAMS 3, 2010-2015 and 2016



The graphs show that "background" levels in 2016 were slightly (but statistically significantly) higher in 2016 for days when MDA8 O_3 levels were <55 ppb and 55-70 ppb, while the local contributions were statistically significantly lower in 2016. The lower local contribution is consistent with lower NO_X

emissions within the CAPCOG region in 2016 than the average NO_X emissions across the six years from 2010-2015. It is not clear why the background MDA8 O_3 values would have been higher.

7 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.

The downward trend in the region's design value continued in 2016, reaching 66 ppb, although this report shows that several different meteorological factors that tend be associated with high O_3 concentrations occurred less frequently than had been observed in recent years. It is therefore not clear how much of the decline in the region's 2016 ozone levels compared to prior years is attributable to ongoing decreases in emissions as opposed to meteorology in 2016 that was less conducive to high O_3 concentrations. The fact that as of the date this report was written, the region's design value for 2015-2017 had jumped up to 69 ppb suggests that 2016's meteorology played a more significant role in explaining the lower O_3 concentrations than decreases in NO_X emissions.

Other significant findings included:

- There was a substantial difference in the monthly profile of high MDA8 O_3 values in the region in 2016, with February having far more days with MDA8 $O_3 \geq 55$ ppb and August having far fewer such days than was typical in 2010-2015.
- Given that EPA used observed MDA8 values of ≥ 60 ppb as its way of determining which months should be included in an area's official O_3 monitoring season, and given that a value of 64 ppb in February 2016 was the region's 4th-highest MDA8 O_3 value for 2016 suggests that there may be a need to further expand the region's official ozone monitoring season and for CAPCOG to expand the period it operates its own monitors.
- There did not appear to be statistically significant differences in the day-of-week distribution of high MDA8 O_3 values or, except for CAMs 1603, the start hour for MDA8 O_3 values.
- While the "typical" meteorology for days with high MDA8 O_3 levels was statistically significantly different in 2016 than what was typical for 2010-2015, the general relationships between meteorology and high MDA8 O_3 in 2016 were consistent with what the relationships observed 2010-2015.
- Meteorology in 2016 was less conducive to high MDA8 O_3 levels than was typical for 2010-2015:
    - Mid-day temperatures, diurnal temperature changes, mid-day relative humidity, and mid-day solar radiation were statistically significantly different in 2016 from what was typical for 2010-2015.
    - However, wind patterns did not seem to be statistically significantly different in 2016 relative to what was typical for 2010-2015.
- High MDA8 O_3 levels continued to be positively correlated to high $PM_{2.5}$, NO_2, and SO_2 concentrations.
- Background MDA8 O_3 levels were slightly, but statistically significantly higher in 2016 than what was typical for 2010-2015, with 2016 "background" levels of about 46.5 ppb on days with MDA8 O_3 55-70 ppb and 58.0 ppb on the single day with MDA8 $O_3 > 70$ ppb.

- Local contributions to MDA8 O_3 levels were substantially and statistically significantly lower in 2016 than what was typical for 2010-2015, amounting to 13.3 ppb on days when MDA8 O_3 was 55-70 ppb, and 14.0 ppb on the single day with MDA8 O3 > 70 ppb.

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)	2016 Count	2016 Avg. WS. (mph)	2016 Avg. WS. St. Dev. (mph)
>70 ppb	36	5.93	1.42	1	5.43	n/a
55-70 ppb	260	6.76	2.26	33	6.62	1.76
<55 ppb	1801	7.53	2.60	327	7.37	2.46

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)	2016 Count	2016 Avg. WS. (mph)	2016 Avg. WS. St. Dev. (mph)
>70 ppb	25	5.22	1.06	0	n/a	n/a
55-70 ppb	276	6.41	2.03	28	5.98	2.01
<55 ppb	1802	7.00	2.27	332	6.86	2.34

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)	2016 Count	2016 Avg. WS. (mph)	2016 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	15	7.27	2.77
<55 ppb	1044	9.59	3.59	252	8.83	3.61

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)	2016 Count	2016 Avg. WS. (mph)	2016 Avg. WS. St. Dev. (mph)
>70 ppb	24	6.98	1.49	0	n/a	n/a
55-70 ppb	218	8.24	2.68	22	7.56	2.24
<55 ppb	987	9.26	2.81	243	8.74	2.83

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)	2016 Count	2016 Avg. WS. (mph)	2016 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	3.76	2.73
<55 ppb	858	5.02	1.96	249	4.34	2.06

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)	2016 Count	2016 Avg. WS. (mph)	2016 Avg. WS. St. Dev. (mph)
>70 ppb	28	3.76	1.51	1	6.93	n/a
55-70 ppb	224	4.30	1.91	20	8.56	3.18
<55 ppb	887	6.35	3.39	250	9.51	3.34

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)	2016 Count	2016 Avg. WS. (mph)	2016 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	7.28	2.75
<55 ppb	358	6.01	3.10	239	8.65	3.03

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)	2016 Count	2016 Avg. WS. (mph)	2016 Avg. WS. St. Dev. (mph)
>70 ppb	0	n/a	n/a	0	n/a	n/a
55-70 ppb	52	3.16	2.28	23	9.18	3.36
<55 ppb	380	5.32	3.34	240	8.88	3.32

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)	2016 Count	2016 Avg. WS. (mph)	2016 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	16	8.60	4.19
<55 ppb	752	5.53	3.85	249	10.27	3.97

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)	2016 Count	2016 Avg. WS. (mph)	2016 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	16	8.60	4.19
<55 ppb	621	3.92	2.22	249	10.27	3.97

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)	2016 Count	2016 Avg. Temp. (deg. F)	2016 St. Dev. Avg. Temp. (deg. F)
>70 ppb	36	92.8	6.2	1	82.35	n/a
55-70 ppb	260	85.3	7.7	33	82.46	6.55
<55 ppb	1810	73.5	16.2	327	75.27	13.85

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)	2016 Count	2016 Avg. Temp. (deg. F)	2016 St. Dev. Avg. Temp. (deg. F)
>70 ppb	25	90.9	7.4	0	n/a	n/a
55-70 ppb	276	86.1	7.4	28	81.79	6.62
<55 ppb	1818	73.3	16.4	332	74.96	14.04

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)	2016 Count	2016 Avg. Temp. (deg. F)	2016 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	15	79.04	5.78
<55 ppb	715	83.5	9.5	252	83.24	9.14

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)	2016 Count	2016 Avg. Temp. (deg. F)	2016 St. Dev. Avg. Temp. (deg. F)
>70 ppb	24	92.0	7.5	0	n/a	n/a
55-70 ppb	214	85.8	7.3	22	83.30	5.93
<55 ppb	967	83.9	9.6	200	77.11	9.68

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)	2016 Count	2016 Avg. Temp. (deg. F)	2016 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	81.24	2.86
<55 ppb	328	81.6	12.7	265	80.98	9.88

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)	2016 Count	2016 Avg. Temp. (deg. F)	2016 St. Dev. Avg. Temp. (deg. F)
>70 ppb	28	90.0	8.4	1	83.60	n/a
55-70 ppb	232	87.2	8.4	20	80.96	5.80
<55 ppb	977	84.2	10.6	249	79.65	10.34

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)	2016 Count	2016 Avg. Temp. (deg. F)	2016 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	23	82.33	6.18
<55 ppb	234	78.0	12.3	239	80.46	9.14

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)	2016 Count	2016 Avg. Temp. (deg. F)	2016 St. Dev. Avg. Temp. (deg. F)
>70 ppb	0	n/a	n/a	0	n/a	n/a
55-70 ppb	39	86.03	6.70	23	79.82	4.77
<55 ppb	312	82.14	12.60	240	82.47	10.71

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)	2016 Count	2016 Avg. Temp. (deg. F)	2016 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	16	80.00	4.32
<55 ppb	311	80.6	11.9	250	79.73	9.28

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)	2016 Count	2016 Avg. Temp. (deg. F)	2016 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	15	81.64	3.77
<55 ppb	164	83.4	8.7	257	79.35	10.53

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)	2016 Count	2016 Avg. Temp Chg. (deg. F)	2016 Avg. Temp. Chg. St. Dev. (deg. F)
>70 ppb	36	23.1	4.8	1	18.20	n/a
55-70 ppb	254	21.3	4.3	34	19.01	4.66
<55 ppb	1776	17.2	6.0	329	16.05	5.50

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)	2016 Count	2016 Avg. Temp Chg. (deg. F)	2016 Avg. Temp. Chg. St. Dev. (deg. F)
>70 ppb	25	23.1	2.9	0	n/a	n/a
55-70 ppb	270	22.2	22.2	28	20.75	4.45
<55 ppb	1791	18.1	6.1	334	17.10	5.72

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)	2016 Count	2016 Avg. Temp Chg. (deg. F)	2016 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	15	24.93	4.95
<55 ppb	709	16.7	4.9	253	18.05	5.45

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)	2016 Count	2016 Avg. Temp Chg. (deg. F)	2016 Avg. Temp. Chg. St. Dev. (deg. F)
>70 ppb	24	25.0	3.8	0	n/a	n/a
55-70 ppb	211	24.6	4.6	22	27.60	4.49
<55 ppb	951	18.8	5.4	201	19.41	6.27

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)	2016 Count	2016 Avg. Temp Chg. (deg. F)	2016 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	34.64	1.90
<55 ppb	325	23.1	7.9	266	22.20	7.62

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)	2016 Count	2016 Avg. Temp Chg. (deg. F)	2016 Avg. Temp. Chg. St. Dev. (deg. F)
>70 ppb	28	26.8	2.9	1	34.10	n/a
55-70 ppb	230	24.6	4.5	20	26.10	4.10
<55 ppb	961	19.2	5.3	250	18.58	6.04

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)	2016 Count	2016 Avg. Temp Chg. (deg. F)	2016 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	23	23.81	4.99
<55 ppb	231	17.5	5.9	239	17.98	5.49

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)	2016 Count	2016 Avg. Temp Chg. (deg. F)	2016 Avg. Temp. Chg. St. Dev. (deg. F)
>70 ppb	0	n/a	n/a	0	n/a	n/a
55-70 ppb	39	26.8	3.4	23	26.52	5.99
<55 ppb	310	20.6	6.5	240	20.92	6.39

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)	2016 Count	2016 Avg. Temp Chg. (deg. F)	2016 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	16	25.44	5.19
<55 ppb	310	18.0	5.6	250	17.92	5.31

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)	2016 Count	2016 Avg. Temp Chg. (deg. F)	2016 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	15	25.65	5.27
<55 ppb	164	19.2	5.6	257	18.24	5.78

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. (%)	2016 Count	2016 Avg. RH (%)	2016 Avg. RH. St. Dev. (%)
>70 ppb	4	26.7	3.8	0	n/a	n/a
55-70 ppb	34	24.8	3.4	15	25.65	5.27
<55 ppb	164	19.2	5.6	257	18.24	5.78

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. (%)	2016 Count	2016 Avg. RH (%)	2016 Avg. RH. St. Dev. (%)
>70 ppb	23	25.0	8.2	0	n/a	n/a
55-70 ppb	275	31.7	9.8	24	42.12	9.80
<55 ppb	1787	48.5	19.2	302	53.29	18.33

Table A-33. Avg. relative humidity 12-4pm statistics for CAMS 601

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. RH (%)	2010-2015 Avg. RH St. Dev. (%)	2016 Count	2016 Avg. RH (%)	2016 Avg. RH. St. Dev. (%)
>70 ppb	23	25.0	8.2	0	n/a	n/a
55-70 ppb	275	31.7	9.8	24	42.12	9.80
<55 ppb	23	25.0	8.2	302	53.29	18.33

Table A-34. 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. (%)	2016 Count	2016 Avg. RH (%)	2016 Avg. RH. St. Dev. (%)
>70 ppb	5	25.2	2.0	0	n/a	n/a
55-70 ppb	60	28.6	7.6	17	32.06	8.16
<55 ppb	292	47.2	17.7	177	47.55	16.85

Table A-35. 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. (%)	2016 Count	2016 Avg. RH (%)	2016 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	33.26	4.92
<55 ppb	1090	47.9	16.1	265	49.21	16.05

Table A-36. 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. (%)	2016 Count	2016 Avg. RH (%)	2016 Avg. RH. St. Dev. (%)
>70 ppb	5	24.5	2.9	1	17.88	n/a
55-70 ppb	53	26.0	8.0	20	28.18	7.79
<55 ppb	298	41.7	17.6	250	42.52	17.95

Table A-37. 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. (%)	2016 Count	2016 Avg. RH (%)	2016 Avg. RH. St. Dev. (%)
>70 ppb	6	28.5	3.2	0	n/a	n/a
55-70 ppb	45	27.8	6.6	23	29.16	8.46
<55 ppb	234	51.5	20.1	239	48.76	17.69

Table A-38. 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. (%)	2016 Count	2016 Avg. RH (%)	2016 Avg. RH. St. Dev. (%)
>70 ppb	0	n/a	n/a	0	n/a	n/a
55-70 ppb	39	29.5	8.2	23	33.08	7.82
<55 ppb	312	47.6	17.2	240	49.30	16.13

Table A-39. 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. (%)	2016 Count	2016 Avg. RH (%)	2016 Avg. RH. St. Dev. (%)
>70 ppb	3	30.2	2.9	0	n/a	n/a
55-70 ppb	46	31.1	7.8	16	31.68	6.44
<55 ppb	319	49.2	17.2	250	50.60	15.42

Table A-40. 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. (%)	2016 Count	2016 Avg. RH (%)	2016 Avg. RH. St. Dev. (%)
>70 ppb	4	28.9	3.7	0	n/a	n/a
55-70 ppb	32	30.2	6.3	7	27.56	8.88
<55 ppb	162	46.5	17.4	166	48.83	17.22

Solar Radiation

Table A-41. 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)	2016 Count	2016 Avg. (langleys / min)	2016 Avg. SR. St. Dev. (langleys / min)
>70 ppb	25	1.18	0.11	0	n/a	n/a
55-70 ppb	276	1.11	0.17	28	1.05	0.17
<55 ppb	1,819	0.81	0.35	334	0.79	0.35

Appendix B: Monitor-by-Monitor Co-Pollutant Data

Table B-1. Avg. 24-hour $PM_{2.5}$ statistics for CAMS 3

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. 24-hr. $PM_{2.5}$ (µg/m³)	2010-2015 Avg. 24-hr. $PM_{2.5}$ St. Dev. (µg/m³)	2016 Count	2016 Avg. 24-hr. $PM_{2.5}$ (µg/m³)	2016 Avg. 24-hr. $PM_{2.5}$ St. Dev. (µg/m³)
>70 ppb	35	12.44	3.51	1	13.95	n/a
55-70 ppb	255	9.09	3.34	34	8.63	2.55
<55 ppb	1736	8.08	4.41	329	7.69	3.79

Table B-2. Avg. 24-hour $PM_{2.5}$ statistics for CAMS 38

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. 24-hr. $PM_{2.5}$ (µg/m³)	2010-2015 Avg. 24-hr. $PM_{2.5}$ St. Dev. (µg/m³)	2016 Count	2016 Avg. 24-hr. $PM_{2.5}$ (µg/m³)	2016 Avg. 24-hr. $PM_{2.5}$ St. Dev. (µg/m³)
>70 ppb	25	11.39	3.90	0	n/a	n/a
55-70 ppb	273	8.90	3.29	28	8.13	2.99
<55 ppb	1773	7.33	4.95	329	7.12	3.71

Table B-3. Avg. 24-hour $PM_{2.5}$ statistics for CAMS 601

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. 24-hr. $PM_{2.5}$ (µg/m³)	2010-2015 Avg. 24-hr. $PM_{2.5}$ St. Dev. (µg/m³)	2016 Count	2016 Avg. 24-hr. $PM_{2.5}$ (µg/m³)	2016 Avg. 24-hr. $PM_{2.5}$ St. Dev. (µg/m³)
>70 ppb	17	12.18	3.99	0	n/a	n/a
55-70 ppb	188	9.27	3.65	15	6.84	2.93
<55 ppb	1773	7.33	4.95	329	7.12	3.71

Table B-4. Avg. MDA1 NO_2 statistics for CAMS 3

MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. MDA1 NO_2 (ppb)	2010-2015 Avg. MDA1 NO_2 St. Dev. (ppb)	2016 Count	2016 Avg. MDA1 NO_2 (ppb)	2016 Avg. MDA1 NO_2 St. Dev. (ppb)
>70 ppb	15	15.02	6.17	1	21	n/a
55-70 ppb	162	13.94	5.93	34	12.28	5.79
<55 ppb	1123	12.54	8.27	329	10.25	7.10

Table B-5. Avg. MDA1 SO_2 statistics for CAMS 3

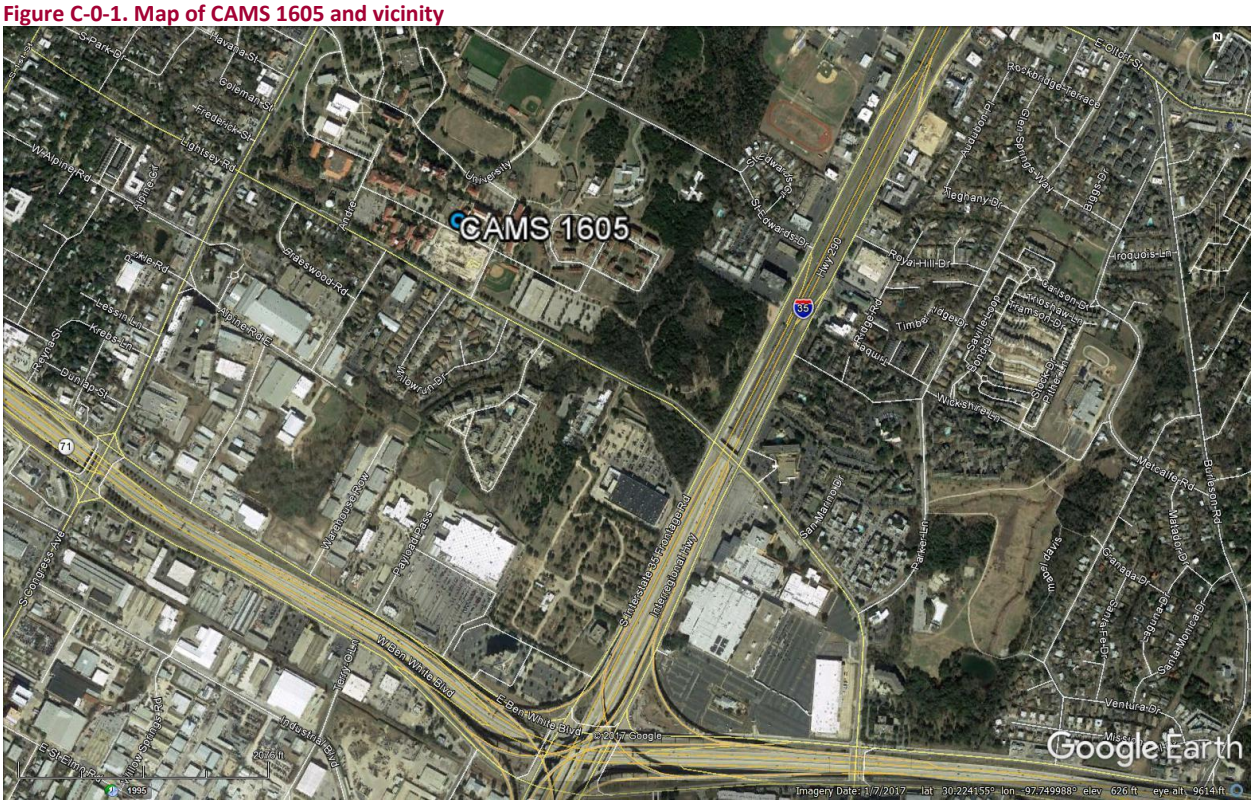
MDA8 O_3 (ppb)	2010-2015 Count	2010-2015 Avg. MDA1 SO_2 (ppb)	2010-2015 Avg. MDA1 SO_2 St. Dev. (ppb)	2016 Count	2016 Avg. MDA1 SO_2 (ppb)	2016 Avg. MDA1 SO_2 St. Dev. (ppb)
>70 ppb	9	1.50	0.75	1	1	n/a
55-70 ppb	126	1.64	1.23	34	0.80	0.80
<55 ppb	951	1.14	1.01	329	0.63	0.65

Appendix C: Analysis of CAMS 1605 Ozone Data

St. Edward's University's CAMS 1605 started collecting data in early 2016. CAPCOG provided financial and logistical support to St. Edward's University for the operation of this station in order to ensure the quality of the data being used there. The station was primarily being used as a way to verify ground-level O_3 measurements as a reference point for ozonesonde launches. As mentioned earlier in this report, analyses of the data collected at CAMS 1605 conducted by CAPCOG, St. Edward's University, and CAPCOG's monitoring contractor (Dios Dado Environmental, Ltd.) indicated that while the data met the completeness, accuracy, and precision standards in CAPCOG's quality assurance project plan (QAPP) for its own monitoring stations, the O_3 data were significantly lower than expected, which may suggest that the monitor is providing data representative of a micro-scale rather than the neighborhood scale as intended. This appendix provides some of the data that led CAPCOG, St. Edwards University, and Dios Dado Environmental (Ltd.) to this conclusion.

On days in 2016 when at either CAMs 1603 or CAMS 1605 had MDA8 values of 55 ppb or higher, CAMS 1605 had MDA8 values that were, on average, 10.6 ppb lower than nearby CAMS 1603, with a range of 2-19 ppb below the values at CAMS 1603. Modeling results from release 2 of the June 2012 episode available from TCEQ, on the other hand, showed that CAMS 1605 was only 1.1 ppb lower, on average, than CAMS 1603 when either site had MDA8 values of 55 ppb or higher, ranging from 3.5 ppb below to 10.6 ppb above. St. Edward's University staff believe that the proximity to highways may be causing NO_X titration of O3 at CAMS 1605, which could explain the lower-than expected values.

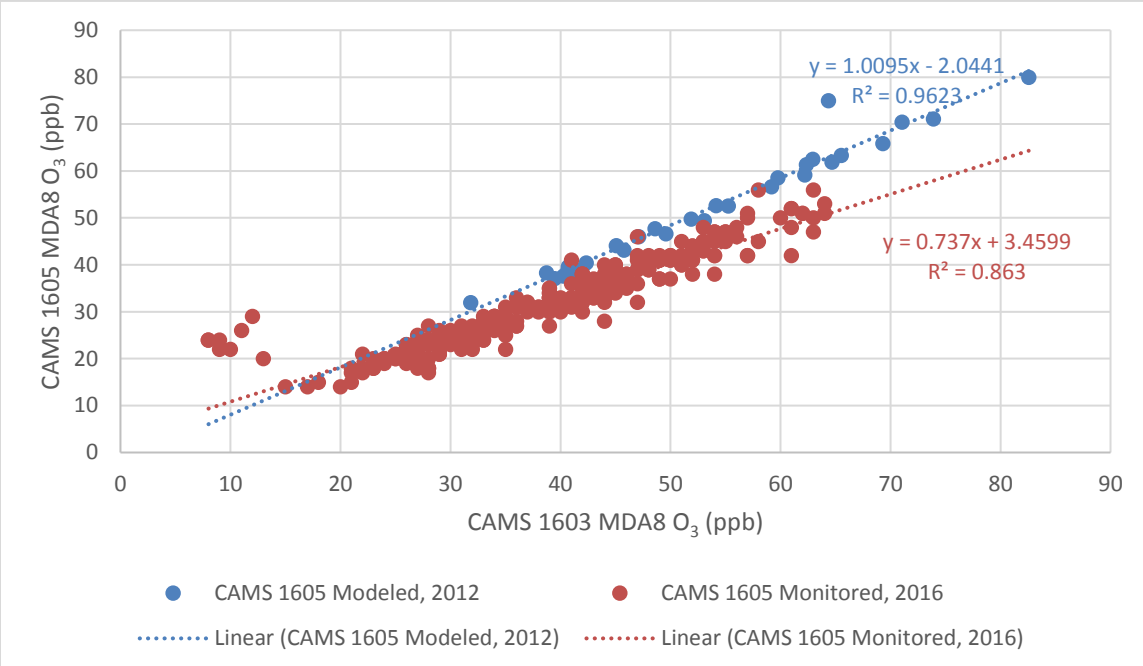
Figure C-0-1. Map of CAMS 1605 and vicinity



The figure below shows a comparison of the correlation between MDA8 O_3 values modeled at the 4 km x 4 km grid cells containing CAMS 1603 and CAMS 1605 for June 2012 in release 2 of TCEQ's 2012 O_3 season model and between the monitored MDA8 O3 values in 2016. As the figure shows, while there is

a high degree of correlation in the modeling data but a substantially less correlation in the monitoring data.

Figure C-0-2. Correlations between CAMS 1603 and CAMS 1605 MDA8 O_3 (ppb)



The following table summarizes the statistics comparing the CAMS 1605 MDA8 O_3 concentrations to CAMS 1603 when the maximum MDA8 O_3 values between the two sites were ≥ 60 ppb. As the table shows, the monitoring data for CAMS 1605 was substantially below what was expected.

Figure C-0-3. Comparison

Statistic	June 2012 Model	2016 Monitoring
Deviation Range (ppb)	-0.84 ≤ X ≤ +10.64	-19 ≤ X ≤ -7
Avg. Deviation (ppb)	-0.84	-11.83
Avg. Abs. Deviation (ppb)	2.97	11.83