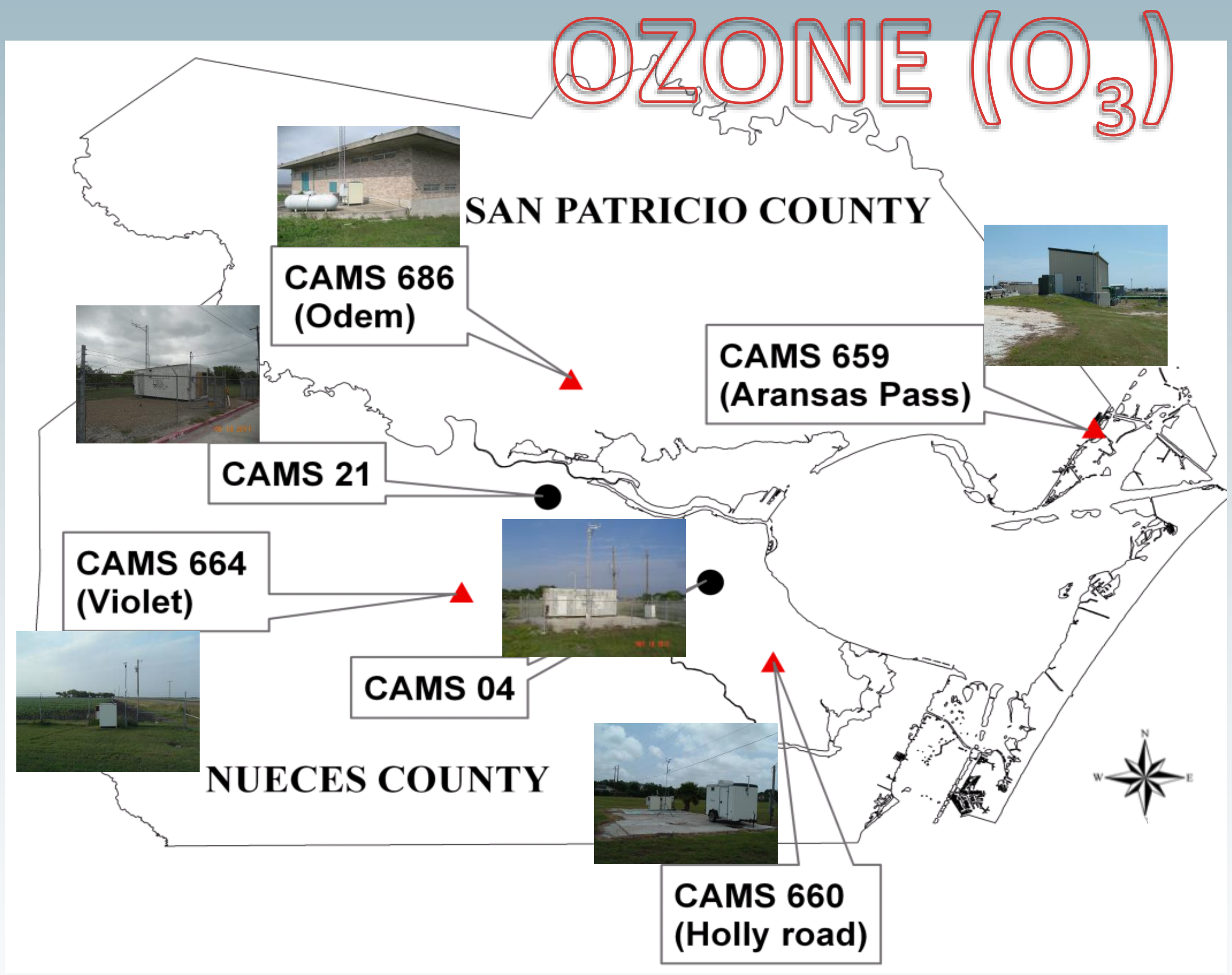
ATTACHMENT C

CONCEPTUAL MODEL REPORT

FY_14_15, Contract # 582-14-40055
PGA #FY14-01
Task 2.2
Amendment #2

A Report on

A Conceptual Model of High Ozone Episodes Through 2014 Affecting Corpus Christi, Texas



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A Conceptual Model of High Ozone Episodes Through 2014 Affecting Corpus Christi, Texas

Prepared for the

City of Corpus Christi
and
Texas Commission on Environmental Quality (TCEQ)

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A Report on

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EXECUTIVE SUMMARY

The City of Corpus Christi in collaboration with University of North Texas (UNT), Texas A&M University-Kingsville (TAMUK) and Texas A&M University-Corpus Christi (TAMUCC) has been active participant in the local as well as regional air quality assessment and planning activities. The Texas Commission on Environmental Quality (TCEQ) maintains and operates two compliance grade air quality monitoring stations in the urban airshed that measure ozone concentrations and prevailing meteorological conditions (CAMS 04 and CAMS 21). As an integral effort of the Rider 8 project, four non-compliance research-grade air quality monitoring stations are being currently maintained and operated by the UNT-TAMUK team. The research-grade monitoring sites are spatially located in Aransas Pass (CAMS 659), San Patricio (CAMS 686), and Nueces (CAMS 664 and CAMS 660) counties. Each of these sites are equipped with an ozone analyzer and weather sensors to measure real-time ambient ozone levels and prevailing meteorological conditions.

A conceptual model of high ozone episodes through 2014 was developed for the Corpus Christi urban airshed using measured ozone and meteorological data from both compliance and non-compliance air quality monitoring sites. The urban airshed was observed to be in attainment with the current NAAQS based on design value trend analysis performed using the ozone concentrations measured. The design value trend at CAMS 04 and CAMS 21 showed an overall decreasing trend from 2002 through 2014. However over the last several years since 2009, this decreasing trend has shown a reversal. A detailed statistical analysis of high ozone days with daily maximum eight hour ozone concentrations exceeding various threshold levels was performed to identify photochemical episodes of high ozone days and to evaluate the influence of prevailing meteorological conditions during these episodes.

Statistical analysis of annual frequencies of high ozone days during 2002 through 2014 also exhibited an overall decreasing trend very similar to the design values. During 2013 and 2014, two days with daily maximum eight hour ozone concentrations >= 75 ppb was recorded at the research grade monitoring stations in urban site – CAMS 660 (March 13, 2013; May 29, 2014), downwind site – CAMS 664 (July 1, 2013) and upwind site – CAMS 659 (April 29, 2014) while zero days were recorded at compliance grade monitoring station (CAMS 04 and CAMS 21). High frequency of episode days with eight hour ozone concentration ranging between threshold levels of 60 ppb to 65 ppb was observed at both research and compliance grade monitoring stations. Bi-modal distribution of exceedance days considering NAAQS as well as potential levels of 70 ppb, 65 ppb and 60 ppb were observed at both TCEQ and UNT-TAMUK sites with highest numbers during May and September as noted historically. Considerably significant number of exceedances were recorded during spring months of March, April, summer months of June, July and August along with Fall months of October and November. Slight variability of 1 to 2 ppb was observed in the average concentrations measured during weekday/weekend days and the maximum eight hour concentrations were higher during weekdays than during weekends.

Prevailing meteorological conditions during high ozone days were further studied to identify the dominant wind conditions impacting the monitoring site. Winds from southeast at maximum speed of 2.0 – 4.0 m/s were observed to be predominant at all monitoring sites during majority of the days .Days with daily maximum eight hour ozone concentrations exceeding the current NAAQS (75 ppb) and three threshold levels of 70 ppb, 65 ppb and 60 ppb were identified as high ozone days. Wind rose analysis of episode days measured during 2013 at both CAMS 04 and CAMS 21 concluded a dominant influence of northerly, northeasterly, and southeasterly winds with speeds ranging between 2.0 – 4.0 m/s. Trajectory analysis performed using the HYSPLIT model of NOAA during the high ozone days identified transport of polluted air parcels from highly industrialized areas of Texas including Houston-Galveston, Dallas-Fort Worth and from surrounding regions of Louisiana associated with the northerly and northeasterly winds. On selected high ozone days during early spring, the influence of polluted air parcels originating from the Eagle Ford Shale gas exploration regions to the northwest was noted.

As specified by U.S. EPA in the "*Guidance on the Use of Models and Other Analysis to Demonstrate Attainment of Air Quality Goals for Ozone and* $PM_{2.5}$ *and Regional Haze*" (EPA, 2007), it was noted that since 2002 there were not any contiguous set of days (three or more) with measured ozone values above the current NAAQS at the compliance grade monitoring stations in the Corpus Christi urban airshed that would be useful for photochemical modeling purpose. Based on the episodic analysis and further characterization zero episode days with potential for photochemical modeling were identified.

1.0 INTRODUCTION

The Corpus Christi metropolitan statistical area comprising of Nueces, San Patricio, Aransas Pass and the northern portion of Kleberg County is currently designated as a near non-attainment area. With the funding made available by the State Legislature through the Texas Commission on Environmental Quality (TCEQ), the city of Corpus Christi has collaborated with the local entities including the port industries, port of Corpus Christi, small businesses and educational institutions including University of North Texas (UNT), Texas A&M University – Kingsville (TAMUK), and Texas A&M University – Corpus Christi (TAMUCC). The collaborative efforts include monitoring of ambient air quality, development of emissions inventory for ozone precursors, identification and implementation of voluntary emission reduction measures, and assessment of the impact of emission changes on local air quality using photochemical models. A Flexible Attainment Region (FAR) and O3Flex Agreement were also developed with the support of TCEQ and EPA for further emission reductions in order to maintain the attainment status of the urban airshed. As a result of these efforts, ozone levels in the urban airshed have demonstrated an overall decreasing trend. The area is currently in attainment of the National Ambient Air Quality Standards (NAAQS) for ozone set by the United States Environmental Protection Agency (U.S. EPA).

As a continued effort to evaluate the attainment status, Texas Commission on Environmental Quality (TCEQ) maintains and operates two compliance grade continuous ambient monitoring stations (CAMS 04 and CAMS 21) located within the Corpus Christi urban airshed. In addition to these existing compliance grade monitoring stations, three additional research grade monitoring stations were set up by TAMUK as an integral part of Rider 13 (2001-2002) which included (1) an upwind site at the waste water treatment plant in Aransas Pass (CAMS 659), (2) a downwind site located at Violet road, near Robstown (CAMS 664), and (3) an urban site at the municipal water pumping station on Holly Road (CAMS 660), south of South Padre Island Drive (SPID) in Corpus Christi. With availability of additional funding through Supplemental Environmental Project (SEP) three additional research grade monitoring stations were set up by TAMUK in 2007 which included (1) Ingleside site (CAMS 685) - located on the property of the water pumping station off highway 361 which is situated in between the Sherwin Alumina plant and DuPont/Oxychem PVC production plant of Ingleside, (2) Odem site (CAMS 686) - located northwest of Corpus Christi on the property of the water pumping station in Odem, operated by the San Patricio municipal water district, and (3) Taft site (CAMS 687) - located on the property of the water pumping station in Taft, operated by the San Patricio municipal water district. Each of these sites is equipped with an ozone analyzer, weather sensors and data logger for continuous measurement and data collection. The air quality data collected is posted on TCEQ's website using wireless modems and TCEQ LEADS data acquisition system and made available to the general public, stakeholders and other researchers.

As specified in the Rider work plan for FY 14_15 UNT-TAMUK have continued the maintenance and operation of two non-compliance research grade monitoring sites in Nueces one in Aransas Pass County and one in San Patricio Counties. The two Nueces County monitoring stations included the urban site (CAMS 660 -Holly road) and a downwind site (CAMS 664 - Violet). The other monitoring stations included an upwind site (CAMS 659) located in Aransas Pass of Aransas Pass County, and a rural site (CAMS 686) located in Odem of San Patricio county. Figure 1 shows the spatial and geographical locations of both the compliance and non-compliance grade monitoring stations in the Corpus Christi urban airshed.

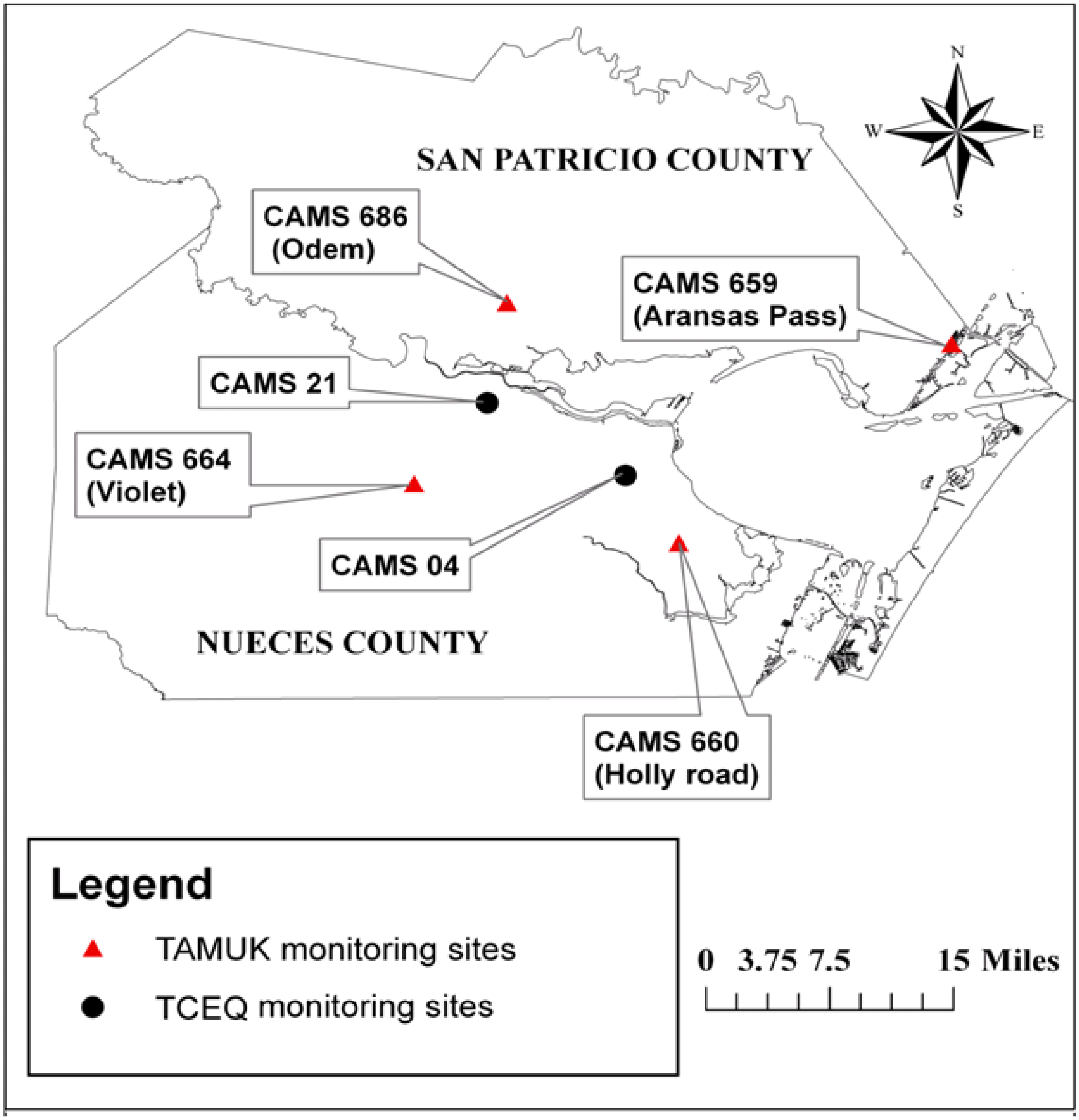

Figure 1. Map showing the location of monitoring sites in the Corpus Christi urban airshed.

A detailed report on the conceptual modeling of high ozone episodes based on the analysis of pollutant data acquired through monitoring will help provide the stake holders with pertinent information such as air pollution trends, meteorological conditions influencing the study region and associate major regional sources contributing to the elevated levels of ozone measured in the study region. The data analysis will also assist in the identification of high ozone episodes for photochemical modeling which can be further used to assess the effectiveness of emission control strategies.

This report is a comprehensive conceptual modeling report for the urban airshed through the ozone season of 2014. It includes detailed data analysis performed using measured eight hour ozone concentrations and meteorological parameters measured at the TCEQ maintained compliance grade monitoring stations and UNT-TAMUK maintained research grade monitoring stations.

As per TCEQ guidelines, the primary objective was to revise and enhance conceptual modeling report for the Corpus Christi urban airshed. The tasks accomplished as a part of the conceptual modeling report are listed below -

- Evaluate the wind speeds, directions and time of day associated with high ozone events to determine the local conditions and source alignments most frequently associated with high ozone events;
- Develop 24-hour back trajectories to determine source regions most (and least) likely to affect local area ozone;
- Conduct weekday/weekend analysis to evaluate the potential effectiveness of reduced levels of local and industrial and mobile source activity on their area;
- Evaluate the range and average background ozone concentrations associated with local wind directions;
- Investigate ozone and precursor trends and estimate the annual frequency of high ozone days at varying standard levels (above); and
- Address additional relevant questions listed in Section 11.1.1 of U.S. EPA's ozone modeling guidance document, "*Guidance on the use of models and other analysis to demonstrating attainment of air quality goals for ozone,* $PM_{2.5}$ *and regional haze*".

Section 2.0 of this report highlights the analysis of pollutant and meteorological data measured at the compliance and research grade monitoring stations spatially located in the urban airshed. Section 3.0 illustrates the meteorological characteristics of high ozone days and episodes affecting this region. Section 4.0 summarizes the characteristics of recent high ozone episodes observed through 2013 and 2014.

2.0 AIR QUALITY DATA ANALYSIS

Investigate ozone and precursor trends and estimate the annual frequency of high ozone days at varying standard levels

The U.S. Environmental Protection Agency (EPA) has revised the primary and secondary NAAQS for ozone to 0.075 ppm effective March 27, 2008. During 2010 based on the scientific studies U.S. EPA considered further revision of NAAQS set for ground level ozone under Clean Air Act (1970). Ozone levels of 70 ppb, 65 ppb, and 60 ppb are the proposed NAAQS standards being considered. To investigate the air quality trends and estimate the frequency of high ozone days exceeding the existing ozone NAAQS and proposed standards ambient data including eight hour ozone concentrations and concurrent meteorological data measured at the four research grade (non-compliance) monitoring sites (Holly road – CAMS 660, Aransas Pass – CAMS 659, Violet – CAMS 664, and Odem – CAMS 686) that are maintained by the UNT-TAMUK team along with the data from the two compliance grade monitoring sites (CAMS 04 and CAMS 21) maintained by TCEQ during 2014 and 2015 were acquired.

2.1 DESIGN VALUE TREND

The trend of the fourth highest eight hour ozone concentrations along with the design values (three year average of the fourth highest eight hour ozone concentrations) observed at CAMS 04 and CAMS 21 during 2002 through 2014 are shown in Figure 2. The urban airshed is in attainment with current ozone NAAQS, however considering proposed revisions of 70 ppb, 65 ppb and 60 ppb the airshed will be slightly or marginally in nonattainment status. As shown in Figure 2, with continued effort by local industries and small business in implementing effective emission control strategies, an overall decrease in the ozone design values from 2002 through 2014 with a year-to-year variability was noted.

A significant drop of 16 ppb was observed in the fourth highest eight hour ozone concentrations measured at CAMS 04 during 2002 to 2005 followed by a net increase of 2 ppb from 2005 through 2007 (increase of 5 ppb from 2005 through 2006 and decrease by 3 ppb from 2006 through 2007). A further decrease of 6 ppb was observed from 2007 through 2009 followed by net increase of 11 ppb from 2009 through 2011. In the recent years from 2011 through 2014 a drop of 10 ppb was observed as shown in Figure 2. An overall decrease of 14 ppb was observed in the ozone design values from 2002-2004 through 2012-2014. However detailed analysis of the ozone design values from 2007-2009 through 2010-2012 an increase of 5 ppb was recorded followed by a drop of 6 ppb.

At CAMS 21 a net decrease of 10 ppb was observed in the fourth highest eight hour ozone concentrations measured during 2002 through 2009 (decrease of 11 ppb from 2002 through 2006 followed by increase of 6 ppb from 2006 through 2008 and a subsequent decrease of 5 ppb during 2009). An increase of 10 ppb was observed from 2009 to 2011 and during 2012 the fourth highest eight hour ozone concentrations reduced by 13 ppb followed by a slight increase through 2014 (1 ppb). These variations in fourth highest eight hour ozone concentrations showed an overall decrease of 9 ppb in the design values from 2002-2004 to 2012-2014. As shown in Figure 2 gradual decrease in design values was noted for this site from

2002-2004 to 2005-2007 followed by an increasing through 2009-2011. A drop in 7 ppb was observed in the ozone design value from 2009-2011 to 2012-2014.

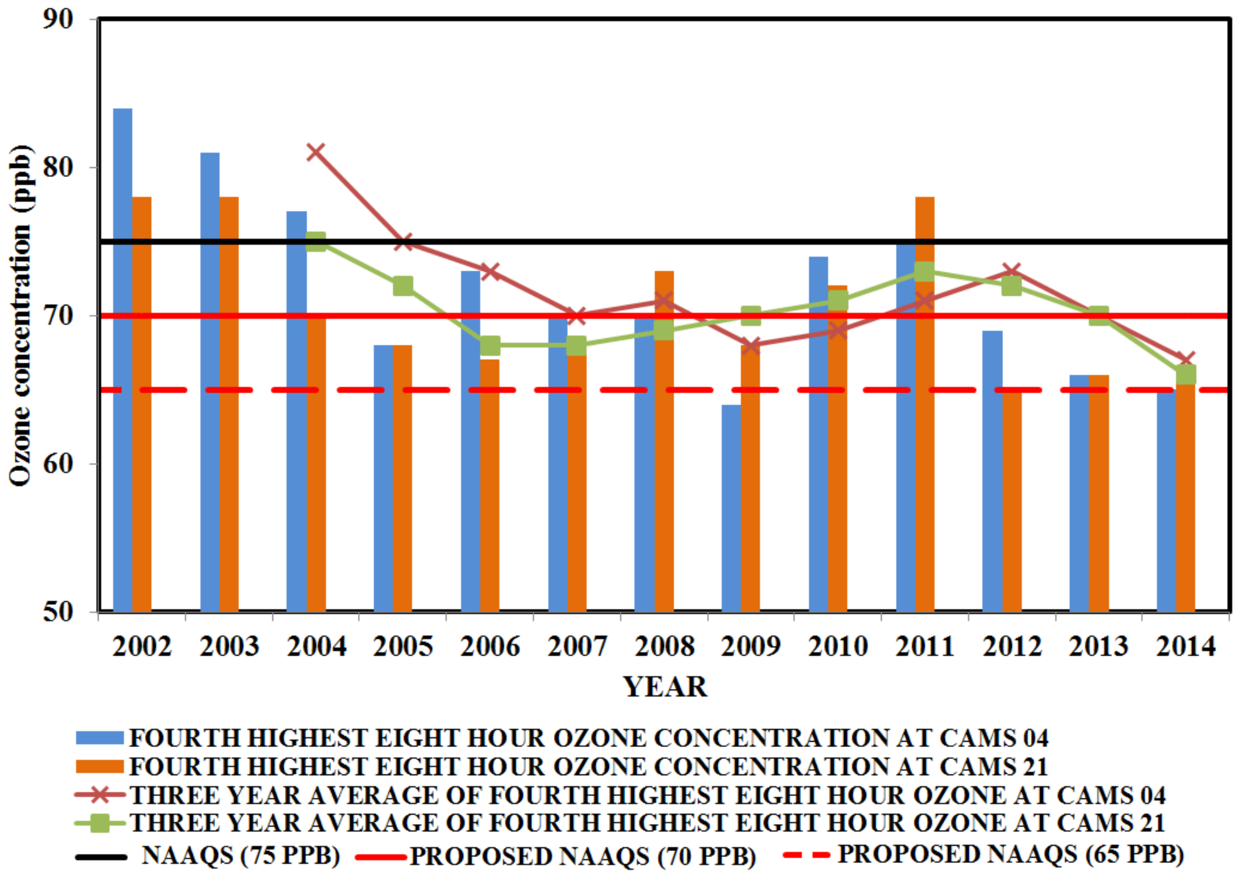

Figure 2. Ozone design value trend observed at the TCEQ maintained compliance grade monitoring sites CAMS 04 and CAMS 21 from 2002 through 2014.

Continuous measurements of ozone concentrations for the four research grade non-compliance monitoring stations were available since 2006 and thus, similar analysis of design value trends was performed for time period of 2006 through 2014 as shown in Figure 3. The fourth highest eight hour ozone concentrations measured at the research grade monitoring stations exhibited year to year variations similar to compliance grade monitoring stations. CAMS 660 surrounded by residential neighborhood and downwind site – CAMS 664 exhibited a decreasing trend of ozone design values from 2006-2008 to 2008-2010. An increase of 2 ppb in the ozone design values was recorded at CAMS 660 during 2009-2011 through 2011-2013 followed by a decrease of 3 ppb through 2012-2014. The downwind site – CAMS 664 recorded a drop of 3 ppb in ozone design values from 2006-2008 through 2007-2009 followed by increase of 3 ppb through 2009-2011. An overall decrease of 5 ppb in ozone design values measured at CAMS 664 during 2009-2011 through 2012-2014 was noted as shown in below Figure 3. The ozone design values recorded at Odem – CAMS 686 showed an gradual increasing trend from 2007-2009 through 2010-2012 followed by significant drop of 7 ppb through 2012-2014. The upwind site in Aransas Pass county – CAMS 659 also recorded an overall decrease in ozone design values during 2006-2008 through 2012-2014. The ozone design values from 2006-2008 through 2008-2010 were stabilized at 75 ppb followed by a increase of 1 ppb during 2009-2011. The ozone design value stabilized at 76 ppb through 2010-2012 followed by a significant drop of 9 ppb through 2012-2014.

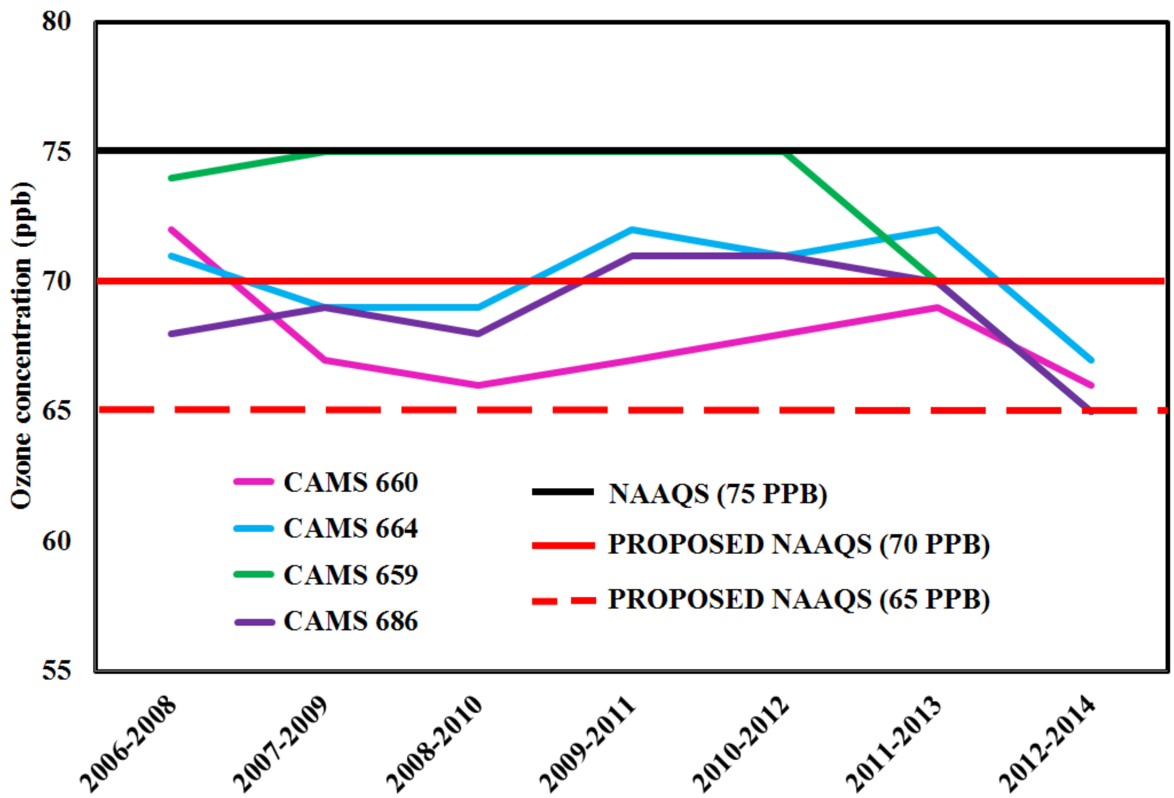

Figure 3. Ozone design values observed at the non-compliance research grade monitoring stations maintained by TAMUK during 2006 through 2014.

Thus, as demonstrated by design value trends of both compliance and research grade monitoring sites the airshed is currently in attainment of ozone NAAQS. However, recent variations noted in the design value put the urban airshed in jeopardy of violating the potential ozone NAAQS of 70 ppb marginally and both 65 ppb and 60 ppb moderately. The ozone design values observed at the research grade non-compliance monitoring stations including urban residential site – CAMS 660, downwind site – CAMS 664, upwind site – CAMS 659 and Odem site – CAMS 686 as shown in Figure 3 were also in compliance with the current NAAQS but by a slight margin and in non-attainment considering potential ozone NAAQS of 70 ppb, 65 ppb and 60 ppb. Elevated levels of ozone design values at the upwind site in Aransas Pass – CAMS 659 and CAMS 686 indicate greater influence of regional sources on the urban airshed in addition to local sources. Such impact of additional sources would affect attainment status of the urban airshed.

2.2 ANNUAL TRENDS

As demonstrated by the design value trend analysis, the Corpus Christi urban airshed is currently in attainment of the current ozone NAAQS by a slight margin. Additional statistical analysis was performed to study the annual and seasonal frequency of occurrence of ozone exceedances at both the TCEQ and the TAMUK maintained monitoring sites. The trend of annual exceedance days measured at the compliance grade monitoring stations, CAMS 04 and CAMS 21, during 2002 through 2014 based on the existing ozone NAAQS (75 ppb) and potential standards of 70 ppb, 65 ppb, and 60 ppb are shown in Figures 4 and 5.

As shown in Figures 4 and 5, both the compliance grade monitoring stations demonstrated a decrease in the annual frequency of days exceeding the current ozone NAAQS from 2002 through 2004. During 2005 zero exceedance days were observed at both CAMS 04 and CAMS 21 followed by 1 to 3 exceedances during 2006 and 2007. At CAMS 04 zero exceedances were recorded during 2008 while CAMS 21 recorded 3 days. Zero exceedance days were recorded during 2009 followed by a gradual increase to 5 days in 2011. A significant drop in the exceedance days was noted through 2012 at both compliance grade monitoring stations. In 2013 and 2014, zero exceedance days were recorded at both sites considering the current ozone NAAQS.

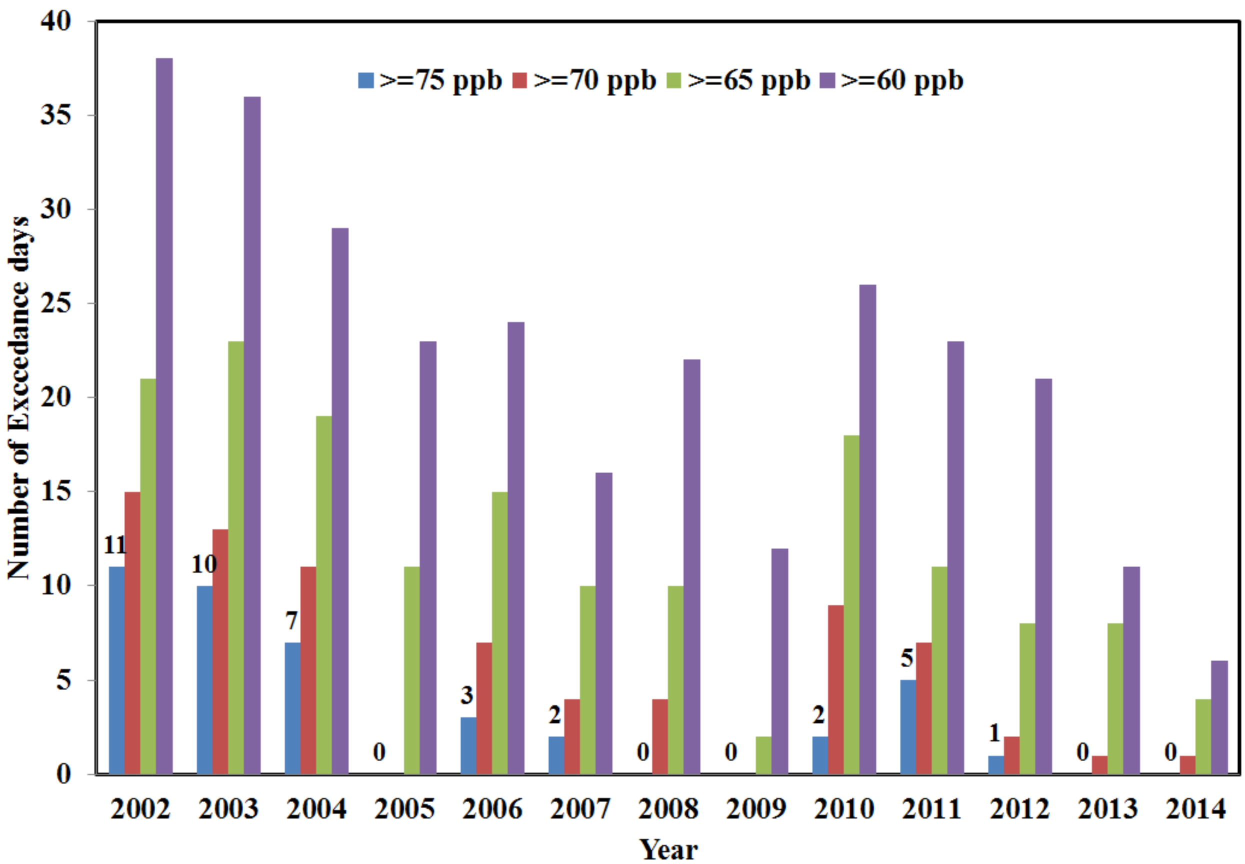

Figure 4. Annual frequency of ozone exceedance measured at CAMS 04 during 2002 through 2014.

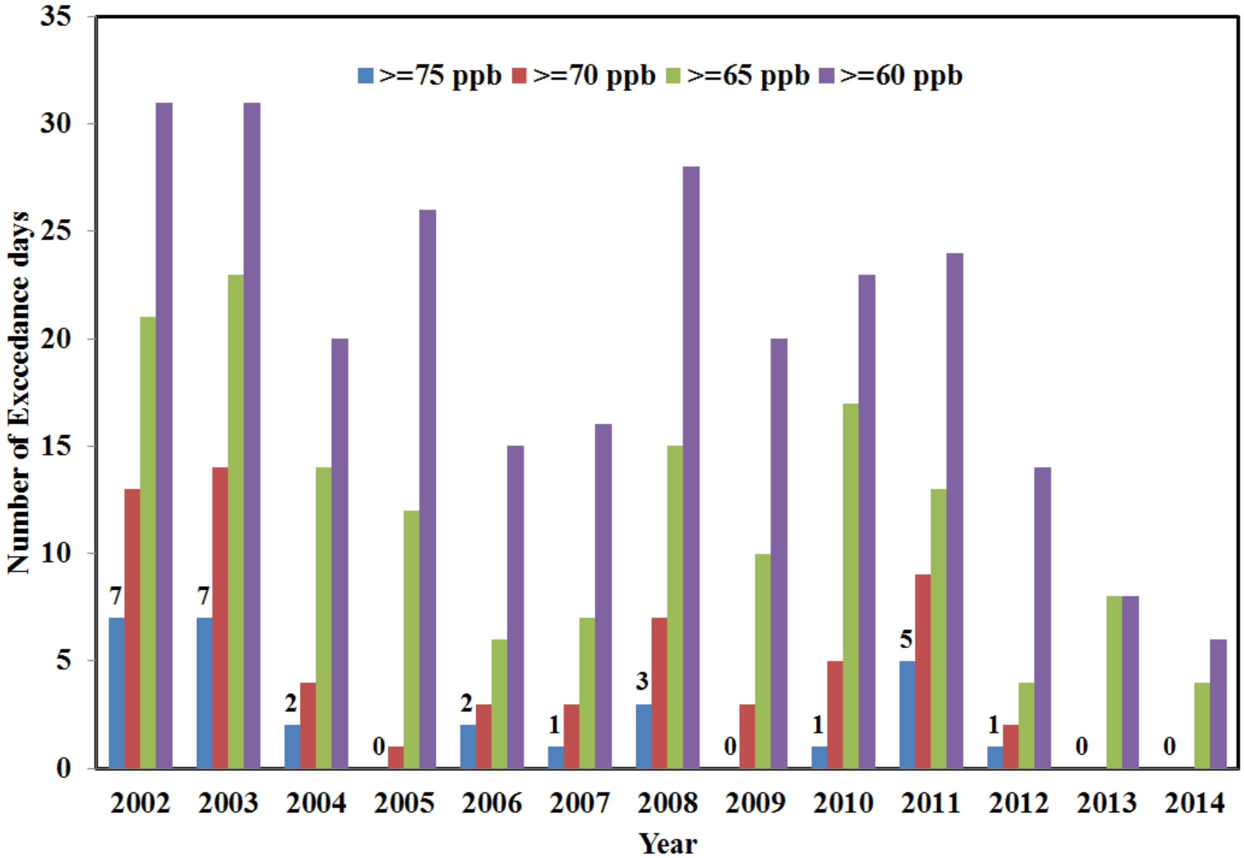

Figure 5. Annual frequency of ozone exceedances measured at CAMS 21during 2002 through 2014.

<u>Ozone concentrations exceeding 70 ppb:</u> The annual frequency of days with the 8-hour averaged ozone concentration exceeding 70 ppb at CAMS 04 exhibited an intermittent decreasing trend (2002 - 2004, 2006 - 2008 and 2010 – 2014). During the years of 2005 and 2009 zero exceedance days were recorded at CAMS 04, followed by a significant increase in 2010. Since 2010 (9 days) a gradual decreasing trend was observed through 2013 (1 day) and 2014 (1 day). At CAMS 21, the overall trend showed a decrease as noted at CAMS 04 but with a significant year-to-year variability. Over the recent years starting from 2012 through 2014 a gradual decrease in ozone exceedances was observed with zero days in 2014.

<u>Ozone concentrations exceeding 65 ppb:</u> The annual frequency of days with the 8-hour averaged ozone concentration exceeding 65 ppb at CAMS 04 and CAMS 21 also showed an overall decreasing trend through 2009. At CAMS 04 a significant increase in exceedance days was observed from 2009 to 2010 accounting for eighteen days while a decrease was observed from 2009 to 2010 followed by decreasing trend through 2014. In 2013 and 2014 a total of eight and four exceedance days were recorded at CAMS 04. At CAMS 21 an increase of seven exceedance days was observed from 2009 to 2010 followed by decreasing trend through 2012. A considerable increase in the exceedance days was observed from 2012 (4 days) to 2013 (8 days) followed by a decrease in 2014 (4 days).

<u>*Ozone concentrations exceeding 60 ppb:*</u> An overall decrease was noted in the frequency of days with the 8-hour averaged ozone concentrations exceeding 60 ppb at both CAMS 04 and 21 during 2002 through 2014. A significant increase in frequency of days exceeding 60 ppb was observed at CAMS 04 from 12 days during 2009 to 26 days in 2010 followed by a decreasing trend through 2014 as shown in Figure 4. The annual exceedance days at CAMS 21 as shown in Figure 5 also exhibited a decreasing trend from 2002 through 2007 followed by an increase in 2008. From 2009 through 2011 an increase in exceedance days was observed followed by a significant drop in 2012 through 2014 (6 days).

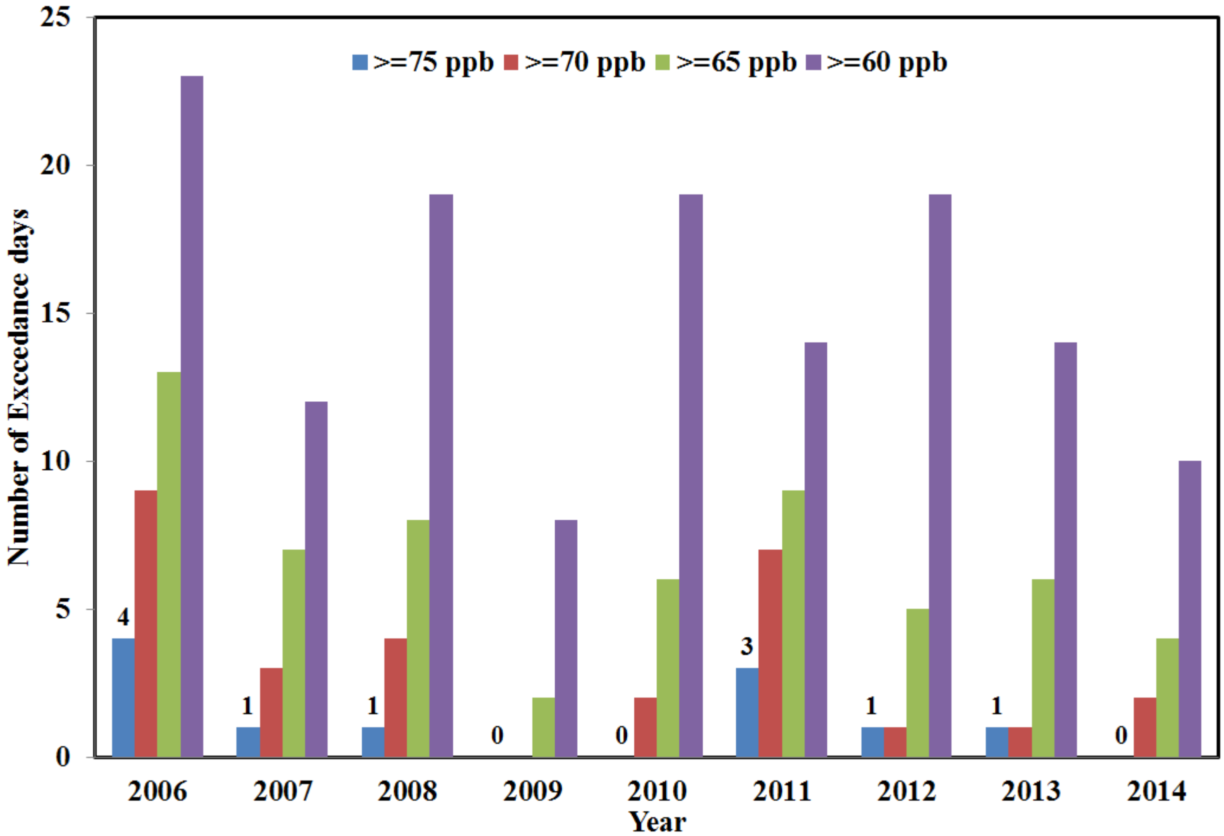

Figure 6. Annual frequency of ozone exceedances measured at Holly road site – CAMS 660 during 2006 through 2014.

A similar statistical analysis of annual exceedance days considering the current NAAQS of 75 ppb as well as the three potential ozone standards of 70 ppb, 65 ppb and 60 ppb was performed using the ozone concentrations measured at the non-compliance research grade monitoring stations during 2006 through 2014. As shown in below Figure 6 at the urban site – CAMS 660, a decrease in days exceeding current NAAQS was observed from 2006 through 2010. During 2011 a total of three days exceeding current NAAQS were recorded while during 2012 and 2013 only one day was recorded. Zero exceedance days were recorded during 2014 as shown in Figure 6. Days exceeding potential levels of 70 ppb and 65 ppb also exhibited an overall decrease from 2006 through 2009 followed by considerable increase in 2011. A considerable drop to 1 episode day was noted from 2011 through 2013 followed by an increase to 2 days during 2014 as shown in Figure 6. Exceedance days considering the potential level of 60 ppb also exhibited an overall decreasing trend from 2006 through 2009 followed by significant increase in 2010. A constant variability by ± 5 days was observed during 2010 through 2013 and a drop of 4 days in year 2014.

During 2006 and 2007 two days exceeding current NAAQS were recorded at the downwind site – CAMS 664. A gradual increase was noted from 2006 through 2008 followed by zero exceedances during 2009. From 2009 through 2011 a gradual increase in the exceedance days was observed with a drop of 4 in 2012. During 2013 only one day exceeding current NAAQS was observed while zero exceedance days were recorded during 2014 as shown in Figure 7. Frequency of days exceeding potential levels of 70 ppb and 65 ppb exhibited similar annual trends as noted at the urban site – CAMS 660. The days exceeding potential level of 60 ppb exhibited an overall decreasing trend from 2006 through 2014 with varying trends from year to year.

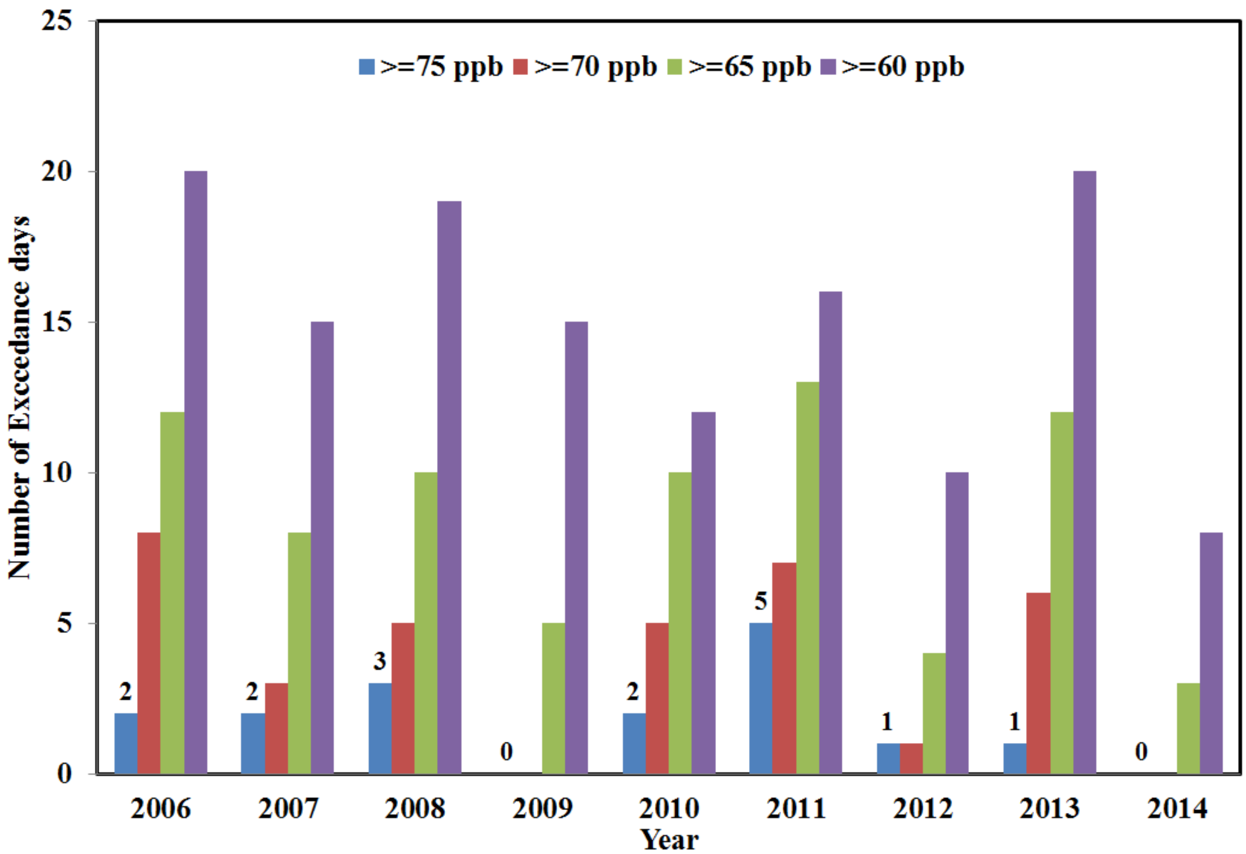

Figure 7. Annual frequency of ozone exceedances measured at downwind site – CAMS 664 during 2006 through 2014.

Annual frequency of exceedance days considering the current NAAQS recorded at the upwind site in Aransas Pass – CAMS 659 exhibited increasing trend over three year period from 2006 through 2008 and 2009 through 2011. Total of nine days exceeding current NAAQS were observed during 2011 with a significant drop to two days in 2012 and zero days in 2013. Frequency of days exceeding potential level of 70 ppb exhibited similar year to year variability as those exceeding current NAAQS with zero exceedance days during 2013 and 2014 as shown in Figure 8. Annual frequency of days exceeding potential levels of 65 ppb and 60 ppb exhibited an increasing trend over three year period of 2006 through 2008, 2009 through 2012 as noted for current NAAQS exceedances. A significant drop in exceedance days was observed from 2012 through 2013 proceeded by an significant increase of 5 to 6 exceedance days during 2014.

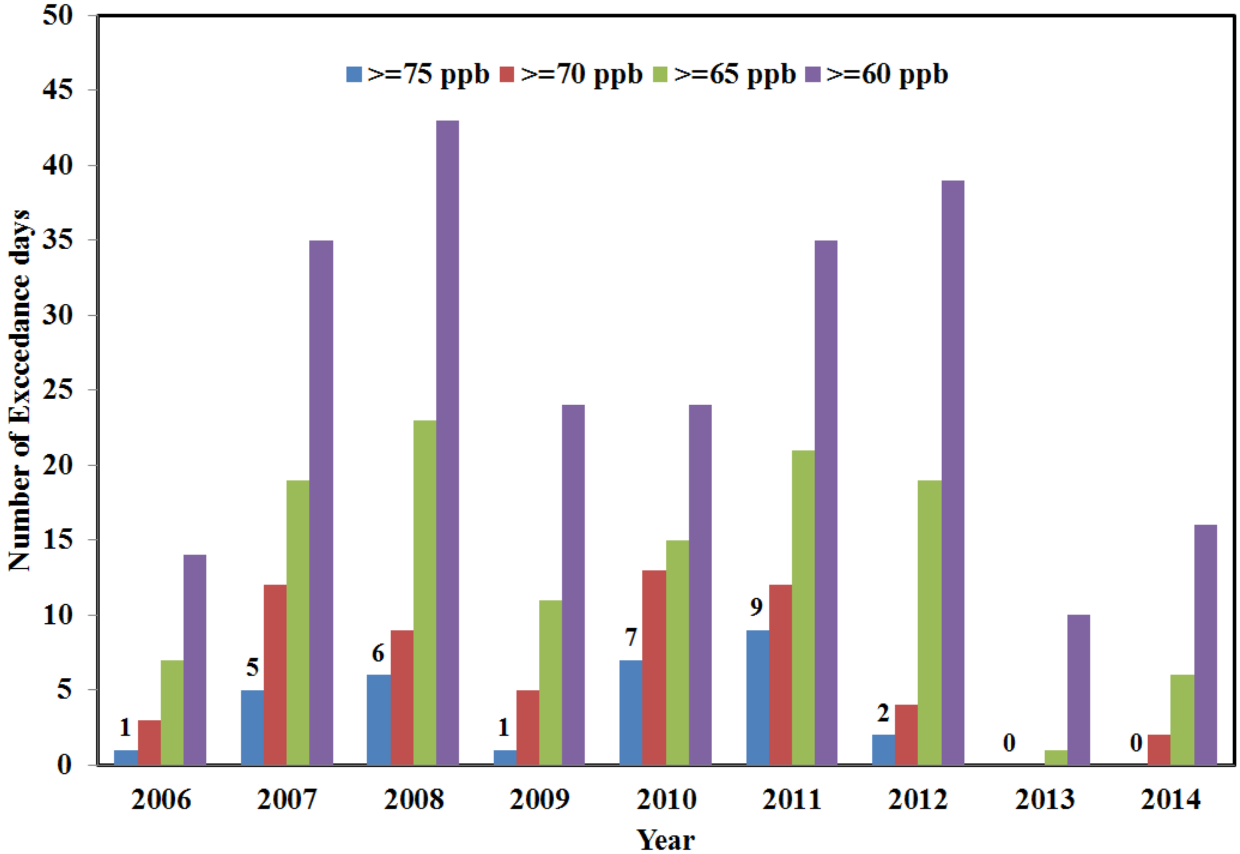

Figure 8. Annual frequency of ozone exceedance days measured at upwind site – CAMS 659 during 2006 through 2014.

At Odem – CAMS 686 Annual frequency of days exceeding current NAAQS exhibited an increasing trend from 2007 through 2008 and 2010 through 2011 with zero exceedance days during 2009. As shown in Figure 9 a significant drop in the days exceeding current NAAQS was noted from 2011 to 2012 (1 day) and zero exceedance days during 2013 and 2014. An overall increase in the days exceeding potential level of 70 ppb was noted from 2007 through 2010 with zero days during 2009. During 2009 through 2012 a gradual drop in the exceedance days (potential level of 70 ppb) was observed. A dissimilar trend of increase was noted from 2012 to 2014 as shown in Figure 8. Annual frequency of days with eight hour ozone concentrations exceeding potential level of 65 ppb and 60 ppb exhibited a bi-modal distribution with maximum exceedances during 2008, 2010 and 2011 as shown in Figure 9. Days exceeding potential levels of 65 ppb and 60 ppb also exhibited an alternative significant drop and increase during 2011 through 2014 as noted in those exceeding potential level of 70 ppb.

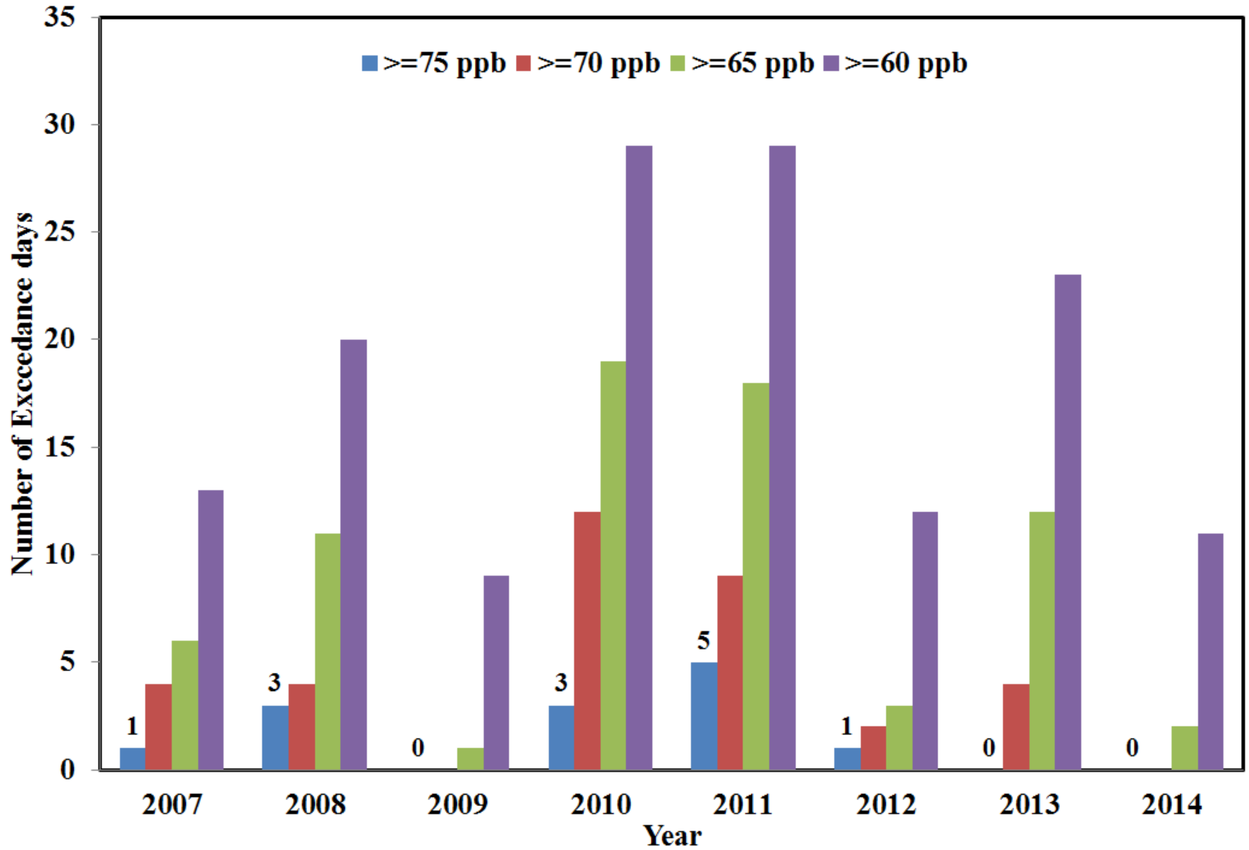

Figure 9. Annual frequency of ozone exceedance days measured at Odem – CAMS 686 during 2007 through 2014.

As demonstrated by exceedance days trends at both TCEQ and UNT-TAMUK sites during 2013 (Figure A-1) and 2014 (Figure A-2) only two days exceeding current NAAQS was recorded at urban site – CAMS 660 and one at both downwind site – CAMS 664 and upwind site – CAMS 659 . Highest number of days exceeding potential levels of 70 ppb was recorded at downwind site – CAMS 664 during 2013, while those exceeding potential levels of 65 ppb and 60 ppb were recorded at CAMS 686 – Odem site. During 2014, upwind site in Aransas Pass – CAMS 659 recorded highest number of days exceeding potential levels of 70 ppb, 65 ppb and 60 ppb. With the detailed knowledge of annual exceedance frequency trends observed during 2002 through 2014 at the TCEQ sites and 2006 through 2014 at the UNT-TAMUK sites further study of seasonal variations in the exceedance days was performed.

2.3 MONTHLY VARIATIONS

The monthly variations in days exceeding current NAAQS as well as potential levels of 70 ppb, 65 ppb and 60 ppb recorded at both TCEQ and UNT-TAMUK maintained sites were studied to further assess the influence of seasonal variations. The eight hour ozone concentrations measured at TCEQ sites during 2002 to 2014 were used for the analysis and results are shown in Figures 10 through 11.

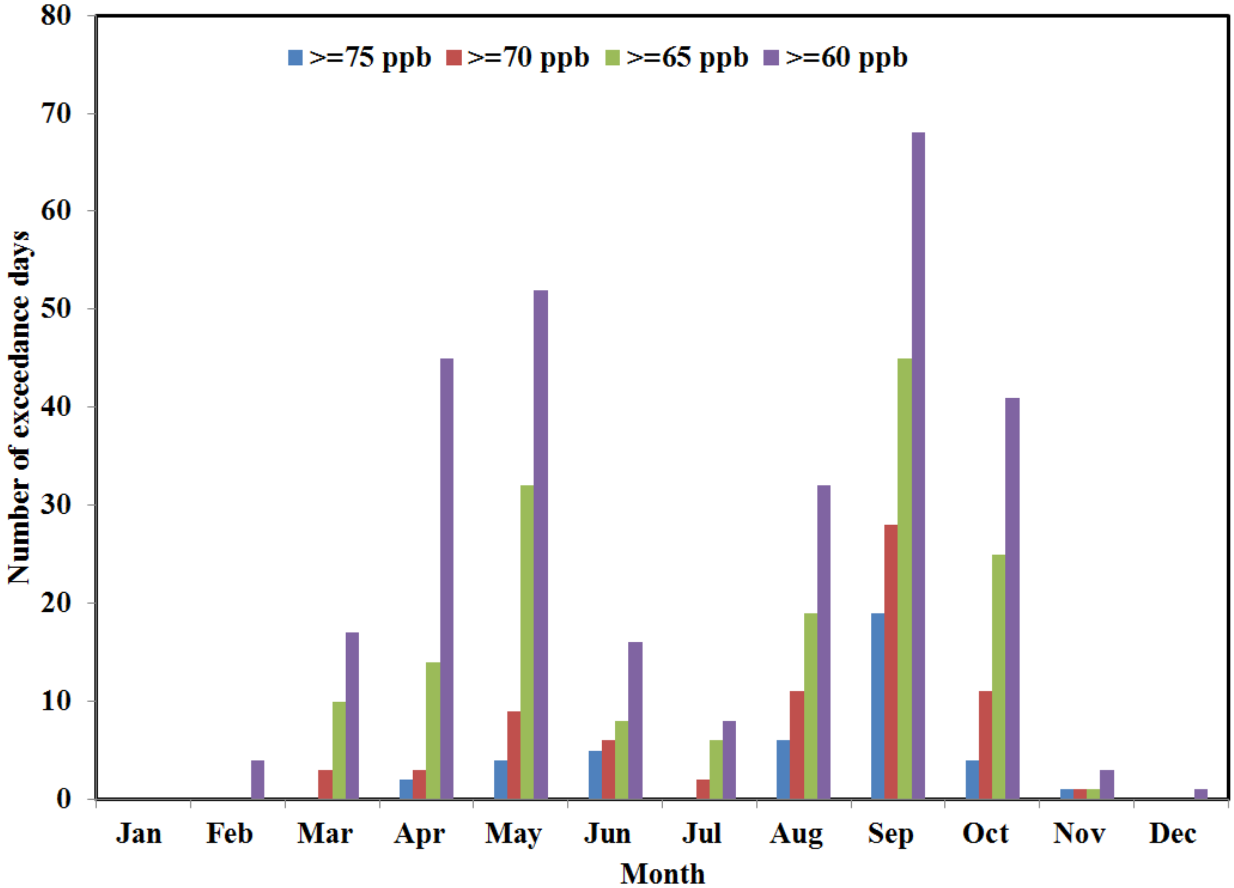

Figure 10. Monthly variations in frequency of exceedance days observed at CAMS 04 during 2002 through 2014 considering the current NAAQS and the three proposed levels.

Historically fewer exceedance days were recorded in Corpus Christi during the hottest summer months of June and July. This was distinctly different than observed in other urban areas within the continental U.S. Such behavior could be primarily attributed to the fast-moving coastal winds in South Texas that rapidly dilute the urban atmosphere and disperses the pollution levels without any significant stagnation events. However, as shown in the above Figure 10 a considerable number of days exceeding current NAAQS were recorded during June. Highest number of exceedances were recorded during September with considerable numbers in April, May, August, and October. Frequency of days exceeding potential levels of 70 ppb, 65 ppb and 60 ppb exhibited a bi-modal distribution with peak months being May and September as shown in Figure 10 with significant levels of exceeding days during March, April, August, and October.

At CAMS 21 distribution of days exceeding current NAAQS similar to that observed at CAMS 04 was noted with highest in September and significant exceedances during May, June, August and October as shown in Figure 11. Days with eight hour ozone concentrations exceeding potential levels of 70 ppb, 65 ppb and 60 ppb exhibited a similar bi-modal distribution with highest frequency during May and September along with significant exccedances during other months of the ozone season including March, April, June, July, August and October.

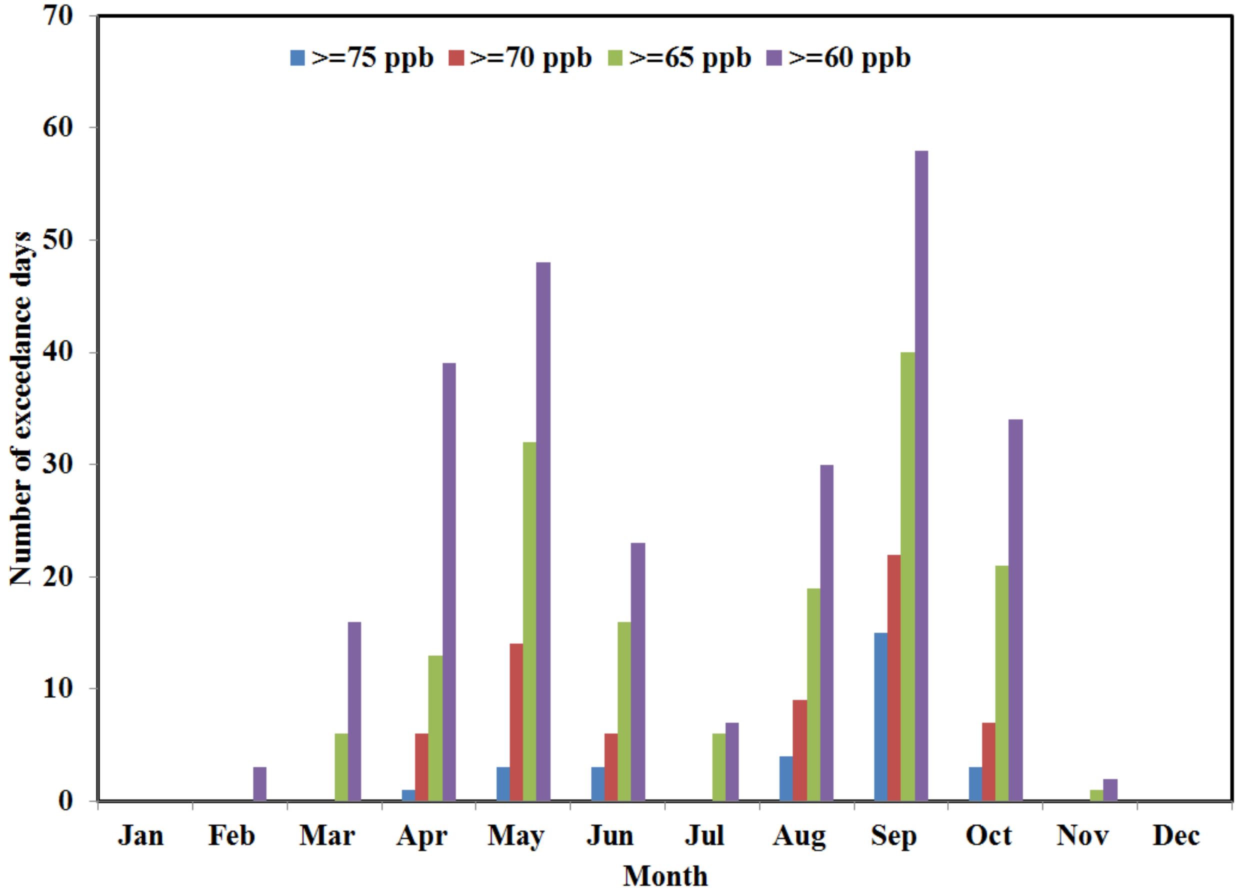

Figure 11. Monthly variations in frequency of exceedance days observed at CAMS 21 during 2002 through 2014 considering the current NAAQS and the three proposed levels.

Similar analysis of monthly variations was performed for the non-compliance research grade monitoring stations including urban site – CAMS 660, upwind site – CAMS 659, downwind site – CAMS 664 and CAMS 686 using the daily maximum eight hour ozone concentrations measured during 2006 through 2014. Figures 12 through 15 demonstrate the monthly variations at each site considering the current NAAQS as well as potential standards of 70 ppb, 65 ppb and 60 ppb.

As shown in Figure 12 at the urban site – CAMS 660 highest number of exceedance days based on the current NAAQS were recorded during September with significant counts in March, June, and August. Highest number of days exceeding potential standard of 70 ppb were recorded in September while during March, May, June, August, and October significant numbers were recorded. Few episode days were also recorded during April and November. Days with eight hour ozone concentration exceeding potential level of 65 ppb and 60 ppb exhibited a bi-modal distribution as shown in Figure 12 with the highest in months of April and September with a significant number in March, May, June, August and October. Few episode days were also recorded in July and November months.

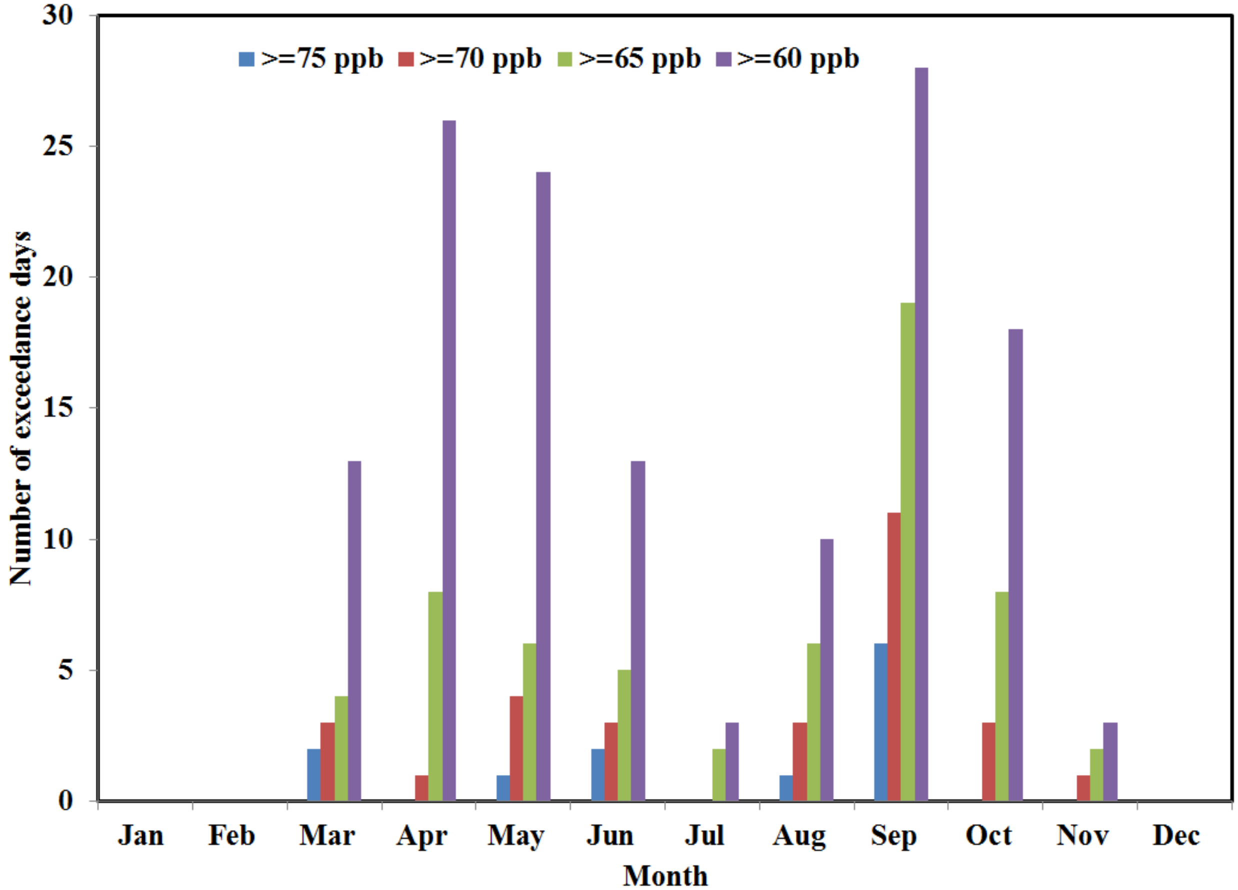

Figure 12. Monthly variations in frequency of exceedance days observed at CAMS 660 during 2006 through 2014 considering the current NAAQS and the three proposed levels.

Days exceeding current NAAQS exhibited a bi-modal distribution (Figure 13) at downwind site – CAMS 664 with peak numbers in June and September. Significant number of exceedance days were recorded during May, June, August and October. As shown in Figure 13 the highest number of days exceeding potential level of 70 ppb was recorded during September with significant numbers in May, June, July, August and October. Few exceedance days were also recorded during November. Bi-modal distribution of exceedance days considering potential levels of 65 ppb and 60 ppb were observed at the downwind site – CAMS 664 (Figure 13) with highest numbers during May and September as noted historically. Considerably significant number of exceedances were recorded during spring months of March, April, summer months of June, July and August along with Fall months of October and November.

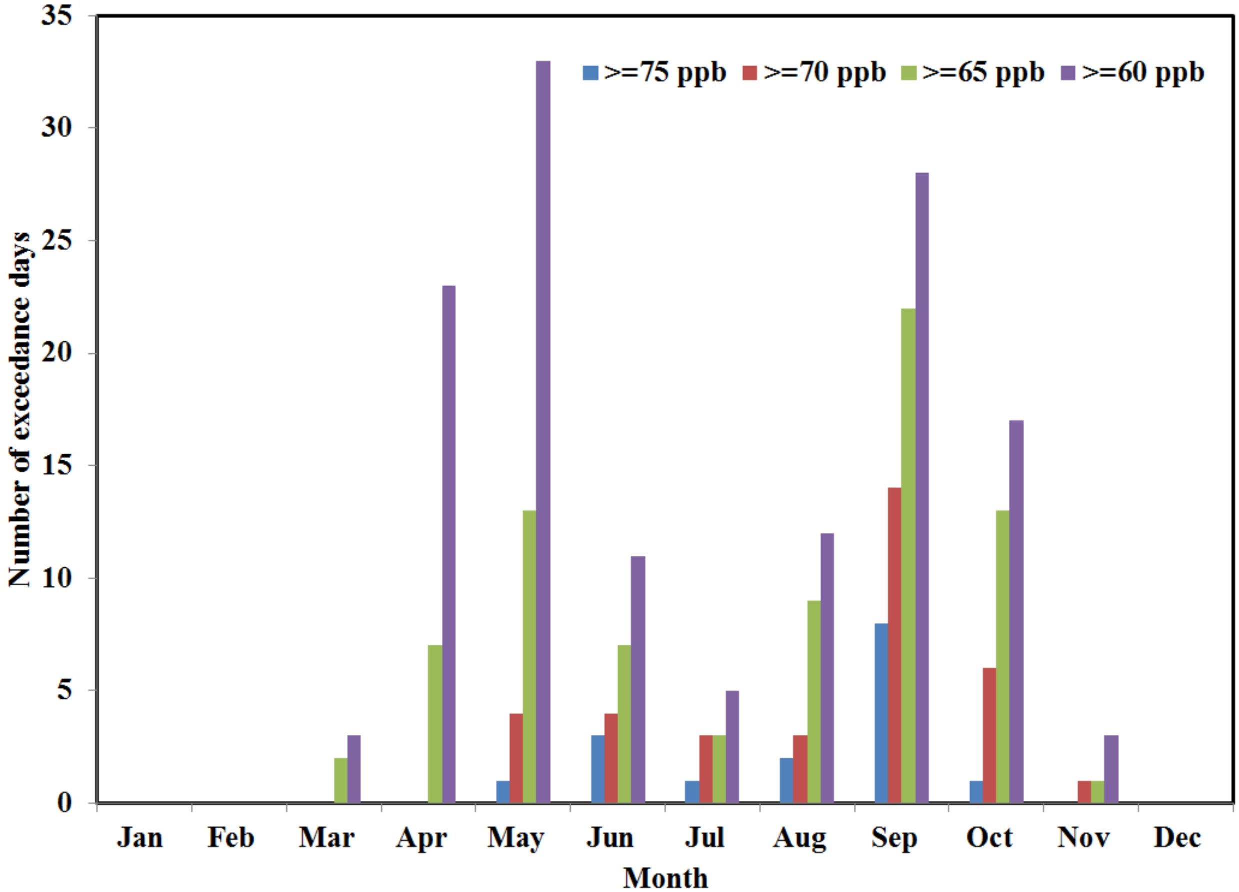

Figure 13. Monthly variations in frequency of exceedance days observed at CAMS 664 during 2006 through 2014 considering the current NAAQS and the three potential levels.

At the upwind site – Aransas Pass (CAMS 659) frequency of days exceeding current NAAQS and potential levels of 70 ppb observed during 2006 through 2014 demonstrated a bi-modal distribution with the highest frequency during May and September as shown in Figure 14. Significant numbers were recorded during April, August and October along with fewer days during June and November. Monthly frequency of days with ozone concentrations exceeding potential levels of 65 and 60 ppb exhibited a bi-modal distribution with the highest number of days during April and September. Significant count of days were also recorded during the remainder of month including March, May, June, August, October, November and December.

At CAMS 686 days exceeding current NAAQS exhibited bi-modal distribution with peak during May and September followed by significant numbers during April, August, and October (Figure 15). Fewer days were recorded during March, June and November as shown in Figure 15. Days exceeding potential level of 70 ppb also exhibited trend similar to those exceeding current NAAQS as shown in Figure 15. Considering the potential levels of 65 ppb and 60 ppb a bi-modal distribution of ozone exceedance days was observed with peak numbers during April and September. Significant number of exceedances was recorded during March, May, June, August, October and November while during February, July and December few episode days were recorded.

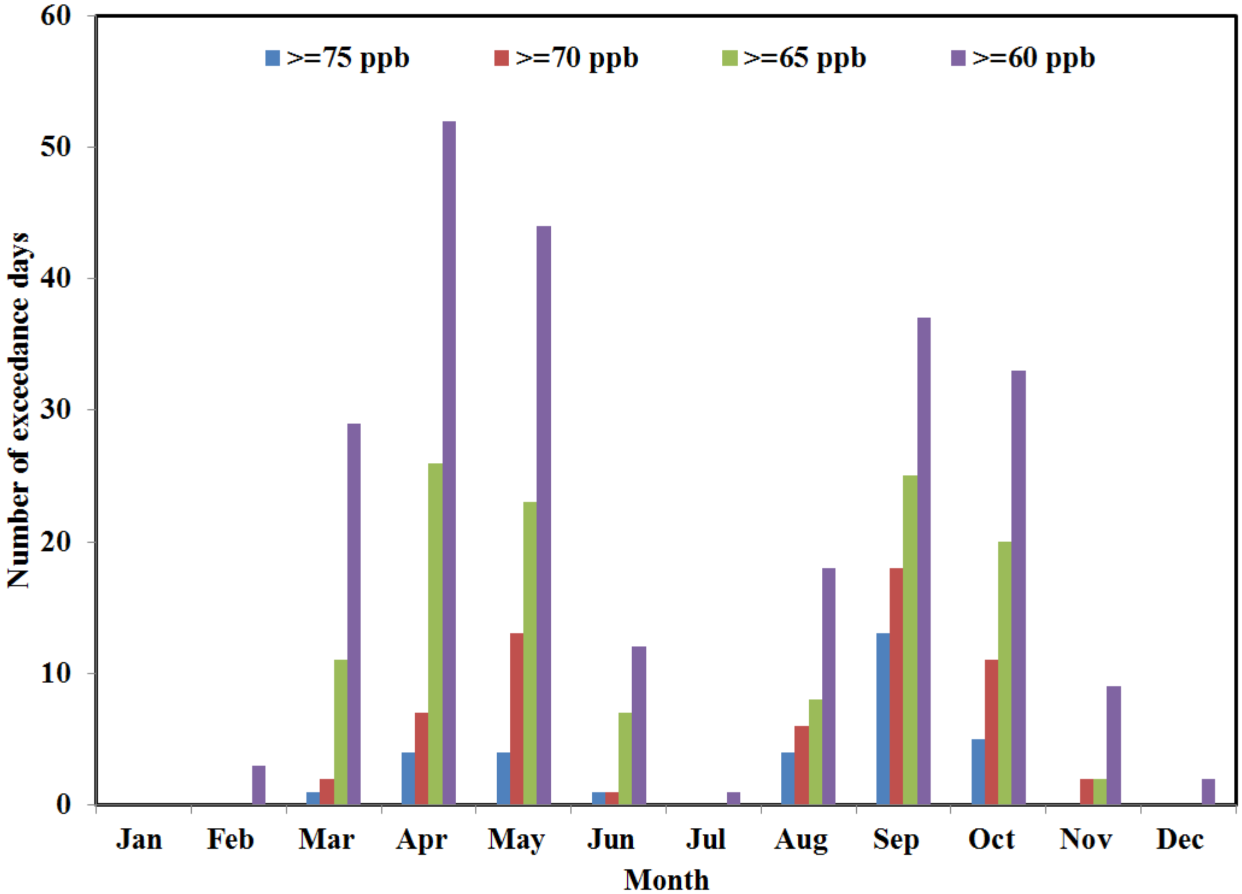

Figure 14. Monthly variations in frequency of exceedance days observed at CAMS 659 during 2006 through 2014 considering the current NAAQS and the three proposed levels.

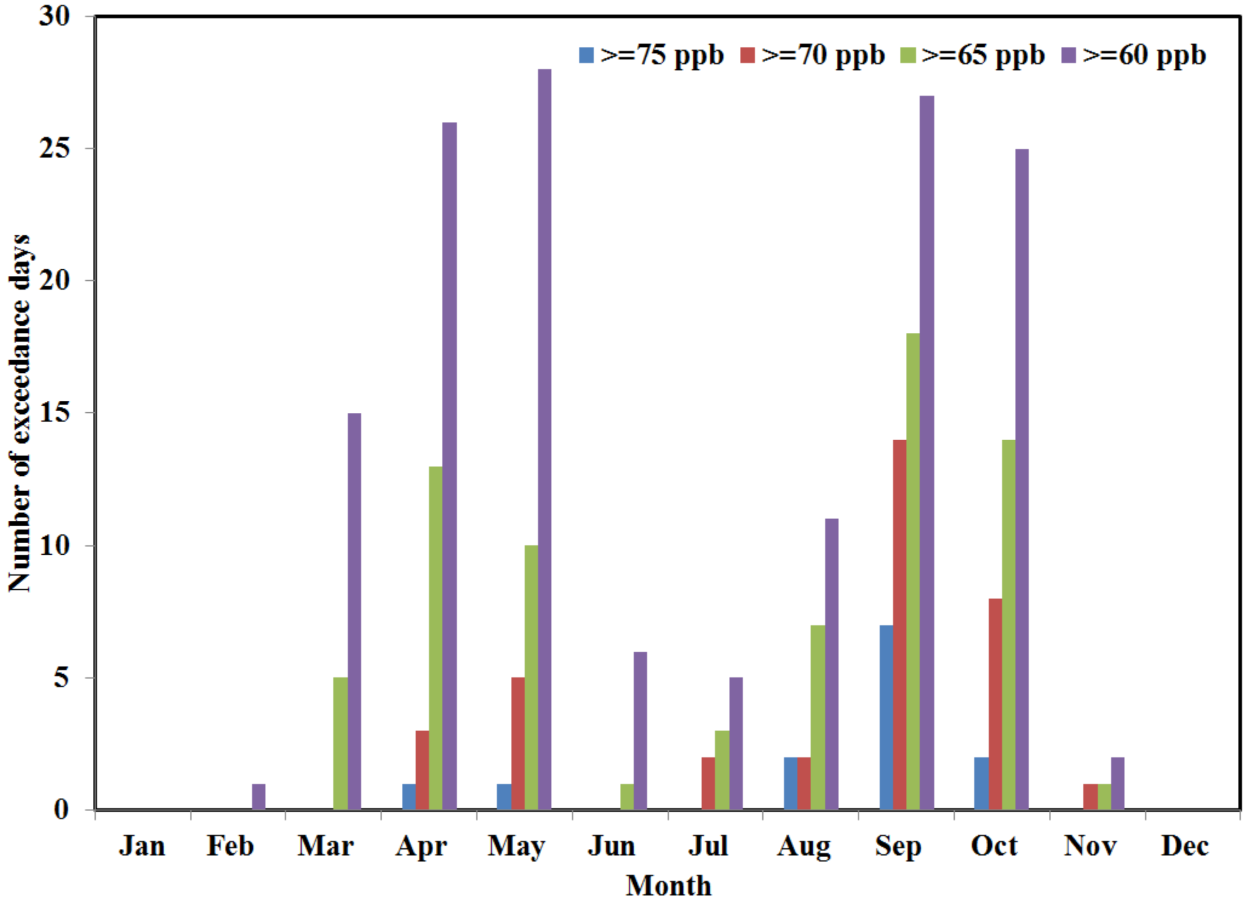

Figure 15. Monthly variations in frequency of exceedance days observed at CAMS 686 during 2007 through 2014 considering the current NAAQS and the three proposed levels.

As shown in the above analysis varying seasonal trends have been observed during 2002 through 2014 at TCEQ and 2006 through 2014 at UNT-TAMUK maintained monitoring stations. Seasonal variations in specific to 2013 and 2014 observed at the TCEQ and TAMUK sites are shown in Figures A-3 and A-14 of Appendix. As demonstrated by Figure A-2 zero days exceeding current NAAQS were recorded at CAMS 04 during 2013 and 2014 while one day was recorded during March of 2013 exceeding potential level of 70 ppb. Considering the potential levels of 65 ppb two episode days were recorded during July, August and September while only one day was recorded in March and October of 2013. In 2014 two days of exceedance were recorded in May exceeding 65 ppb and 60 ppb while one day was recorded during September exceeding 60 ppb. In October one day exceeding 70 ppb were noted while two and three days exceeding 65 ppb and 60 ppb were recorded as shown in Figure A-4. At CAMS 21, during 2013 zero days were recorded exceeding the current NAAQS as well as potential level of 70 ppb while highest number of days exceeding potential level of 65 ppb and 60 ppb were recorded in July (Figure A-5). During 2014 (Figure A-6) only two days exceeding 65 ppb and 60 ppb were recorded during May and October.

As shown in Figure A-7 during 2013, one day exceeding current NAAQS and potential level of 70 ppb was recorded in March at urban site – CAMS 660. Similar to compliance grade monitoring stations highest number of days exceeding potential level of 65 ppb were recorded during July along with one day during March, April, September and October. During March highest number of days exceeding potential level of 60 ppb was recorded with significant numbers in April, July and September. During 2014 one day exceeding current NAAQS and two exceeding 70 ppb were recorded during May (Figure A-8), while those exceeding 65 ppb were recorded in April, May and October months. Peak number of days exceeding proposed standard of 60 ppb were recorded during March and July months along with considerable counts during April, June, September and October months.

During 2013, at the downwind site – CAMS 664 one and three days exceeding current NAAQS and potential level of 70 ppb, respectively were recorded in July (Figure A-9). Days exceeding potential level of 65 ppb exhibited a bi-modal distribution with peak numbers in May and July. One to Two days of exceedance were recorded during March, June, August, September and October. Bi-modal distribution of days exceeding potential level of 60 ppb were recorded with peak months in May and July along with significant exceedances in March, April, August, September and October. During 2014 (Figure A-10) zero days exceeding both current NAAQS and proposed standard of 70 ppb were recorded while one and two days exceeding proposed standard of 65 ppb were recorded during May and October. Days exceeding proposed standard of 60 ppb demonstrated a bi-modal distribution with exceedances during April, May, August and October.

Zero days exceeding current NAAQS and potential levels of 70 ppb were recorded at upwind site – CAMS 659 during 2013 very similar to the trend observed at CAMS 21 (Figure A-11). One day exceeding potential level of 65 ppb was recorded in October while one to two days exceeding potential level of 60 ppb were recorded in March, May, July, August and September as shown in Figure A-11. As shown in Figure A-12 one day of exceedance was recorded during April considering the current NAAQS while one day in April and May were recorded exceeding proposed level of 70 ppb. Days exceeding proposed level of 65 ppb exhibited a bi-modal distribution with significant count during April, May and October months. As shown in Figure A-12 considerable number of days exceeding proposed level of 60 ppb were recorded during March, April, May, August, September and October months.

Highest number of days exceeding potential level of 70 ppb was recorded in July at CAMS 686 during 2013 as shown in Figure A-13. Bi-modal distribution of days exceeding potential levels of 65 ppb and 60 ppb with peak numbers during March and July were recorded during 2013 at Odem – CAMS 686. Significant numbers were recorded during April, May, August, September and October. As demonstrated in Figure A-14 zero days exceeding current NAAQS and proposed level of 70 ppb were recorded during 2014. One day of exceedance considering proposed level of 65 ppb was recorded during March and May while those exceeding 60 ppb were recorded during February through May and October.

As discussed above during 2013 and 2014 dissimilar to historical bi-modal distribution zero to two days exceeding current NAAQS and potential level of 70 ppb was recorded at TCEQ and UNT-TAMUK sites were recorded. Unusual to historical findings considerable number of exceedance days were recorded during July with fast moving winds. Further data analysis was performed to study the diurnal variations and characterize the few episode days recorded at UNT-TAMUK maintained research grade monitoring stations.

2.4 WEEKDAY/WEEKEND DAY TRENDS

Conduct a weekday/weekend analysis to evaluate the potential effectiveness of reduced levels of local and industrial and mobile source activity on their area

Potential variability in the distribution of anthropogenic emissions between weekday and weekend days could result in variations of the measured ozone concentrations. Thus to evaluate these changes, additional statistical analysis was performed on the temporal variability of hourly eight hour ozone concentrations measured during 2013 and 2014.

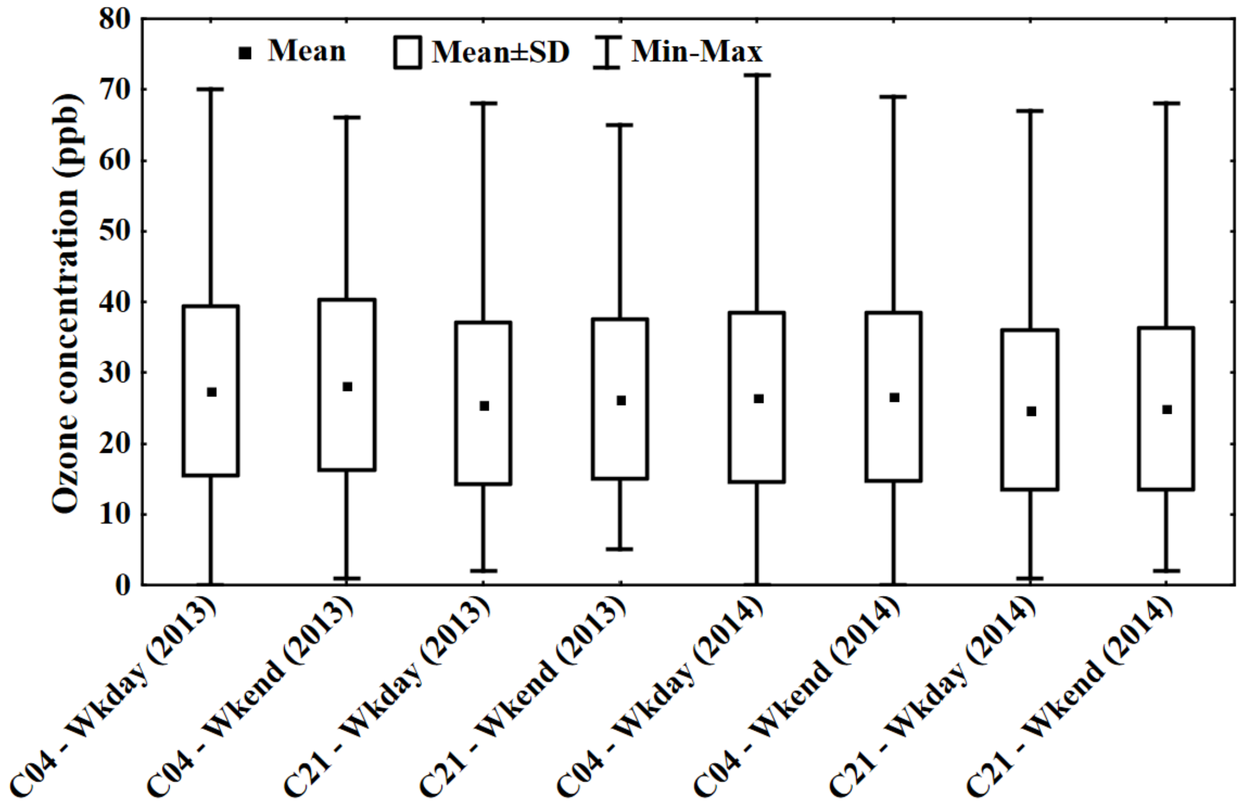

Figure 16. Statistical variability in the eight hour ozone concentrations measured at TCEQ maintained compliance grade monitoring sites during weekday/weekend of 2013 and 2014.

The statistical variability in the eight hour ozone concentrations measured at the TCEQ maintained compliance grade monitoring stations (CAMS 04 and CAMS 21) during the weekdays and weekend days of 2013 and 2014 is shown in Figure 16. The daily maximum eight hour ozone concentrations measured during weekdays were observed to be higher than weekend day concentrations at both CAMS 04 and CAMS 21 while the average concentrations showed variability of one to two ppb. This variability could be attributed to the presence of lower anthropogenic emissions, primarily NOx from traffic sources, resulting in a decreased titration of ozone from fresh emissions. Such weekend weekday phenomenon has been noted in studies from other areas such as Los Angeles and New York.

Figure 17 shows weekday/weekend variability's observed at the research grade monitoring sites during 2013 and 2014. The daily maximum eight hour ozone concentrations measured during weekdays were observed to be higher than weekends as noted at TCEQ maintained sites. The average eight hour concentrations during weekday/weekend of 2013 and 2014 at the research grade monitoring stations showed variability of one to two ppb as observed at TCEQ. The urban site – CAMS 660, downwind site – CAMS 664 and upwind site – CAMS 659 recorded the highest eight hour ozone concentrations during weekdays of 2013 and 2014, such variability in the measurements could be attributed to increased local anthropogenic emissions along with long range transport.

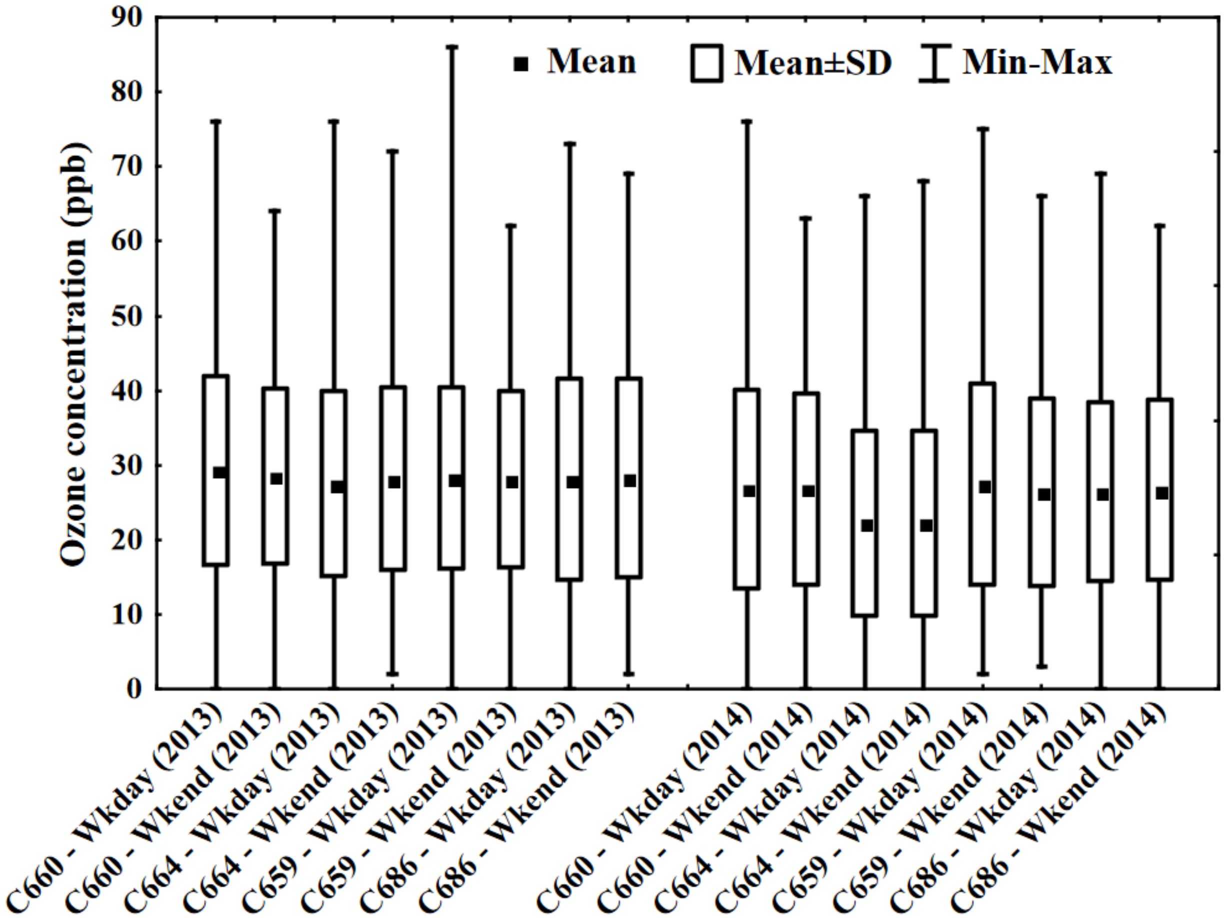

Figure 17. Statistical variability in the daily maximum eight hour ozone concentrations measured at research grade monitoring sites maintained and operated by UNT-TAMUK during weekday/weekend of 2013 and 2014.

Additional analysis was performed to study the seasonal variations in weekday/weekend eight hour ozone concentrations measured during 2013 and 2014. The results from this analysis for CAMS 04 and CAMS 21 are shown below in Figures 18 through 21. As shown in Figures 18 through 21, a bi-modal distribution of ozone levels was observed during weekdays/weekends. At both CAMS 04 and CAMS 21 peak eight hour ozone concentrations were observed during weekdays of March, May and October as shown in Figures 18 and 21. Unusual peak concentrations were recorded during weekdays of July while the lowest concentrations were measured during weekends of July ascertained with calm winds and considerably low levels of long range transport.

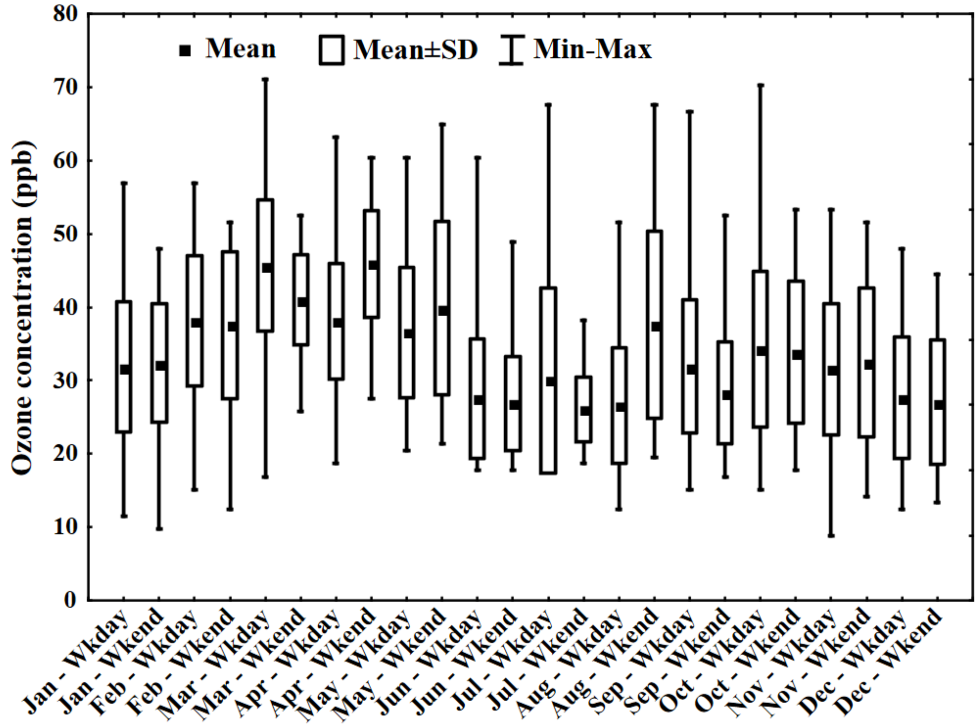

Figure 18. Monthly variations in the weekday/weekend ozone concentrations observed at CAMS 04 during 2013.

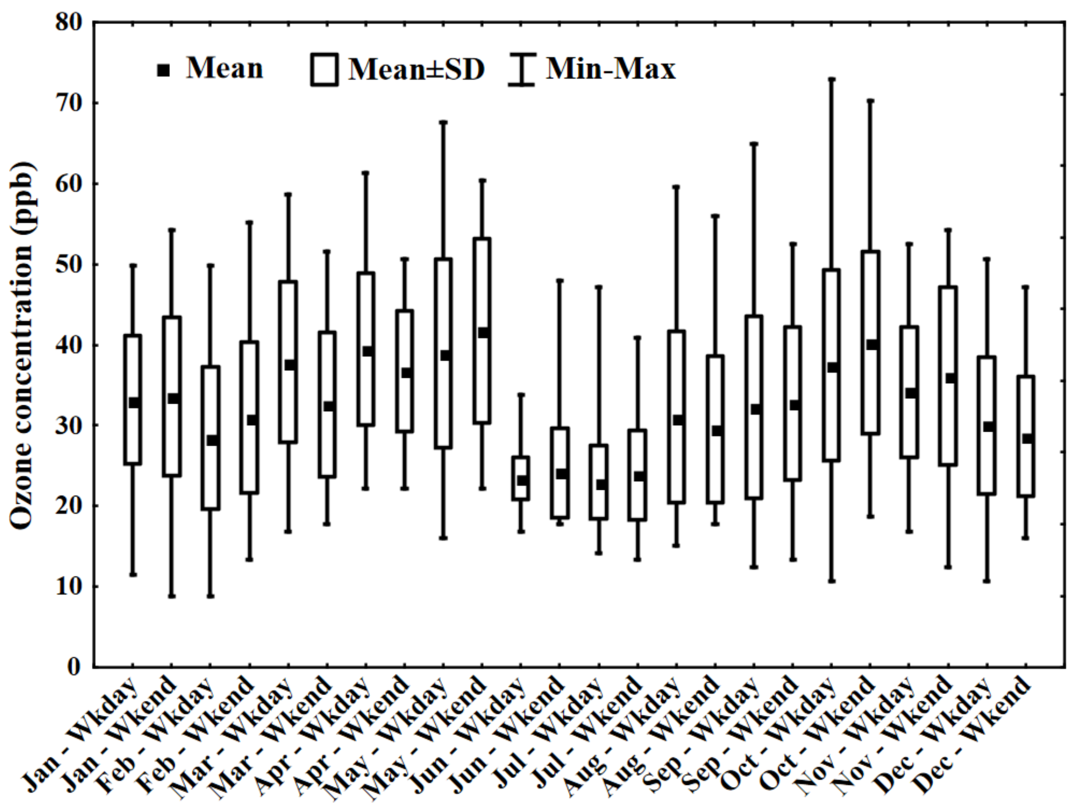

Figure 19. Monthly variations in the weekday/weekend ozone concentrations observed at CAMS 04 during 2014.

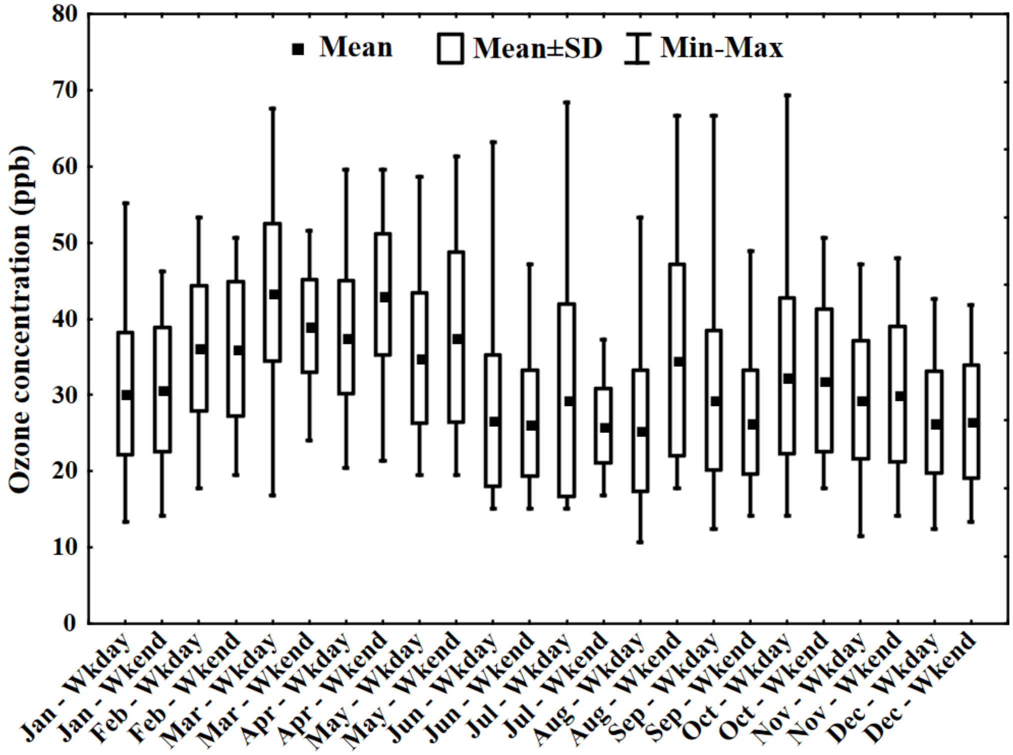

Figure 20. Monthly variations in the weekday/weekend ozone concentrations observed at CAMS 21 during 2013.

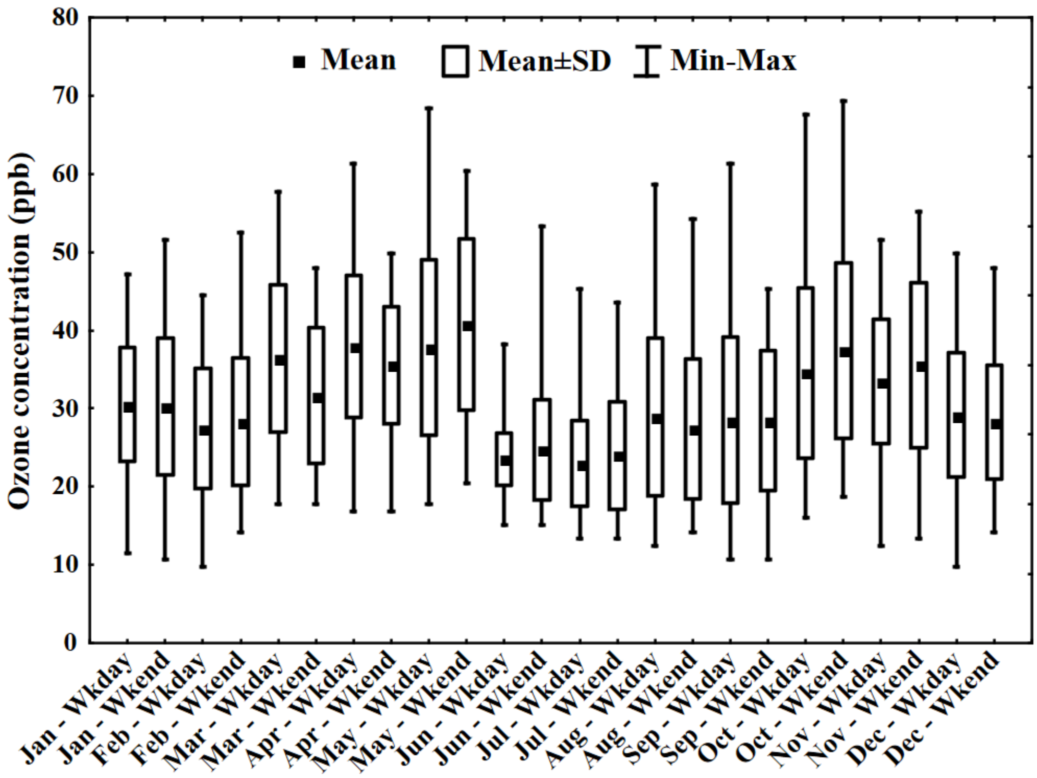

Figure 21. Monthly variations in the weekday/weekend ozone concentrations observed at CAMS 21 during 2014.

Similar analysis was performed using the ozone concentrations measured during 2013 and 2014 at the non-compliance grade monitoring stations. The monthly variations in the weekday/weekend ozone concentrations at the urban site - CAMS 660, downwind site - CAMS 664 and upwind site – CAMS 659 demonstrated trends very similar those observed at CAMS 21 as shown in Figure A-15 through A-22. The daily maximum eight hour ozone concentrations at urban site – CAMS 660 exhibited a bi-modal distribution with peak concentrations during weekdays of April and October while the average eight hour ozone concentrations were observed to be higher during weekends of April (Figures A-15 and A-16). The daily maximum eight hour ozone concentrations recorded at the downwind site – CAMS 664 also exhibited an overall bi-modal distribution with high's in weekdays of March, and October as well as weekends of May. As shown in Figure A-17 unusual high concentrations were observed during weekdays of July as observed at the TCEQ maintained compliance monitoring stations. Average ozone concentrations recorded at CAMS 664 during 2013 and 2014 also exhibited a bi-modal distribution with peak levels during weekdays of March and weekends of August.

As shown in Figures A-19 and A-20, the daily maximum eight hour ozone concentrations recorded at the upwind site – CAMS 659 also exhibited a bi-modal distribution with peak levels during weekdays of March, September and October. Average eight hour ozone concentrations also demonstrated a similar bi-modal distribution with additional high levels during weekends of August. The eight hour ozone concentrations measured at Odem – CAMS 686 in San Patricio county also demonstrated similar distribution of daily maximum and average concentrations as noted at the upwind site – CAMS 659 (Figures A-21 and A-22).

As demonstrated by the above analysis daily maximum and average eight hour ozone concentrations measured at TCEQ and UNT-TAMUK sites exhibited similar seasonal variations as noted by the frequency of exceedane days. In addition to the historical bi-modal distribution with peak concentrations during Spring months of April, May and Fall months of September, October considerably high levels were recorded during July. Hence additional analysis on high ozone days and concurrent meteorological characteristics was conducted.

2.5 HIGH OZONE DAYS IN 2013 and 2014

The Corpus Christi urban airshed is currently in attainment with the current NAAQS (75 ppb) as shown by the design value trend analysis. However as shown by the temporal trends, fewer days were recorded with daily maximum eight hour ozone concentrations above the current NAAQS of 75 ppb which are potential candidate days for future photochemical modeling. This is also true for the other threshold levels of 70, 65, and 60 ppb. Table 1 summarizes the high ozone days considering current NAAQS and the concentrations measured at the compliance grade monitoring stations maintained and operated by TCEQ along with UNT-TAMUK sites during 2013 and 2014. Tables 2 through 7 summarize the exceedance days considering the potential levels of 70 ppb, 65 ppb and 60 ppb. As summarized in the tables very few days with concentrations above the current NAAQS were observed while the frequency of days increased with the three threshold levels (70 ppb, 65 ppb, and 60 ppb).

Table 1. High ozone days observed exceeding current NAAQS at TCEQ and UNT-TAMUK sites during 2013 and 2014.

Date	CAMS 04	CAMS 21	CAMS 660	CAMS 664	CAMS 659	CAMS 686
3/13/2013			76 ppb			
7/1/2013				76 ppb		
4/29/2014					75 ppb	
5/29/2014			76 ppb			

Table 2. High ozone days observed considering potential levels of 70 ppb, 65 ppb, and 60 ppb at CAMS 04 during 2013 and 2014.

Days with Ozone < 75 ppb and >= 70 ppb	Days with Ozone < 70 ppb and >= 65 ppb	Days with Ozone < 65 ppb and >= 60 ppb
3/13/2013 (70 ppb)	7/2/2013 (66 ppb)	4/12/2013 (61 ppb)
10/24/2014 (72 ppb)	7/3/2013 (65 ppb)	5/5/2013 (63 ppb)
	8/17/2013 (66 ppb)	7/1/2013 (63 ppb)
	8/18/2013 (66 ppb)	9/24/2014 (63 ppb)
	9/24/2013 (65 ppb)	10/23/2014 (62 ppb)
	9/25/2013 (65 ppb)	
	10/8/2013 (69 ppb)	
	5/29/2014 (65 ppb)	
	5/30/2014 (66 ppb)	
	10/25/2014 (69 ppb)	

Table 3. High ozone days exceeding potential levels of 70 ppb, 65 ppb, and 60 ppb at CAMS 21 during 2013 and 2014.

Days with Ozone < 75 ppb and >= 70 ppb	Days with Ozone < 70 ppb and >= 65 ppb	Days with Ozone < 65 ppb and >= 60 ppb
	3/13/2013 (66 ppb)	
	7/1/2013 (67 ppb)	
	7/2/2013 (67 ppb)	
	7/3/2013 (66 ppb)	
	8/17/2013 (65 ppb)	
	8/18/2013 (65 ppb)	
	9/25/2013 (65 ppb)	
	10/8/2013 (68 ppb)	
	5/29/2014 (67 ppb)	
	5/30/2014 (66 ppb)	
	10/24/2014 (66 ppb)	
	10/25/2014 (68 ppb)	

Table 4. High ozone days exceeding potential levels of 70 ppb, 65 ppb, and 60 ppb at CAMS 660 during 2013 and 2014.

Days with Ozone < 75 ppb and >= 70 ppb	Days with Ozone < 70 ppb and >= 65 ppb	Days with Ozone < 65 ppb and >= 60 ppb
5/30/2014 (71 ppb)	4/12/2013 (65 ppb)	3/14/2013 (64 ppb)
	7/2/2013 (68 ppb)	3/20/2013 (62 ppb)
	7/3/2013 (66 ppb)	3/26/2013 (61 ppb)
	9/25/2013 (67 ppb)	3/27/2013 (61 ppb)
	10/8/2013 (66 ppb)	4/20/2013 (64 ppb)
	4/18/2014 (66 ppb)	6/3/2013 (61 ppb)
	10/24/2014 (67 ppb)	7/4/2013 (60 ppb)
		9/24/2013 (63 ppb)
		3/20/2014 (64 ppb)
		3/25/2014 (63 ppb)
		5/15/2014 (63 ppb)
		5/16/2014 (63 ppb)
		5/17/2014 (61 ppb)
		10/25/2014 (63 ppb)

Table 5. High ozone days exceeding potential levels of 70 ppb, 65 ppb, and 60 ppb observed at CAMS 664 during 2013 and 2014.

Days with Ozone < 75 ppb and >= 70 ppb	Days with Ozone < 70 ppb and >= 65 ppb	Days with Ozone < 65 ppb and >= 60 ppb
5/5/2013 (72 ppb)	3/13/2013 (68 ppb)	3/14/2013 (62 ppb)
6/3/2013 (72 ppb)	5/6/2013 (66 ppb)	4/12/2013 (64 ppb)
7/2/2013 (74 ppb)	8/17/2013 (65 ppb)	4/20/2013 (64 ppb)
7/3/2013 (71 ppb)	8/18/2013 (68 ppb)	5/4/2013 (61 ppb)
10/8/2013 (71 ppb)	9/24/2013 (68 ppb)	5/11/2013 (62 ppb)
	9/25/2013 (67 ppb)	5/13/2013 (61 ppb)
	5/29/2014 (65 ppb)	7/4/2013 (63 ppb)
	10/24/2014 (66 ppb)	7/5/2013 (63 ppb)
	10/25/2014 (68 ppb)	4/18/2014 (60 ppb)
		4/29/2014 (62 ppb)
		5/3/2014 (61 ppb)
		5/30/2014 (63 ppb)
		8/5/2014 (62 ppb)

Table 6. High ozone days exceeding potential levels of 70 ppb, 65 ppb, and 60 ppb observed at CAMS 659 during 2013 and 2014.

Days with Ozone < 75 ppb and >= 70 ppb	**Days with Ozone < 70 ppb and >= 65 ppb**	**Days with Ozone < 65 ppb and >= 60 ppb**
5/29/2014 (70 ppb)	10/8/2013 (66 ppb)	3/1/2013 (60 ppb)
	4/18/2014 (68 ppb)	3/12/2013 (63 ppb)
	5/30/2014 (67 ppb)	5/4/2013 (60 ppb)
	10/24/2014 (67 ppb)	5/5/2013 (61 ppb)
	10/25/2014 (66 ppb)	7/2/2013 (60 ppb)
		8/17/2013 (62 ppb)
		8/18/2013 (61 ppb)
		9/24/2013 (64 ppb)
		9/25/2013 (62 ppb)
		3/6/2014 (62 ppb)
		3/7/2014 (62 ppb)
		3/13/2014 (63 ppb)
		3/18/2014 (61 ppb)
		4/9/2014 (60 ppb)
		4/28/2014 (60 ppb)
		5/15/2014 (63 ppb)
		8/4/2014 (62 ppb)
		9/24/2014 (61 ppb)
		10/21/2014 (63 ppb)

Table 7. High ozone days exceeding potential levels of 70 ppb, 65 ppb, and 60 ppb observed at CAMS 686 during 2013 and 2014.

Days with Ozone < 75 ppb and >= 70 ppb	Days with Ozone < 70 ppb and >= 65 ppb	Days with Ozone < 65 ppb and >= 60 ppb
7/2/2013 (71 ppb)	3/13/2013 (68 ppb)	3/12/2013 (61 ppb)
7/3/2013 (72 ppb)	3/14/2013 (65 ppb)	3/20/2013 (60 ppb)
9/25/2013 (70 ppb)	4/12/2013 (65 ppb)	3/26/2013 (60 ppb)
10/8/2013 (73 ppb)	5/5/2013 (67 ppb)	3/27/2013 (62 ppb)
	7/1/2013 (69 ppb)	4/20/2013 (62 ppb)
	8/17/2013 (68 ppb)	5/6/2013 (60 ppb)
	8/18/2013 (69 ppb)	5/13/2013 (61 ppb)
	9/24/2013 (67 ppb)	6/3/2013 (62 ppb)
	3/20/2104 (69 ppb)	7/4/2013 (63 ppb)
	5/29/2014 (67 ppb)	7/5/2013 (61 ppb)
		10/24/2013 (60 ppb)
		2/15/2014 (60 ppb)
		3/7/2014 (62 ppb)
		4/18/2014 (61 ppb)
		4/29/2014 (60 ppb)
		5/3/2014 (62 ppb)
		5/4/2014 (60 ppb)
		5/30/2014 (61 ppb)
		10/24/2014 (62 ppb)
		10/25/2014 (61 ppb)

As shown in the above Table 1, zero days exceeding current NAAQS were recorded at TCEQ maintained monitoring stations while two episode days was recorded at the urban site - CAMS 660 and one episode day at downwind site – CAMS 664 and upwind site – CAMS 659. Considering the potential levels of 70 ppb only one episode day was recorded at CAMS 04 during 2013 and 2014 while zero at CAMS 21. Episode days with daily maximum eight hour concentrations ranging between potential levels of 65 pp to 700 ppb were observed to be more as compared to those ranging between 60 ppb to 65 ppb at both CAMS 04 and CAMS 21. As shown in Tables 4 and 5 at both urban site – CAMS 660 and downwind site – CAMS 664 considerably higher frequency of episode days those ranging between potential levels 60 ppb and 65 ppb were observed to higher as compared to current NAAQS and other potential levels. The upwind site – CAMS 659 (Table 6) recorded zero days with daily maximum eight hour ozone concentrations exceeding current NAAQS as well as ranging between 70 ppb to 75 ppb during 2013 while during 2014 one day exceeding current NAAQS and one exceeding proposed standard of 70 ppb was recorded. As shown in Table 6 only one and four days with daily maximum ozone concentration ranging between 65 ppb to 70 ppb was recorded during 2013 and 2014, respectively indicating probable reduction or very low influence of long range transport.

At CAMS 686 during 2013 and 2014, zero episode days exceeding current and NAAQS were recorded as shown in Table 1. A total of four days with daily maximum eight hour ozone concentration ranging between 70 ppb and 75 ppb were recorded during 2013 while those ranging between 65 ppb through 70 ppb a total of eight days were recorded during 2013 and two days during 2014. As shown in Table 7 approximately nine to ten episode days with daily maximum eight hour ozone concentration ranging between 60 ppb to 65 ppb were recorded during 2013 and 2014.

Based on the above analysis and "Guidance on the Use of Models and Other Analysis to Demonstrate Attainment of Air Quality Goals for Ozone and $PM_{2.5}$ and Regional Haze" (EPA, 2007), zero episode days potential for photochemical modeling were recorded during 2013. However in consideration of possible revisions to existing ozone NAAQS and to better assess the influence of local emissions along with regional transport further characterization of identified high ozone episodes using the meteorological data and backward trajectory analysis has been performed.

3.0 METEOROLOGICAL CHARACTERISTICS

Corpus Christi is located in a semi-arid coastal region of South Texas with a monthly average temperature ranging between 49.8 – 83.6˚F in 2013; monthly average precipitation ranging between 0.29 – 2.95 inches in 2013 and 2014 (National climatic data center, 2015). Ozone season spans from April through October, however, as shown in the previous section high ozone levels were observed during late spring (April – May), early summer (June) and fall periods (August – October). A bi-modal distribution of high ozone days on an annual basis was reported in the previous section with low levels during the warmer month of July. Historically the area has been studied to be impacted by local emissions and long-range transport of pollutants contributing to ozone and $PM_{2.5}$ during three specific types of regional air pollution events as shown by research studies. The these include (1) Biomass burns in Central America and Mexico during April and May, (2) Sub-Saharan dust transport from Africa during June and July, and (3) Regional haze transport from highly industrialized areas of Texas and beyond during August and September.

A detailed meteorological analysis of the episode days measured during 2013 and 2014 exceeding current NAAQS as well as potential standards (as listed in Tables 1 through 7) is provided below.

3.1 WIND CONDITIONS

Evaluate the wind speeds, directions and time of day associated with high ozone events to determine the local conditions and source alignments most frequently associated with high ozone events.

Local meteorological conditions including resultant wind speed and resultant wind direction measured during 2013 and 2014 at TCEQ and UNT-TAMUK maintained monitoring sites were evaluated using the Lakes Environmental- WRPlotview software. Figure 22 shows the year round prevailing wind conditions observed at CAMS 04 and CAMS 21 during 2013 and 2014, while Figures 23 and 24 shows those measured at the research grade monitoring stations including CAMS 660, CAMS 664, CAMS 659 and CAMS 686. As shown in the figures below, considering all the 365 measured days of 2013 and 2014 at CAMS 04 and CAMS 21, winds from the south-southeast and southeast direction were observed to be predominant followed by southerly, easterly and northerly winds. At CAMS 04, 37% - 55% of the measured days during 2013 and 2014 recorded wind speeds ranging between 2.0 – 4.0 m/s, while 25% - 34% recorded slower wind speeds ranging between 0.5 – 2.0 m/s. Winds with speed ranging between 4.0 – 6.0 m/s accounted for 38% - 10% of measured data. Remainder of the days recorded calm winds with speed below 0.5 m/s.

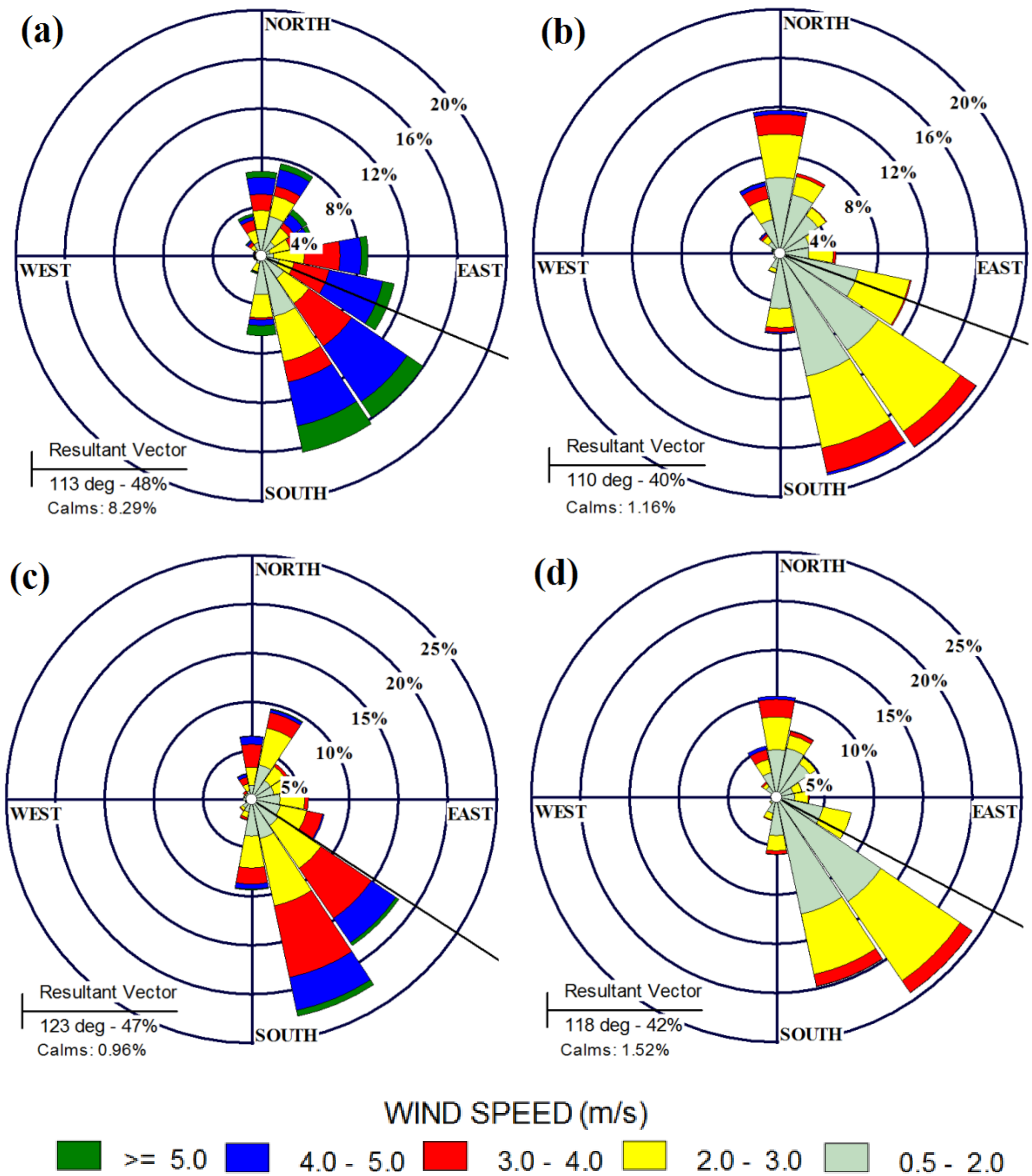

Figure 22. Prevailing wind speed and wind direction during 2013 at (a) CAMS 04 and (b) CAMS 21 and 2014 at (c) CAMS 04 and (d) CAMS 21.

As shown in Figure 22, at CAMS 21, 59% - 60% of the days during 2013 and 2014 measured wind speeds ranging between 0.5 – 2.0 m/s. Wind speeds ranging between 2.0 - 4.0 m/s were noted during 39% of the days, while during 1% of the days wind speeds above 4.0 m/s were recorded during 2013 as well as 2014.

As demonstrated in Figures 23 and 24, dominant southeasterly winds were recorded at the urban site (CAMS 660), downwind site (CAMS 664), while Odem (CAMS 686) was impacted by south-southeasterly and southeasterly winds during 2013 and 2014. On the contrary the upwind site in Aransas Pass was impacted by dominantly by south-southeasterly winds. A detailed analysis of the wind speeds contributing to the ambient pollution levels measured at the research grade monitoring stations is provided below:

(a) **CAMS 660:** At Holly road (CAMS 660) located within the residential area of urban airshed 72% and 64% of the measurements during 2013 and 2014 recorded wind speeds ranging between 0.5 – 2.0 m/s contributing to the accumulation of local emissions. Average wind speeds ranging between 2.0 - 4.0 m/s were recorded during 22% and 29% of measurements, while remainder of the hourly measurements recorded calm winds below 0.5 m/s.

(b) **CAMS 664:** At the downwind site in Violet (CAMS 664) in year 2013 and 2014 approximately 34% - 38% of the hourly measurements recorded winds ranging between 0.5 – 2.0 m/s respectively, while 48% - 41% of the measured days recorded winds with speeds ranging between 2.0 - 4.0 m/s. Wind speeds ranging above 4.0 m/s were recorded during 5% - 13% of the days recorded during 2013 and 2014 while remainder of days calm winds with speed below 0.5 m/s were recorded.

(c) **CAMS 659:** Distribution of winds very similar to that observed at the downwind site – CAMS 664 were measured at the upwind site in Aransas Pass (CAMS 659). The upwind site in Aransas Pass (CAMS 659) recorded wind speeds ranging between 0.5 – 2.0 m/s and 2.0 – 4.0 m/s during 56% and 37% of hourly measurements in 2013, respectively. Associated with 2% of the hourly measurements winds with speeds ranging above 4.0 m/s while remainder of the days calm winds with speed below 3% were recorded. During 2014, 45% to 48% of measurements recorded were associated with wind speeds ranging between 2.0 – 4.0 m/s and 0.5 – 2.0 m/s while 3% of winds recorded winds with speed greater than 4.0 m/s.

(d) **CAMS 686:** Odem (CAMS 686) monitoring site in San Patricio County was influenced by wind conditions very similar to the downwind site – CAMS 664 as shown in Figures 23 and 24. During 29% of hourly measurements in 2013 winds with speeds ranging between 0.5 – 2.0 m/s were recorded while 47% of the days recorded those ranging between 2.0 – 4.0 m/s. Around 21% of the days recorded wind speeds ranging above 4.0 m/s were recorded while remainder of the day's calm winds with speed below 0.5 m/s were measured. During 2014, 50% of measurements recorded wind speeds ranging between 2.0 – 4.0 m/s while 30% recorded those ranging between 0.5 – 2.0 m/s. Wind speeds above 5.0 m/s accounted for 18% of measurements while 2% accounted for calm winds.

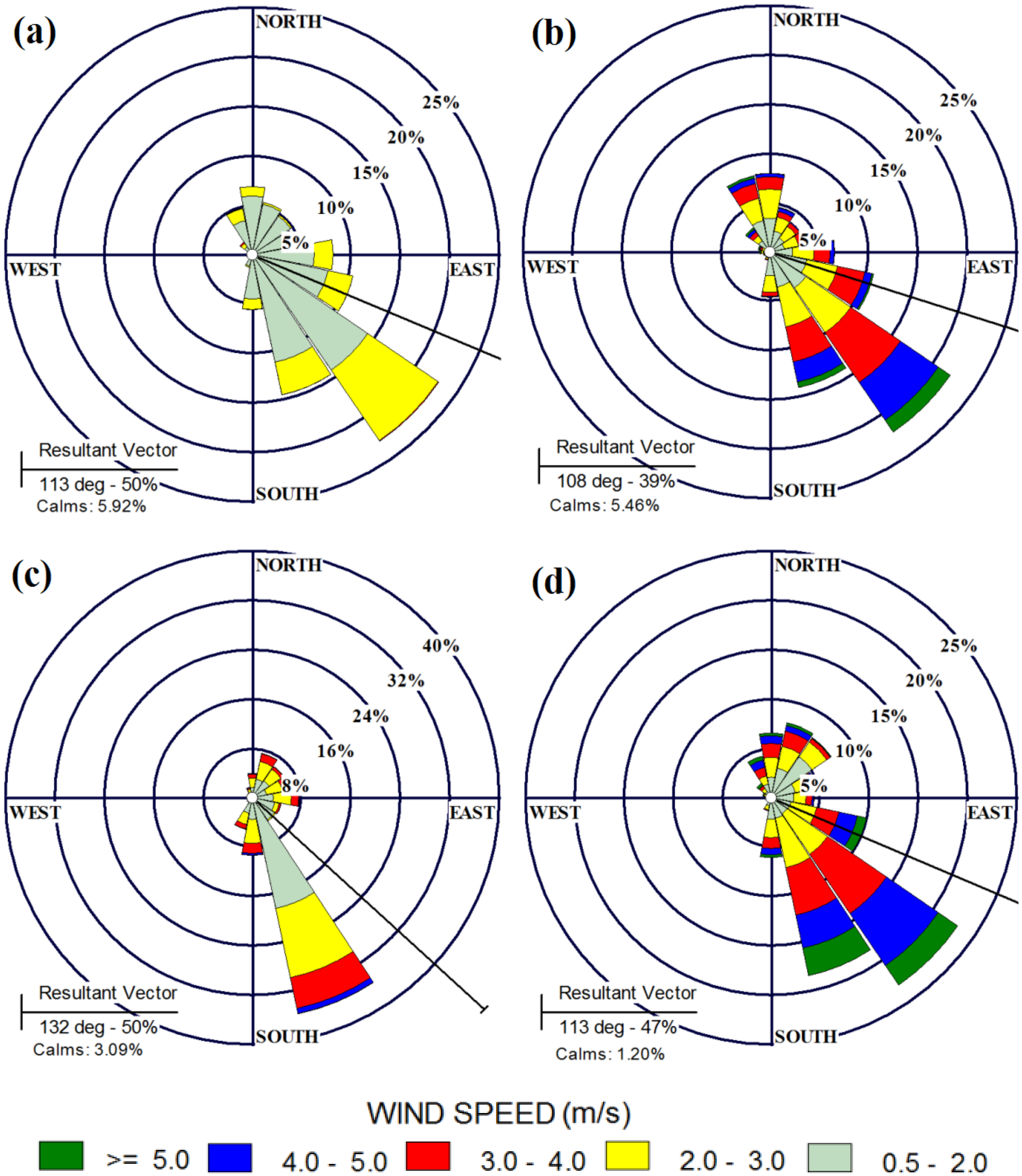

Figure 23. Prevailing wind speed and wind direction during 2013 at (a) CAMS 660 and (b) CAMS 664, (c) CAMS 659 and (d) CAMS 686.

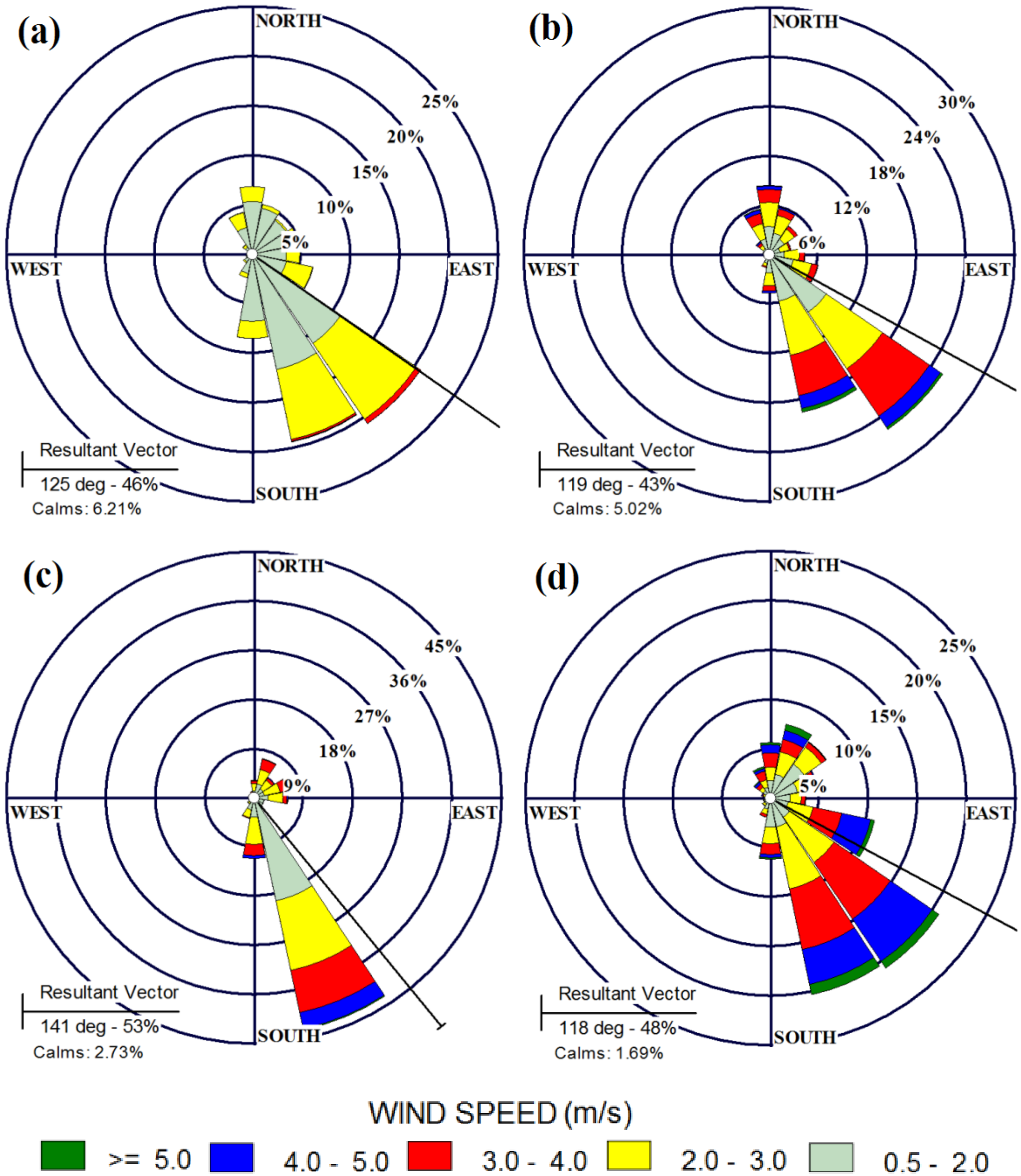

Figure 24. Prevailing wind speed and wind direction during 2014 at (a) CAMS 660 and (b) CAMS 664, (c) CAMS 659 and (d) CAMS 686.

Further analysis was performed to study the prevailing wind conditions influencing the ozone concentrations measured at both TCEQ and TAMUK sites during the identified episode days based on both current NAAQS of 75 ppb as well as threshold levels of >= 70 ppb, >=65 ppb and >=60 ppb. The results of the analysis are discussed below.

<u>CAMS 04:</u> Dominant winds from northeast, east and east-southeast were observed during the days with daily maximum eight hour ozone concentrations ranging potential level of 70 ppb and NAAQS (75 ppb) as shown in Figures 25 and 26. During the episode days with eight hour ozone concentration ranging between potential levels of 65 ppb to 70 ppb and 60 ppb to 65 ppb southeasterly winds were observed to be dominant with minor contribution from northerly, northwesterly, easterly and westerly winds (Figures 25 and 26). During 2013, wind speeds ranging between 0.5 – 2.0 m/s were recorded during 46% of the measurements recorded during episode days with concentrations ranging between 70 ppb to 75 ppb while remainder of the measurements recorded wind speeds ranging between 2.0 – 4.0 m/s.

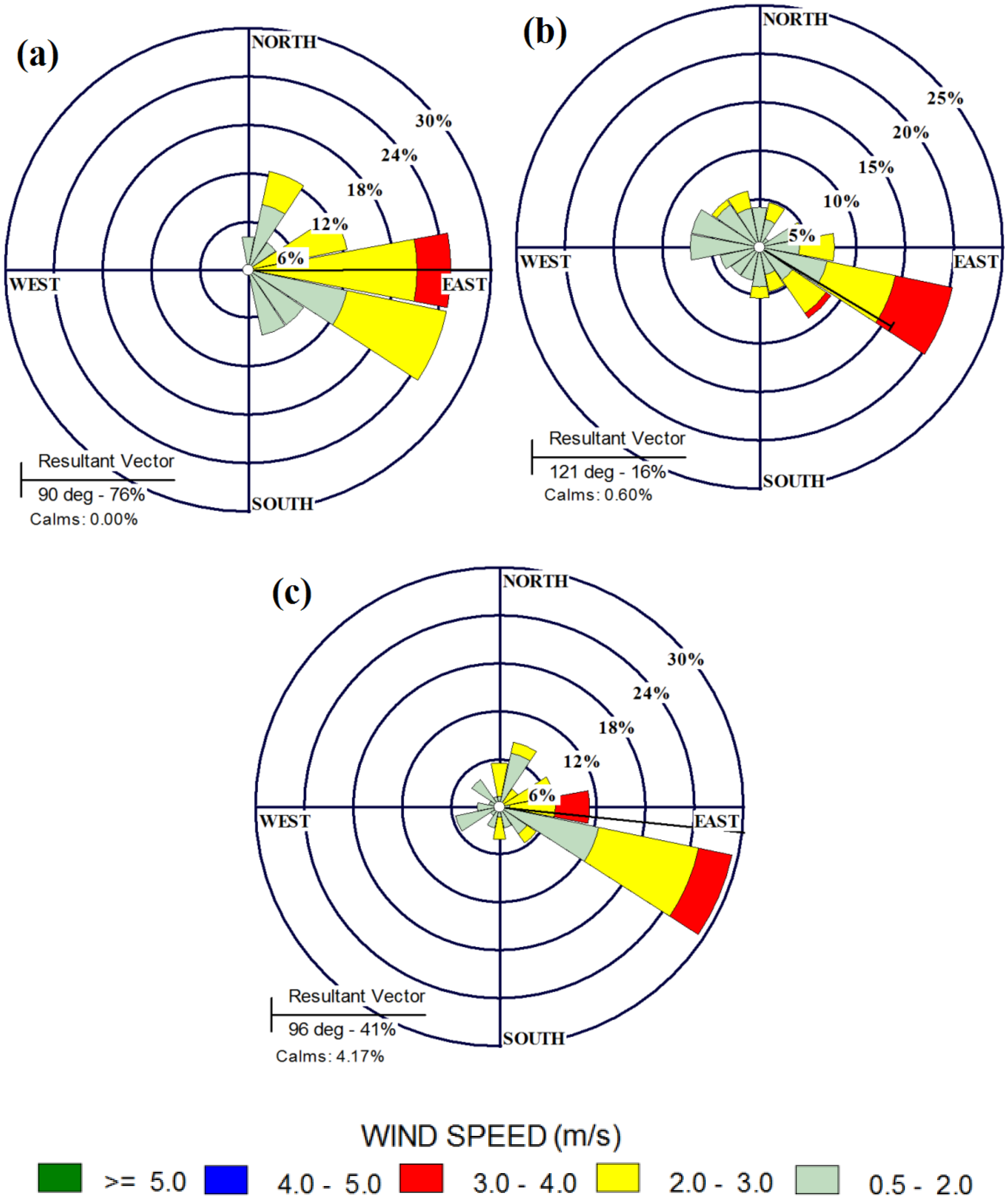

Figure 25. Prevailing wind speed and wind direction during high ozone days measured at CAMS 04 during 2013 (a) 70 ppb to 75 ppb, (c) 65 ppb to 70 ppb, and (d) 60 ppb to 65 ppb.

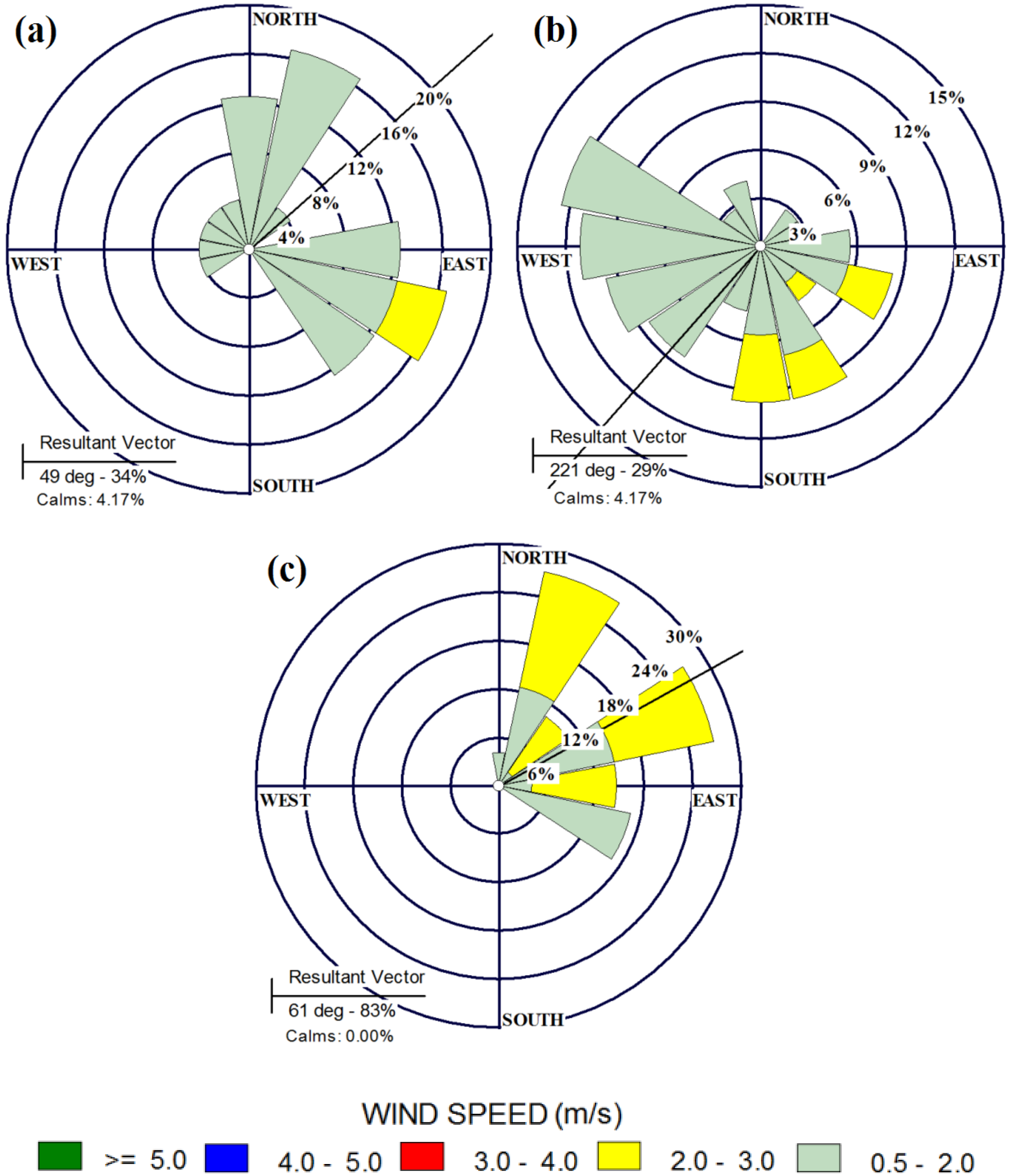

Figure 26. Prevailing wind speed and wind direction during high ozone days measured at CAMS 04 during 2014 (a) 70 ppb to 75 ppb, (c) 65 ppb to 70 ppb, and (d) 60 ppb to 65 ppb.

During 2013 episode days with daily maximum eight hour ozone concentrations ranging between 65 ppb to 70 ppb wind speeds ranging between 69% ranged between 0.5 – 2.0 m/s while 30% recorded those ranging between 2.0 – 4.0 m/s. Winds with speed ranging between 0.5 – 2.0 m/s were observed during 50% of the measurements recorded on episode days with daily maximum eight hour ozone concentration ranging between 60 ppb to 65 ppb. Approximately 46% of the measurements recorded wind speeds ranging between 2.0 – 4.0 m/s and remainder of measurements recorded calm winds below 0.5 m/s.

During episode days with daily maximum eight hour ozone concentrations ranging between 70 ppb to 75 ppb and 65 ppb to 70 ppb, approximately 92% - 85% of data measured winds with speeds ranging between 0.5 – 2.0 m/s while those ranging between 2.0 – 4.0 m/s accounted for 4% - 11%. As shown in Figure 26, remainder of days recorded calm winds. Winds with speed ranging between 0 .5 – 2.0 m/s accounted for 54% of episode days with daily maximum eight hour ozone concentrations ranging between 60 to 65 ppb while those ranging between 2.0 – 4.0 m/s accounted for remainder.

CAMS 21: Similar analysis was performed using the data measured at CAMS 21 during 2013 and 2014 as shown in Figures 27 and 28. As shown in Figure 27 dominant winds from east-southeast were noted during episode days with daily maximum eight hour ozone concentration ranging between potential levels of 65 ppb to 70 ppb. Minor contribution by winds from north, northwest, south and southeast were also observed. Wind speeds ranging between 0.5 - 2.0 m/s were observed during 86% - 98% of the hourly measurements, while 12% - 37% of the measurements recorded wind speeds ranging between 2.0 – 4.0 m/s, respectively during 2013 and 2014. Remainder of the measurements recorded calm winds with speeds below 0.5 m/s.

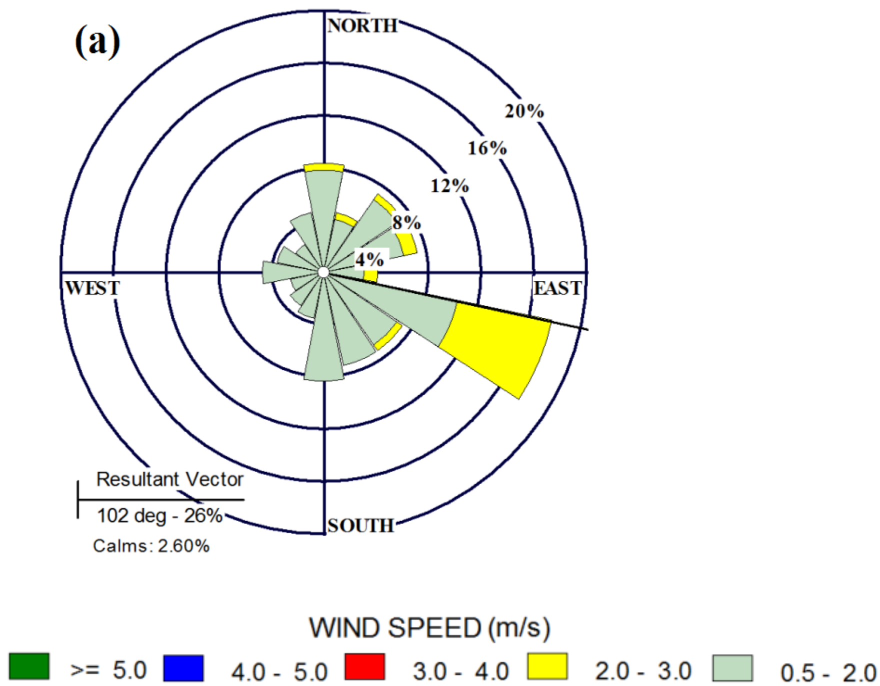

Figure 27. Prevailing wind speed and wind direction during high ozone days measured at CAMS 21 during 2013 (a) 65 to 60 ppb.

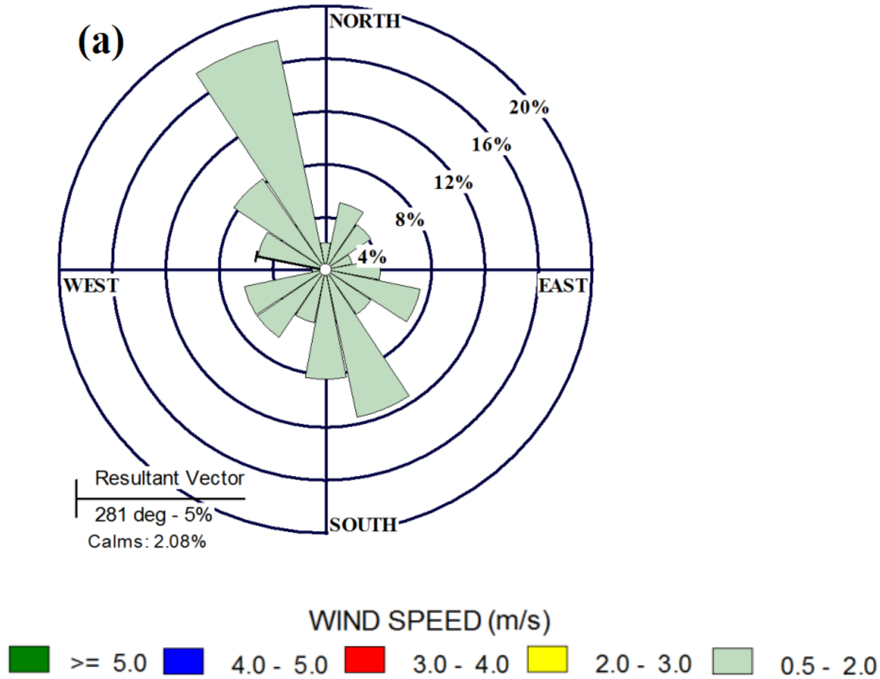

Figure 28. Prevailing wind speed and wind direction during high ozone days measured at CAMS 21 during 2014 (a) 65 to 60 ppb.

CAMS 660: At the urban research grade site easterly and southeasterly winds were observed to be dominant during days with eight hour ozone concentrations exceeding potential levels of 60 ppb, 65 ppb and 70 ppb during 2013 as shown in Figure 29. During episode days with daily maximum eight hour ozone concentration exceeding current NAAQS winds with speeds ranging from 0.5 – 2.0 m/s were noted to account for 56%, while those ranging between 2.0 – 4.0 m/s accounted for 33%. The remainder of measurements was noted to record calm winds below 0.5 m/s as shown in Figure 29. As demonstrated by wind rose analysis in Figure 29 winds with speed ranging between 0.5 – 2.0 m/s accounted for 67% - 66% of measurements during high ozone days with daily maximum eight hour ozone concentration ranging between 65 to 70 ppb and 60 ppb to 65 ppb. Winds with speed ranging between 2.0 – 4.0 m/s were noted to account for 11% - 19% while remainder were calm winds with speeds below 0.5 m/s.

Wind rose analysis conducted (Figure 30) for episodes days recorded at CAMS 660 during 2014 exceeding current NAAQS as well as proposed levels of 70 ppb, 65 ppb, and 60 ppb demonstrated dominant influence of southeasterly, southwesterly, northerly and easterly winds. Dominant contribution by winds with speed ranging between 0.5 – 2.0 m/s accounting for 76% to 96% was noted during episode days exceeding current NAAQS and proposed level of 70 ppb. Remainder of the measurements during these episodes comprised of calm winds with speed below 0.5 m/s. During episode days with daily maximum eight hour ozone concentration ranging between 65 ppb to 70 ppb 69% of the winds comprised of speeds ranging between 2.0 – 4.0 m/s while the remainder was above 4.0 m/s. Calm winds accounted for 7% during episode days with ozone concentration ranging between 60 ppb to 65 ppb (Figure 30) while those ranging between 0.5 – 2.0 m/s and 2.0 – 4.0 m/s accounted for 23% and 42%, respectively. Significant part of measurements accounting to 27% during these episode days recorded winds with speed above 4.0 m/s.

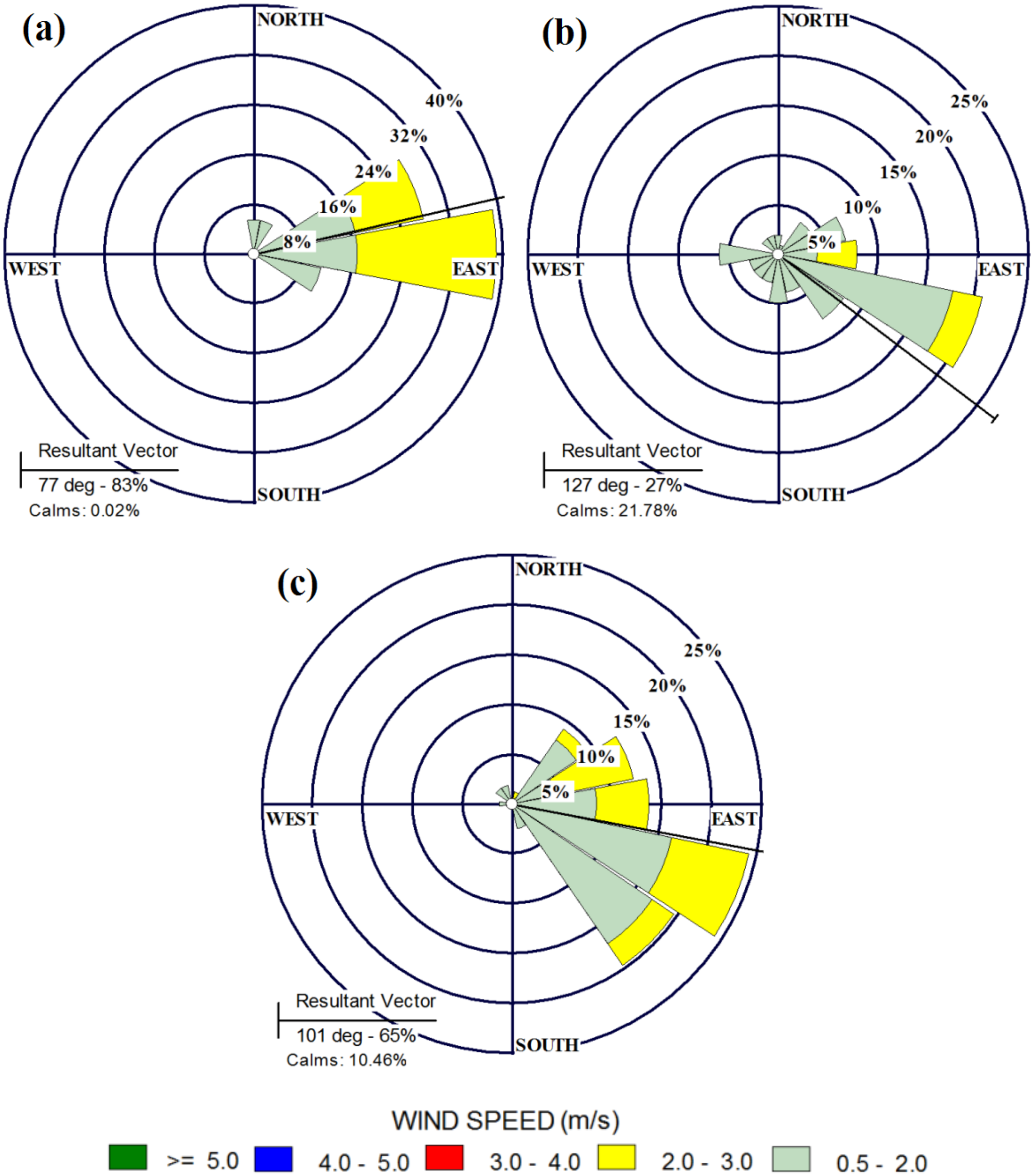

Figure 29. Prevailing wind speed and wind direction during high ozone days measured at CAMS 660 during 2013 (a) >= 75 ppb, (b) 65 ppb to 70 ppb, and (c) 60 ppb to 65 ppb.

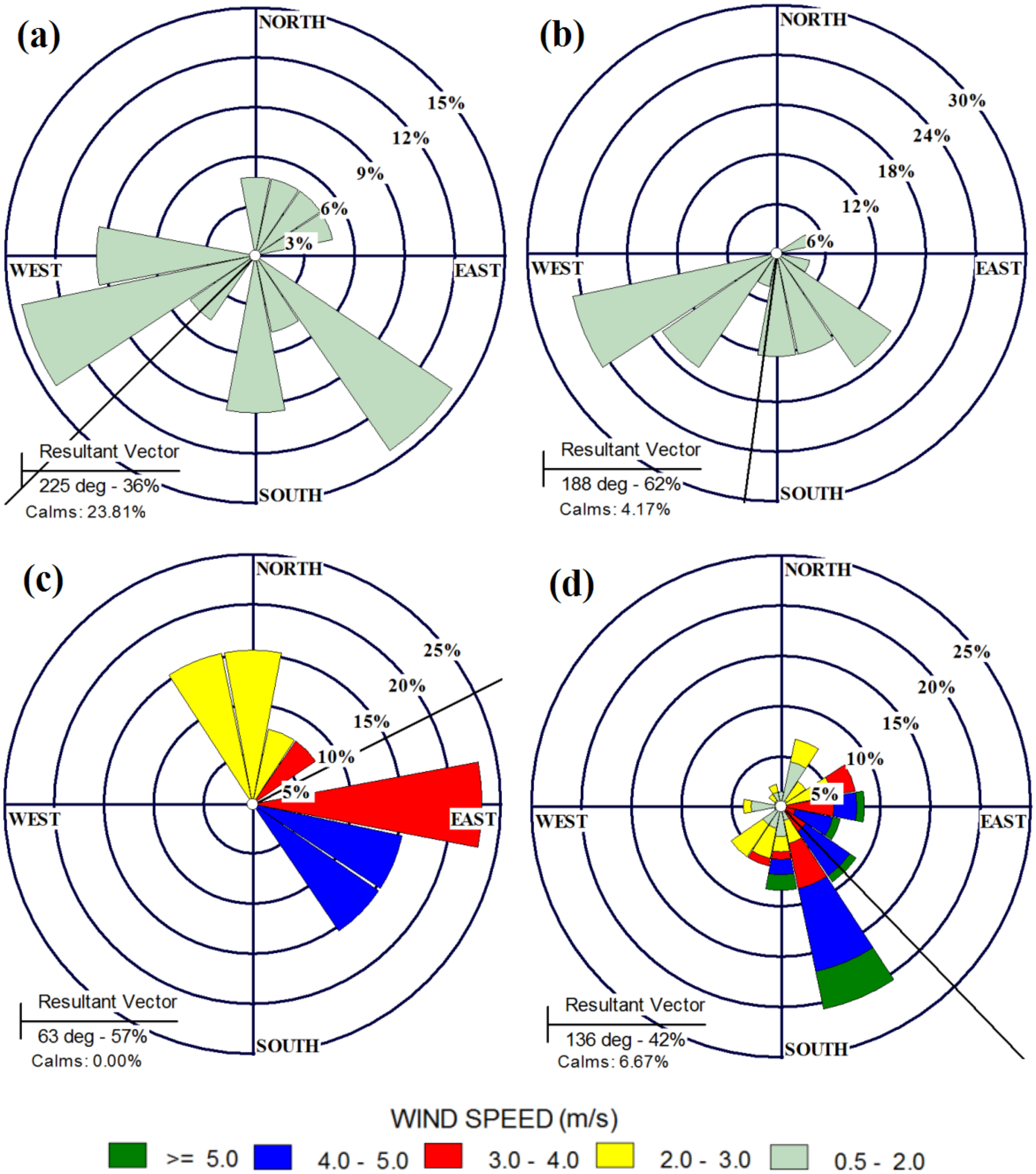

Figure 30. Prevailing wind speed and wind direction during high ozone days measured at CAMS 660 during 2014 (a) >= 75 ppb, (b) 70 ppb to 75 ppb, (c) 65 ppb to 70 ppb, and (d) 60 ppb to 65 ppb.

CAMS 664: At the downwind research grade southeasterly winds were observed to be dominant during days with ozone concentrations exceeding potential levels of 60 ppb, 65 ppb and 70 ppb observed during 2013 as noted at TCEQ maintained compliance sites. As shown in Figure 31 minor contribution from northerly, northwesterly, easterly and northeasterly winds were observed during episodes with daily maximum eight hour ozone concentrations ranging between (a) >= 70 ppb, (b) 70 ppb to 75 ppb, (c) 65 ppb to 70 ppb and (d) 60 ppb to 65 ppb. Wind speeds ranging between 0.5 – 2.0 m/s and 2.0 – 4.0 m/s were observed to account for 40% each respectively as shown in Figure 31. Calm winds with speed below 0.5 m/s accounted for 6% of the measurements During days with daily maximum eight hour ozone concentration ranging between 70 ppb to 75 ppb approximately 62% of the measurements were associated with wind speeds ranging between 0.5 – 2.0 m/s while 24% were associated with those ranging between 2.0 – 4.0 m/s. Remainder of the measurements recorded calm winds with speeds below 0.5 m/s.

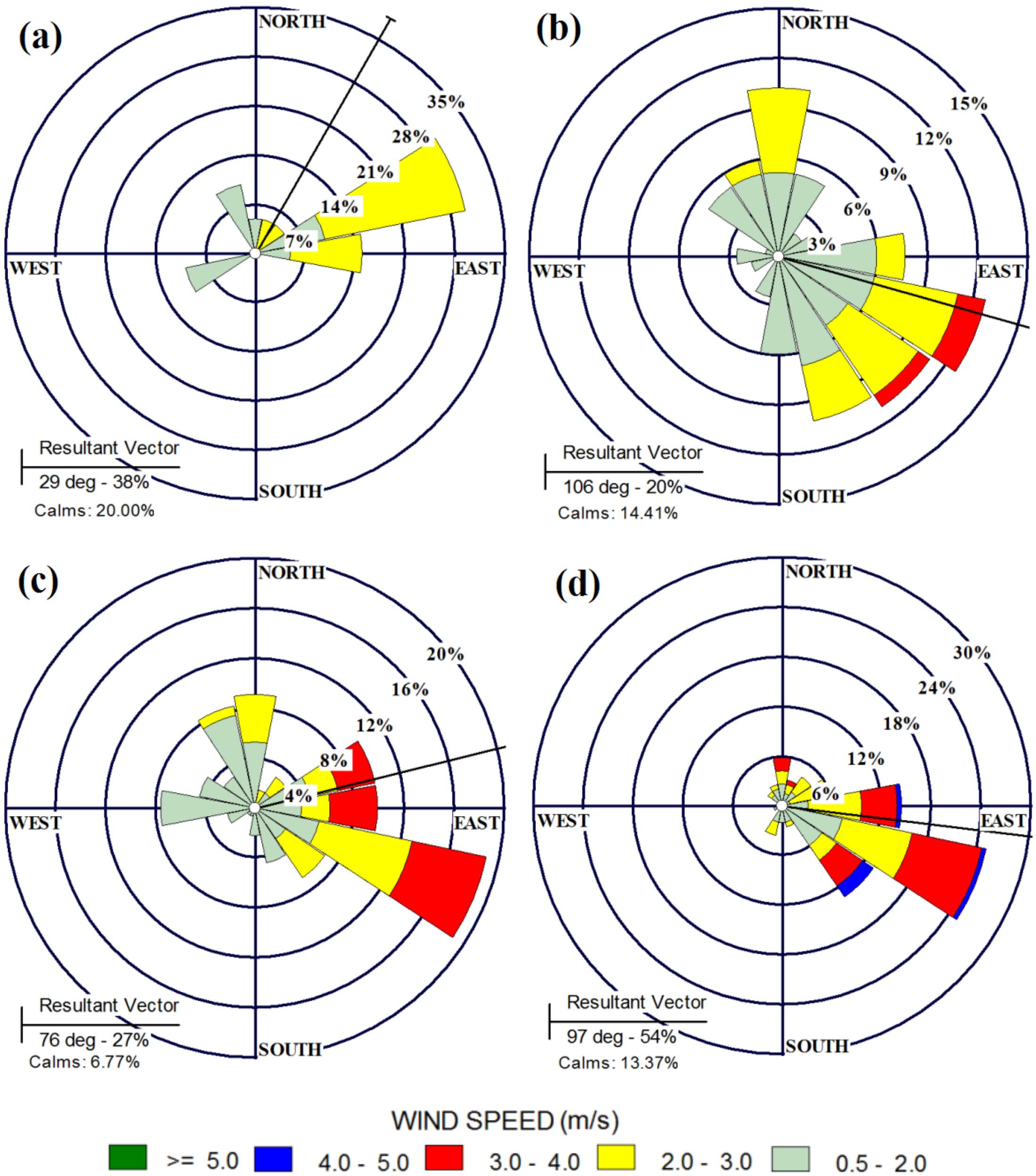

Figure 31. Prevailing wind speed and wind direction during high ozone days measured at CAMS 664 during 2013 (a) >=75 ppb, (b) 70 to 75 ppb, (c) 65 to 70 ppb, and (d) 60 to 65 ppb.

While during days with ozone concentrations ranging between 65 ppb to 70 ppb wind speeds ranging between 0.5 – 2.0 m/s were associated with 57% of measurements while 37% recorded wind speeds ranging between 2.0 – 4.0 m/s and remainder of measurements recorded calm winds below 0.5 m/s. As shown in Figure 31 during episode days with concentrations ranging between 60 ppb to 65 ppb wind speeds ranging between 0.5 – 2.0 m/s were recorded approximately during 35% of the measurements. Winds with speeds ranging between 2.0 – 4.0 m/s were recorded during approximately 49% of measurements along with a fewer measurements accounting for 3% recorded wind speeds ranging between 4.0 – 6.0 m/s. Remainder of the measurements accounting for 13% measured wind speeds below 0.5 m/s.

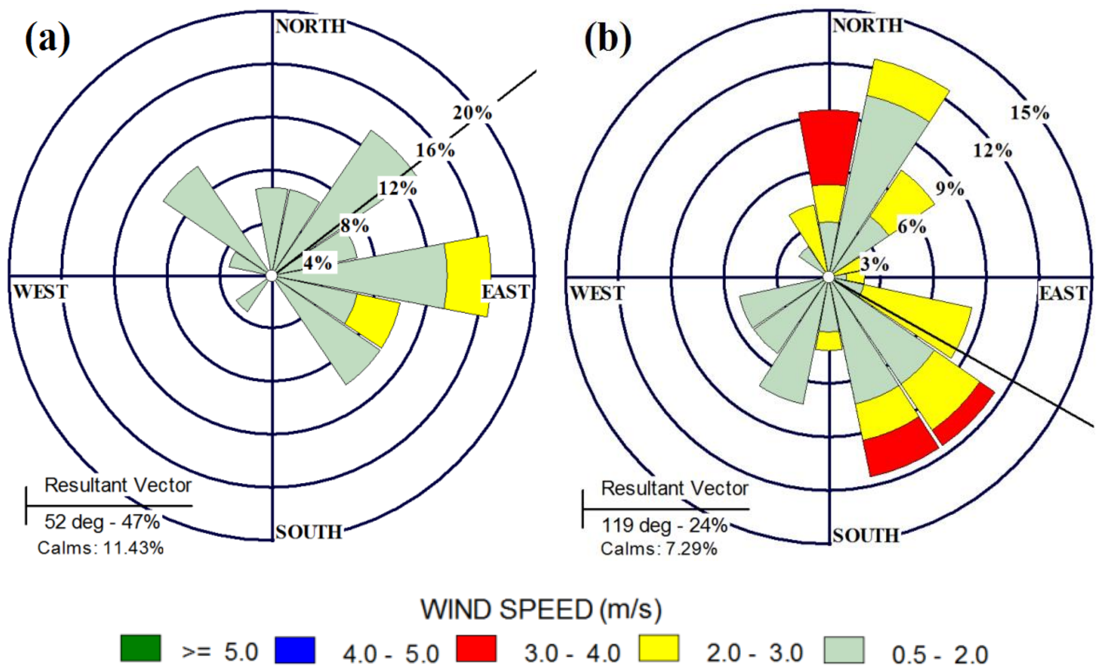

Figure 32. Prevailing wind speed and wind direction during high ozone days measured at CAMS 664 during 2014 (a) 65 to 70 ppb, and (b) 60 to 65 ppb.

Strong influence of northeasterly easterly and southeasterly winds was noted to influence ambient measurements acquired at the downwind site – CAMS 664 (Figure 32) along with a minor contribution from southwesterly and northwesterly winds. Winds with speed ranging between 2.0 – 4.0 m/s accounted for 7% and 34% during episode days with ozone concentrations ranging between 65 ppb and 70 ppb; 60 ppb and 65 ppb, respectively. Greater percentage of measurements accounting for 80% and 58% during these episode days included winds with speed ranging between 0.5 – 2.0 m/s. The remainder of the measurements was noted to calm winds contributing to stagnation and influence of local sources.

CAMS 659: As shown in Figure 33, dominant winds from south-southeasterly, northeasterly and northwesterly were observed during episode days with eight hour ozone concentrations ranging between potential levels of 65 ppb to 70 ppb and 60 ppb to 65 ppb. During the days with ozone levels ranging between 65 ppb to 70 ppb 92% of the measurements recorded wind speeds ranging between 0.5 – 2.0 m/s while remainder recorded calm winds below 0.5 m/s. Approximately 73% of the measurements during episode days with ozone concentrations ranging between 60 ppb to 65 ppb recorded wind speeds between 0.5 – 2.0 m/s while 20% recorded those ranging between 2.0 – 4.0 m/s. Calm winds below 0.5 m/s were recorded during 7% of the hourly measurements as shown in Figure 33.

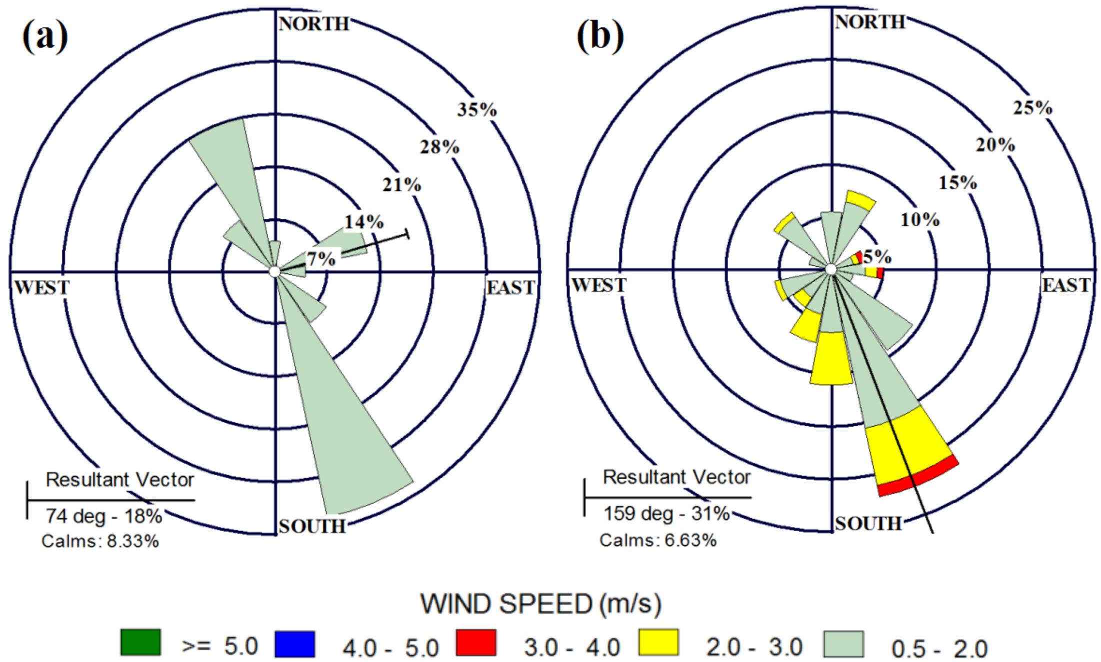

Figure 33. Prevailing wind speed and wind direction during high ozone days measured at CAMS 659 during 2013 (a) 65 to 70 ppb and (b) 60 to 65 ppb.

During the identified episode days of 2014 at CAMS 659 dominant contribution by winds from northeast, south, and southeast was noted as shown in Figure 34. Only one episode day with daily maximum eight hour ozone concentration exceeding 75 ppb was recorded in 2014 during which 79% of the measurements were associated with wind speeds ranging between 2.0 – 4.0 m/s while remainder comprised of those ranging between 0.5 – 2.0 m/s. Wind speeds ranging between 0.5 – 2.0 m/s accounted for 84% of measurements acquired during episode days with ozone concentrations between 70 ppb to 75 ppb. Approximately 5% during these days consisted of winds with speed above 2.0 m/s while 11% were calm below 0.5 m/s.

As shown in Figure 34 major contribution by winds with speed ranging between 0.5 – 2.0 m/s accounting for 61% was noted during episode days between 65 ppb to 70 ppb, followed by 30% contribution by winds with speed above 2.0 m/s. During episode days with ozone concentration ranging between 60 ppb to 65 ppb minimal influence of winds with speed above 4.0 m/s accounting for 4% was noted to influence ambient measurements at CAMS 659. Winds with speed ranging between 2.0 – 4.0 m/s accounted for 42% while those ranging between 0.5 – 2.0 m/s accounted for 48%. Remainder of the measurements accounting to approximately 6% were noted to comprise of calm winds with speed below 0.5 m/s (Figure 34).

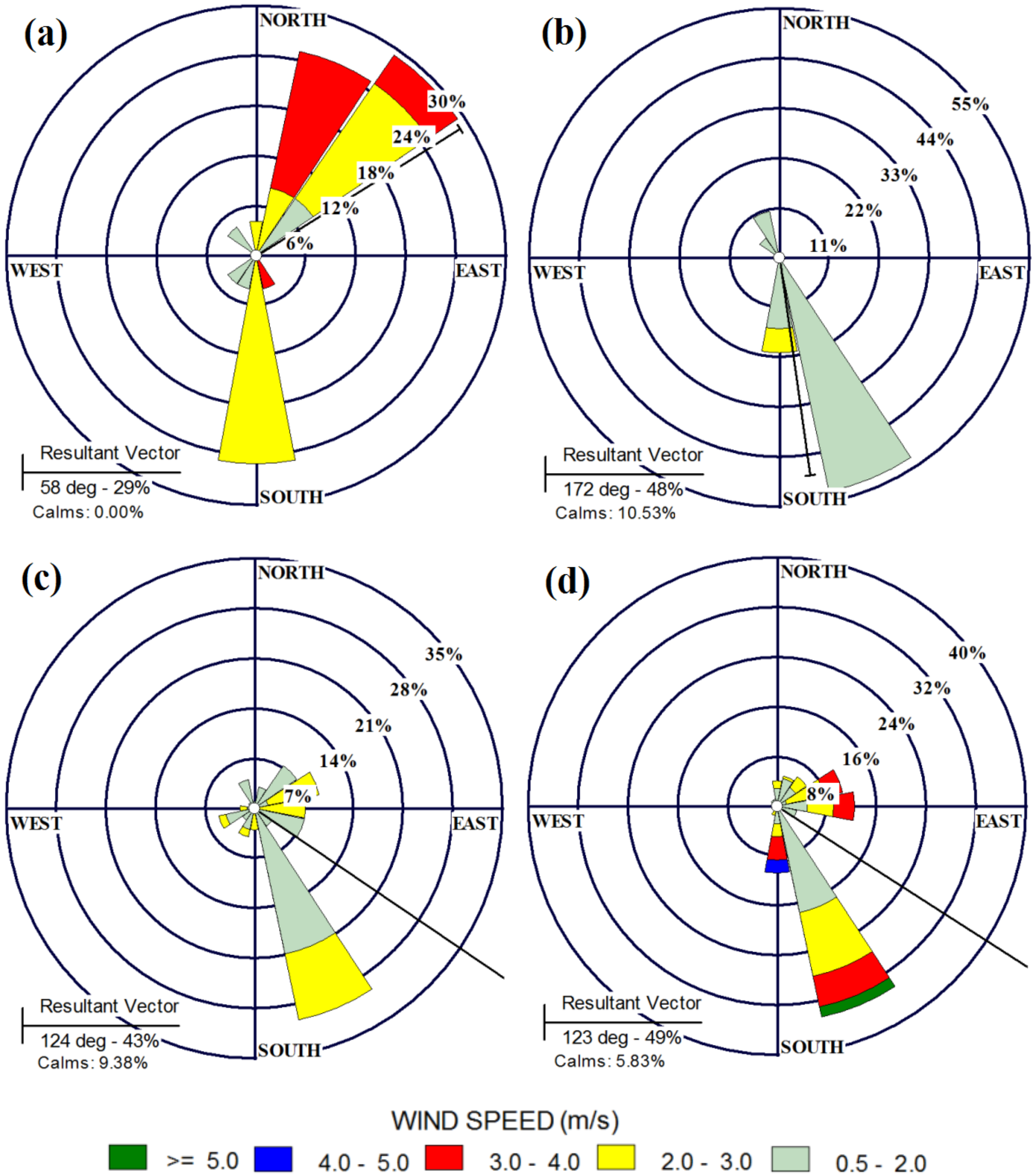

Figure 34. Prevailing wind speed and wind direction during high ozone days measured at CAMS 659 during 2014 (a) >=75 ppb, (b) 70 ppb to 75 ppb, (c) 65 ppb to 70 ppb and (d) 60 ppb to 65 ppb.

<u>CAMS 686:</u> Dominant winds from southeast were recorded during the days with eight hour ozone concentrations exceeding potential levels of 70 ppb, 65 ppb and 60 ppb as shown in Figure 35. The other significant wind directions included north, northeast and northwest. During episode days with eight hour ozone concentrations ranging between 70 ppb to 75 ppb approximately 62% of measurements recorded wind speeds ranging between 0.5 – 2.0 m/s. Approximately 34% of measurements recorded wind speeds ranging between 2.0 – 4.0 m/s while those ranging between 4.0 – 6.0 m/s accounted for 2% of the measurements. As shown in Figure 35 calm winds below 0.5 m/s were observed to account for 2% of the data.

Approximately 51% of measurements observed during episode days with eight hour ozone concentrations ranging between 65 ppb to 70 ppb recorded wind speeds within range of 0.5 – 2.0 m/s. Measurements with wind speeds in range of 2.0 – 4.0 m/s accounted for 36% while 11% of measurements included wind speeds in range of 4.0 – 6.0 m/s. Calm winds with speeds below 0.5 m/s accounted for 2% of the data.

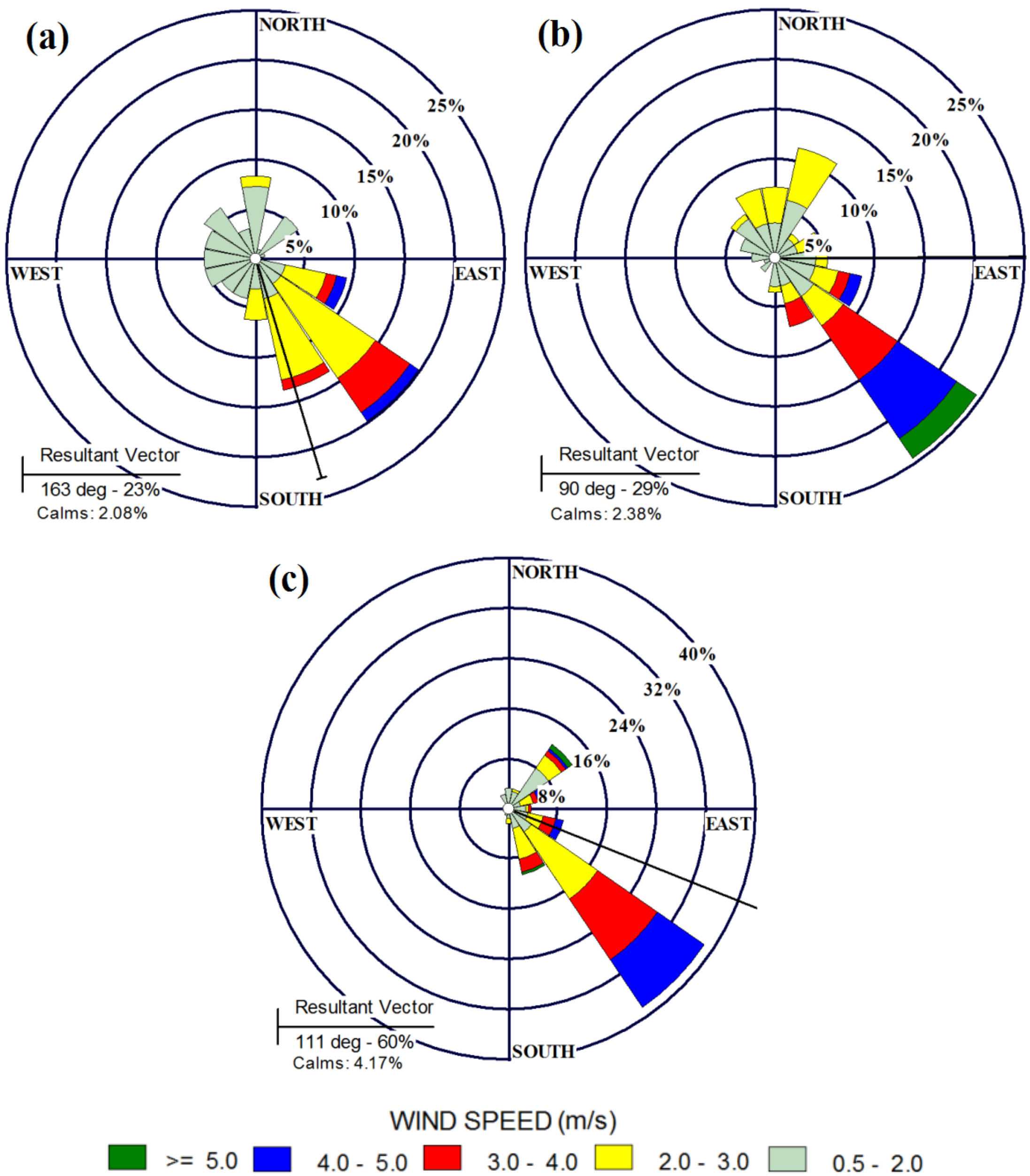

Figure 35. Prevailing wind speed and wind direction during high ozone days measured at CAMS 686 during 2013 (a) 70 to 75 ppb, (b) 65 to 70 ppb, and (c) 60 ppb to 65 ppb.

Winds with speed below 0.5 m/s as shown in Figure 35 accounted for 4% of measurements recorded during days with daily maximum eight hour ozone concentration between potential levels of 60 ppb and 65 ppb. Wind speeds ranging between 0.5 to 2.0 m/s were observed to account for 38% while those ranging between 2.0 – 4.0 m/s were dominant accounting for 45%. Minor contribution by winds with speed ranging from 4.0 – 6.0 m/s accounting for 13% of the measurements was observed as shown in Figure 35.

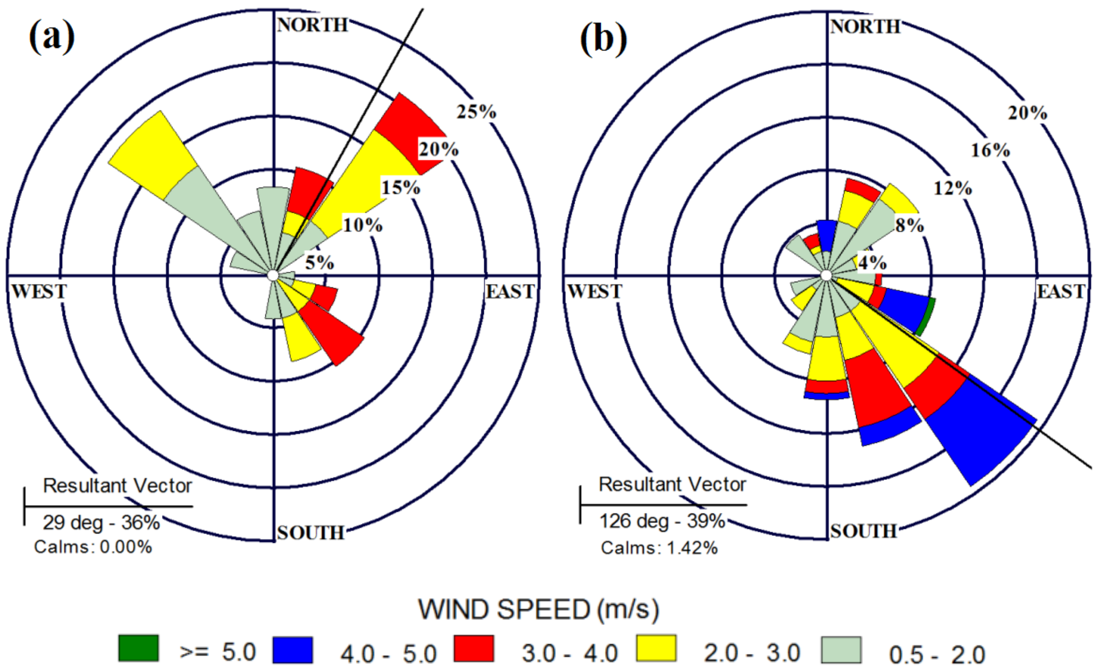

Figure 36. Prevailing wind speed and wind direction during high ozone days measured at CAMS 686 during 2014 (a) 65 ppb to 70 ppb, and (b) 60 ppb to 65 ppb.

As demonstrated in Figure 36 dominant influence of northeasterly and northwesterly winds was noted during episode days with ozone concentration ranging between 65 ppb to 70 ppb while during those ranging between 60 ppb to 65 ppb dominant southeasterly winds with minor contribution from southerly and northeasterly winds was noted. During episode days with ozone concentration ranging between 65 ppb to 70 ppb wind speeds ranging between 0.5 – 2.0 m/s were noted to account for 54% while reminder varied between 2.0 – 4.0 m/s. Dominant influence by winds with speed ranging between 0.5 – 2.0 m/s accounted for 47% of measurements during episode days with ozone concentration between 60 ppb to 65 ppb. Wind speeds ranging between 2.0 – 4.0 accounted for 37% of measurements while 14% recorded winds with speed above 4.0 m/s.

Thus, as shown by the above analysis dominant winds below 2.0 m/s from north, northeast, south and southeast were dominant during days with ozone concentrations exceeding current NAAQS as well threshold levels (70 ppb, 65 ppb, and 60 ppb). Minor contribution by northwesterly and westerly winds was noted and thus additional trajectory analysis was performed to identify the regional sources contributing to long range transport of ozone levels.

3.2 BACK TRAJECTORY ANALYSIS

Develop 24-hour back trajectories to determine source regions most likely to affect local area ozone.

Backward trajectory analysis was performed to identify the pathway of air parcels reaching Corpus Christi urban airshed during the identified high ozone days based on current NAAQS as well as threshold levels. Twenty four hour backward trajectories were generated during the high ozone days identified at each monitoring sites using the hybrid single particle lagrangian integrated trajectory (HYSPLIT) model developed by the National Oceanic and Atmospheric Administration (NOAA). The local time (CST) of peak ozone occurrence during the episode day converted into UTC time as required by the model was used as the starting time to generate backward trajectories. Global reanalysis meteorological data was used to calculate the hourly backward trajectories starting at height of 500 m from the ground level. The backward trajectories generated by HYSPLIT for the identified episode days at the monitoring sites are shown in Figures 37 through 42. The inferences shown below were made using the trajectory analysis of high ozone days at CAMS 04 as shown in Figure 37:

(a) Trajectory analysis of the days with eight hour ozone concentration exceeding current NAAQS of **75 ppb** showed dominant winds from north easterly sector.

(b) The twenty four hour backward trajectories generated during the days with maximum 8-hour ozone concentration between potential level of **70 ppb** and current NAAQS of **75 ppb** indicated winds from northeast transporting polluted air parcels originating from surrounding states of Louisiana and Mississippi traveling through Gulf of Mexico.

(c) Trajectory analysis of days with maximum eight hour ozone concentrations greater than **65 ppb** and less than **70 ppb** indicated impact dominant north and northeasterly winds. Winds from north and northeast were observed to transport polluted air parcels originating from Dallas-Fort Worth, Houston-Galveston, and Beaumont-Port Arthur areas.

(d) As shown in Figure 37 backward trajectories during days with maximum eight hour ozone concentrations ranging between **60 ppb** and **65 ppb** indicated influence of northerly, north-northwesterly and southeasterly winds. Southeasterly winds could be attributed of transporting polluted air parcels from Mexico and polluted air mass formed in Gulf by the high pressure systems. North-Northwesterly and northerly winds were studied to transport polluted air parcels from Eagle ford shale exploration as well as industrialized urban areas including Austin, Houston – Galveston and Beaumont-Port Arthur areas.

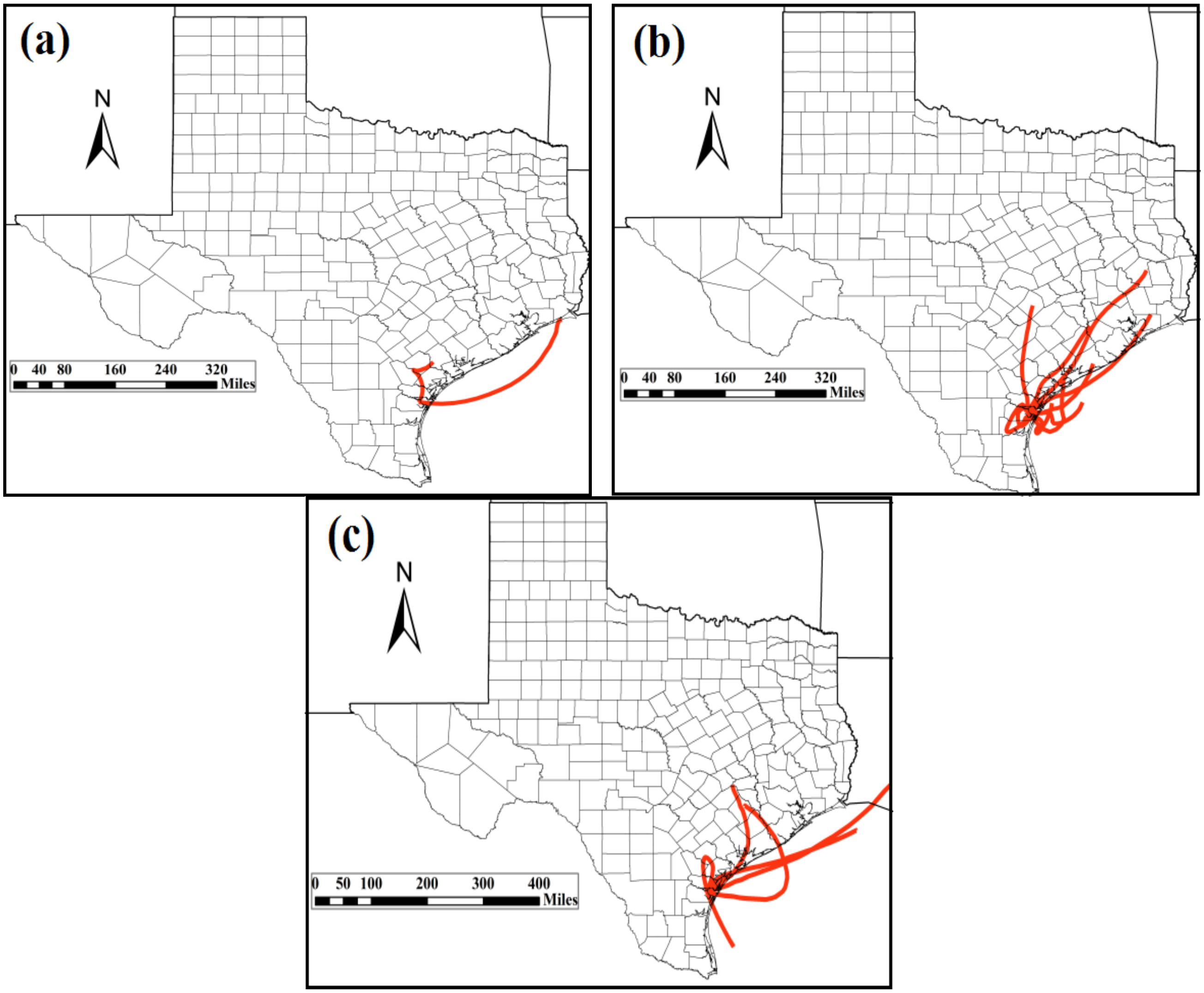

Figure 37. Twenty four hour back trajectories with arrival time at CAMS 04 on hour of peak daily eight hour maximum ozone concentrations (CST) (a) 70 ppb to 75 ppb, (b) 65 ppb to 70 ppb, and (c) 60 ppb to 65 ppb during 2013 and 2014.

Backward trajectories analysis of high ozone days measured at CAMS 21 as shown in Figure 38 exhibited similar source region impacts during episode days exceeding threshold levels of **60 ppb** and less than **65 ppb** as observed at CAMS 04. Long range transport of polluted air parcels originating from Dallas-Fort Worth, Houston-Galveston, and Beaumont-Port Arthur areas was observed associated with northerly and northeasterly winds.

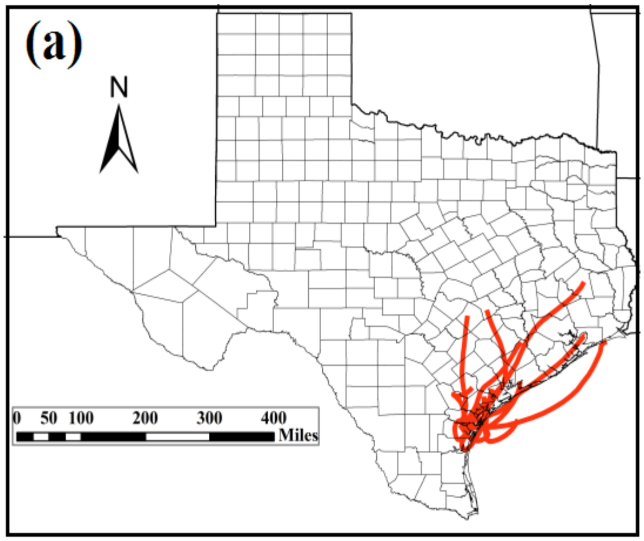

Figure 38. Twenty four hour back trajectories with arrival time at CAMS 21 on hour of peak daily eight hour maximum ozone concentrations (CST) greater than (a) 65 to 60 ppb during 2013 and 2014.

Figure 39 shows the results of the trajectory analysis conducted for CAMS 660 and the results of the analysis are discussed below:

(a) Trajectory analysis of the days with eight hour ozone concentration exceeding current NAAQS of **75 ppb** showed dominant winds from easterly sector.

(b) Trajectory analysis of the days with eight hour ozone concentration ranging between **70 ppb** and **75 ppb** showed calm and stagnant winds suggesting major local influence.

(c) Trajectory analysis of days with eight hour ozone concentration ranging between **65 ppb** and **70 ppb** recorded at CAMS 660 showed influence of northeasterly winds. Polluted air parcels primarily originating from Houston-Galveston, Beaumont-Port Arthur areas along with those originating from Louisiana were identified to be the probable regional sources influence urban airshed (Figure 39).

(c) Twenty four backward trajectories generated during days with maximum eight hour ozone concentration between threshold levels of **60 ppb** and **65 ppb** also indicated influence northeasterly winds. Polluted air parcel transport from upwind industrialized urban areas including Houston-Galveston, and Beaumont-Port Arthur areas and Louisiana traveling through Gulf of Mexico were identified to be the probable regional sources influencing ozone levels measured at CAMS 660.

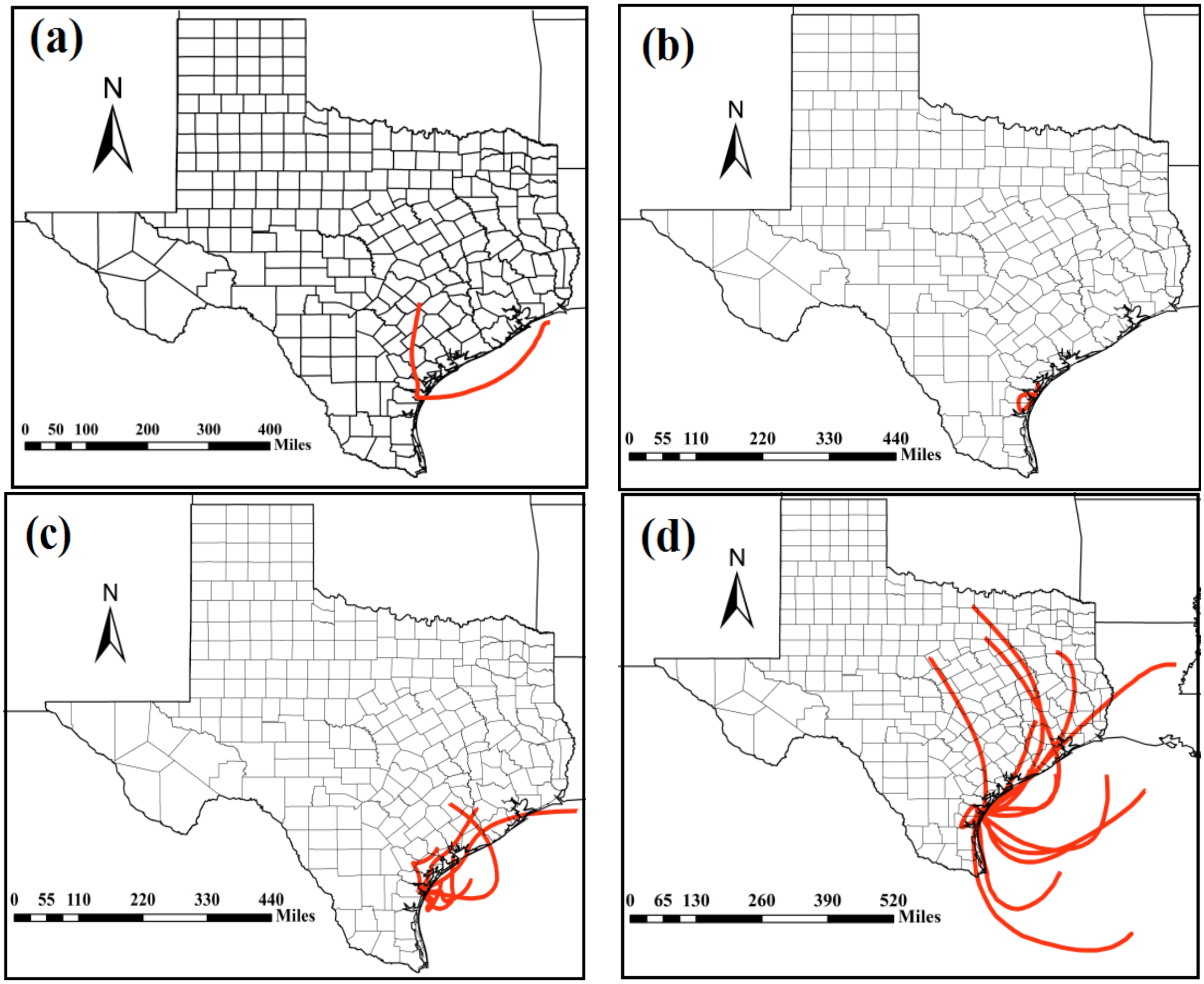

Figure 39. Twenty four hour back trajectories with arrival time at CAMS 660 on hour of peak daily eight hour maximum ozone concentrations (CST) greater than (a) >=75 ppb, (b) 70 ppb to 75 ppb, (c) 65 ppb to 70 ppb, and (d) 60 ppb to 65 ppb during 2013 and 2014.

The 24-hour back trajectory analysis conducted for episode days recorded at downwind site – CAMS 664 is shown in the below Figure 40. The following observations were made from the backward trajectories:

(a) Trajectory analysis of the days with eight hour ozone concentration exceeding current NAAQS of **75 ppb** showed dominant winds from north sector transporting polluted air parcels from surrounding urban areas including Austin and Houston-Galveston.

(b) For days with maximum eight hour ozone concentration ranging between threshold level of **70 ppb** and not exceeding current NAAQS of **75 ppb** trajectory analysis indicated dominant influence of northerly and northeasterly along with southeasterly winds during one episode day as shown in Figure 40. Polluted air parcel transport from Houston-Galveston, Beaumont-Port Arthur along with minor contribution from growing urban areas of Texas including Brownsville McAllen and Mexico were noted to be the regional sources.

(c) As shown in Figure 40 during the days with maximum eight hour ozone concentration ranging between threshold levels of **65 ppb** to **70 ppb** dominant influence of northeasterly winds was observed. The air parcels during these days were observed to be transported predominantly from industrialized areas of Texas including Houston-Galveston and Beaumont-Port Arthur areas, as well as neighboring state of Louisiana.

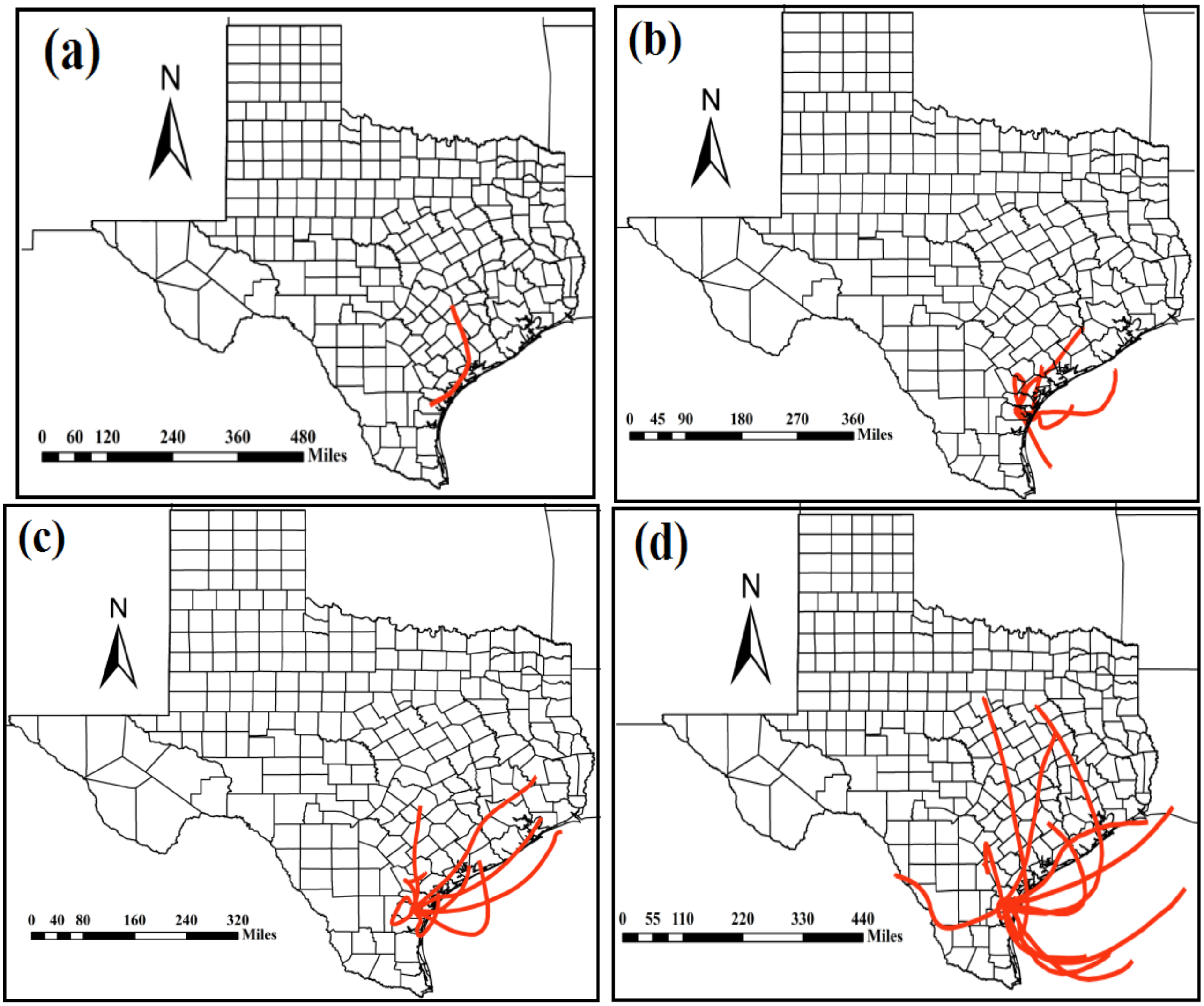

Figure 40. Twenty four hour back trajectories with arrival time at CAMS 664 on hour of peak daily eight hour maximum ozone concentrations (CST) greater than (a) >=75 ppb, (b) 70 to 75 ppb, (c) 65 to 70 ppb, and (d) 60 to 65 ppb during 2013 and 2014.

(d) Twenty-four hour backward trajectory for the identified episode day with maximum eight hour ozone concentration ranging between threshold levels of **60 ppb** to **65 ppb** indicated dominant influence of northwesterly, northerly, easterly and southeasterly winds. Polluted air parcels transported predominantly from industrialized areas of Texas including Houston-Galveston and Beaumont-Port Arthur areas, as well as neighboring state of Louisiana were observed to be the dominant regional sources. Minor influence from occasional polluted air parcel transport from Eagle ford shale explorations was identified to be the probable regional source contributing to elevated levels during these episode days.

The 24- hour backward trajectory analysis conducted for the high ozone days observed at the upwind site, CAMS 659 during 2013 and 2014 is shown in the below Figure 41. The results of the analysis are shown below:

(a) Trajectory analysis of the days with eight hour ozone concentration exceeding current NAAQS of **75 ppb** showed dominant winds from northwesterly sector.

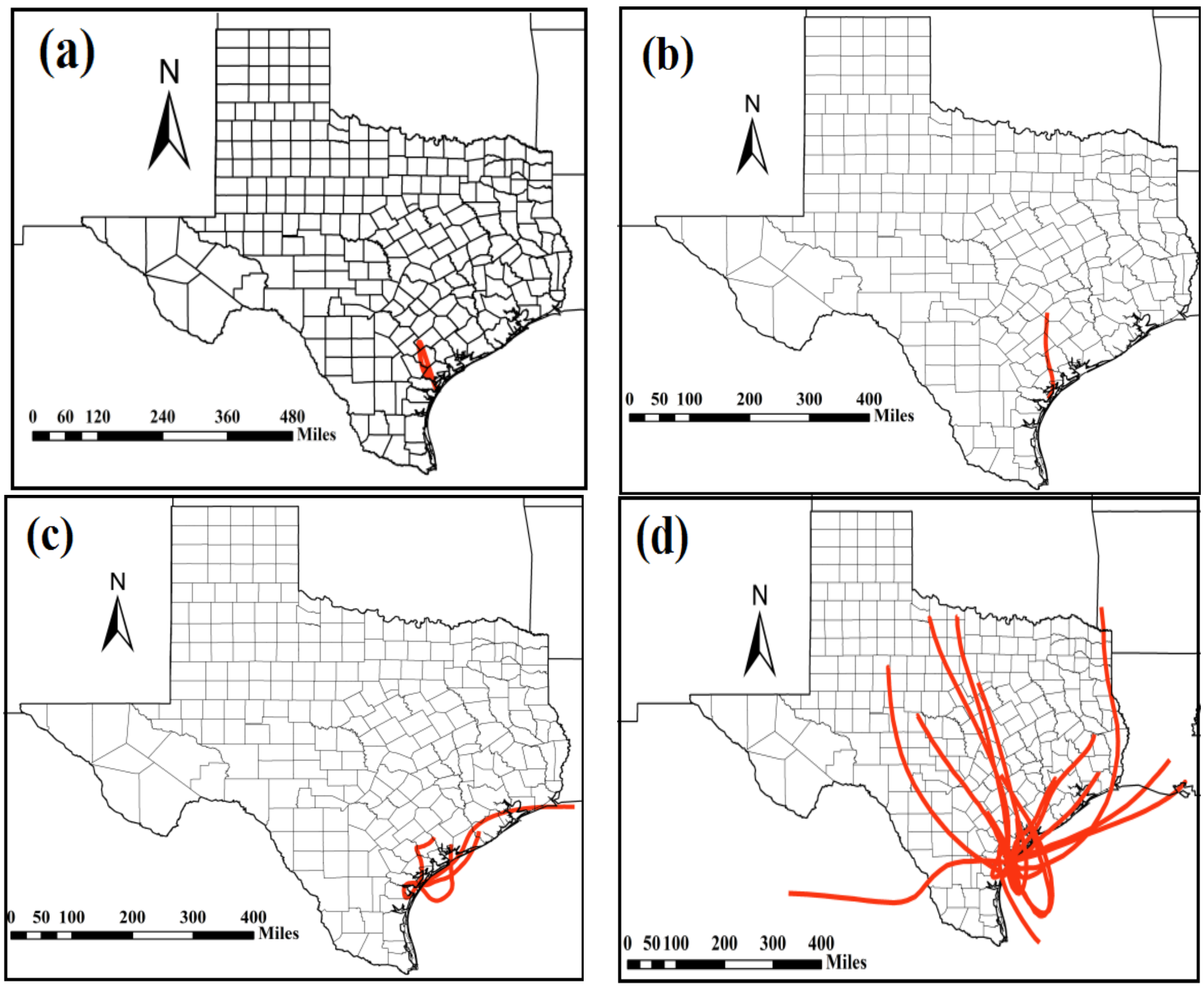

Figure 41. Twenty four hour back trajectories with arrival time at CAMS 659 on hour of peak daily eight hour maximum ozone concentrations (CST) greater than (a) 65 to 70 ppb and (b) 60 to 65 ppb during 2013 and 2014.

(b) Dominant northerly winds were noted during days with daily maximum eight hour ozone concentrations ranging between threshold levels of **70 ppb** to **75 ppb.** As shown in

Figure 41 probable transport of polluted air parcels from industrialized cities of Texas including Dallas – Fort Worth were identified to be the regional sources.

(c) One episode day with daily maximum eight hour ozone concentrations ranging between threshold levels of **65 ppb** to **70 ppb** was recorded at the upwind site – CAMS 659 during 2013. The twenty four hour backward trajectory for the episode day as shown in Figure 41 indicated transport of polluted air parcel from Houston-Galveston and Beaumont-Port Arthur areas associated with northeasterly winds.

(d) Backward trajectory generated during the days with maximum eight hour ozone concentrations in the range of threshold levels **60 ppb** to **65 ppb** indicated dominant influence of winds from northeast and northwest (Figure 41). As shown by the spatial extent of the trajectories northeasterly winds are noted to transport polluted air parcels originating from industrialized metropolitan areas including Fort Worth, Houston-Galveston and Beaumont-Port Arthur areas while those associated with northwesterly winds indicate minor influence of Eagle ford shale exploration.

The 24-hour back trajectory analysis was conducted for the 8-hour ozone thresholds of 75, 70, 65, and 60 ppb at CAMS 686. The following observations were made at CAMS 686:

(a) During days with maximum eight hour ozone concentration ranging between **70 ppb** to **75 ppb**, the trajectory analysis indicated that the wind parcels from northeast region predominantly affected the ozone concentrations measured at CAMS 686 as noted at other monitoring stations. Air parcels during these days were observed to originate from Houston-Galveston, Beaumont-Port Arthur areas and from Louisiana (Figure 42).

(b) During days with maximum eight hour ozone concentration ranging between **65 ppb** to **70 ppb**, the trajectory analysis indicated that the wind parcels from north, northeast and southeast sectors were predominantly affecting the measured ozone concentrations. These wind parcels primarily originated from metropolitan areas of Texas including Houston-Galveston, Beaumont-Port Arthur, Fort Worth areas. Polluted air parcels originating from neighboring state Louisiana traveling through Gulf of Mexico along with those originating from Mexico and Central America were observed to be the contributors to concentrations during the identified episode days.

(a) Trajectory analysis of days with maximum eight hour ozone concentration greater than **60 ppb** and less than **65 ppb** showed dominant influence of northerly, northeasterly and southeasterly winds along with minor contribution from northwest wind sector (Figure 42). Winds from north transported air parcels from Dallas-Fort Worth metropolitan area and Oklahoma while those from northeast transported air parcels from Houston-Galveston, Beaumont-Port Arthur metropolitan areas along with Louisiana. During one of the episode day northwesterly wind indicating transport from Eagle Ford shale exploration area was observed.

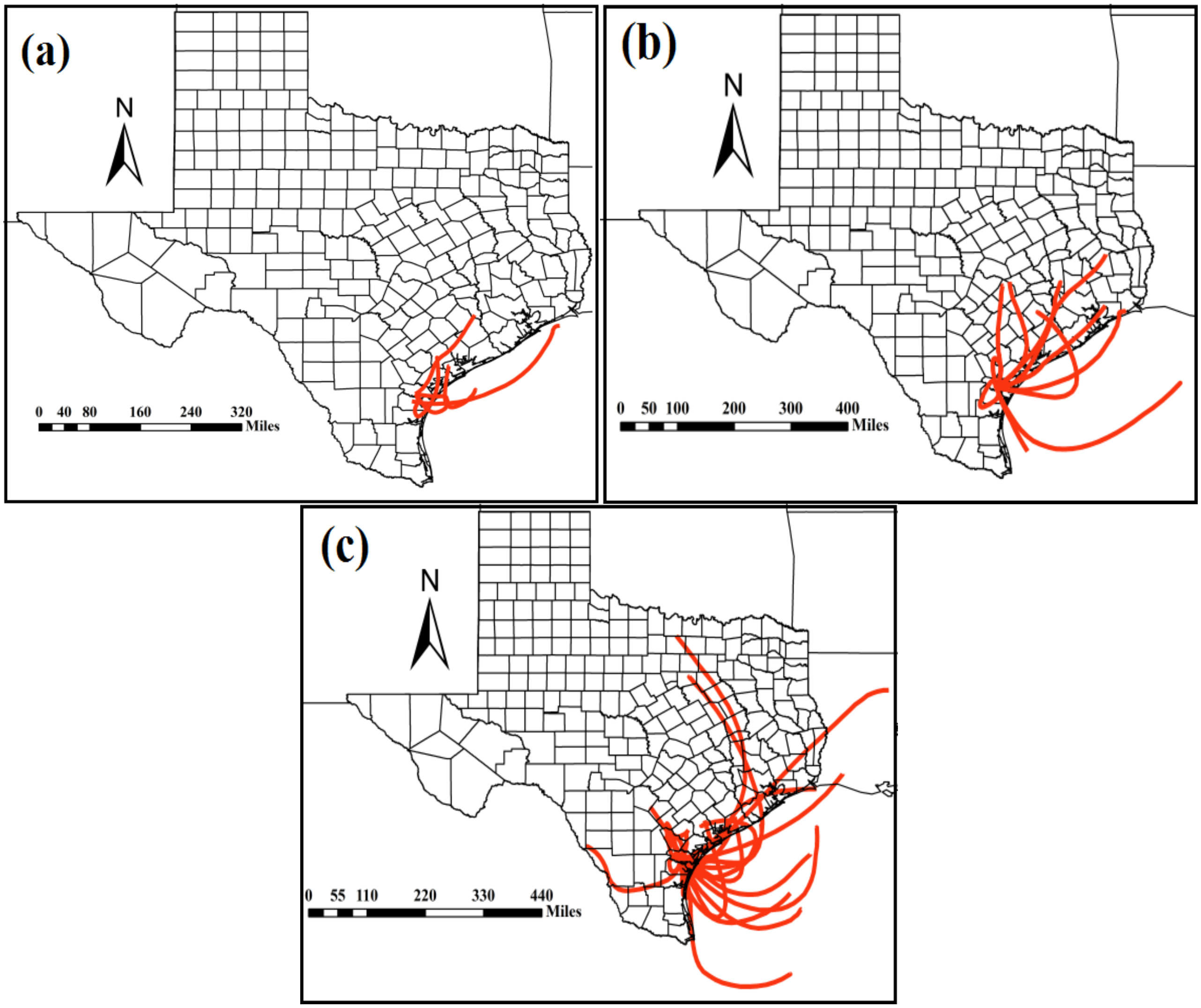

Figure 42. Twenty four hour back trajectories with arrival time at CAMS 686 on hour of peak daily eight hour maximum ozone concentrations (CST) greater than (a) 70 to 75 ppb, (b) 65 to 70 ppb, and (c) 60 ppb to 65 ppb during 2013 and 2014.

Thus, as shown by the backward trajectories the Corpus Christi urban airshed is affected by polluted air parcels transported from highly urbanized and industrialized areas of Texas including Houston-Galveston, Dallas-Fort Worth and Beaumont-Port Arthur along with the active oil and natural gas exploration of Eagle Ford shale. The area was also influenced by transport from surrounding states including Oklahoma, Louisiana and Colorado, and also from Mexico.

4.0 CHARACTERISTICS OF HIGH OZONE EPISODE IN 2013 and 2014

A detailed analysis to identified high ozone days during 2013 and 2014 was performed to study the diurnal variations in the ozone concentrations. As noted in the monthly trends of ozone exceedances elevated levels of ozone concentrations were recorded at both the TCEQ sites including CAMS 04 and CAMS 21 along with the UNT-TAMUK sites including CAMS 660, CAMS 664, CAMS 659 and CAMS 686 exceeding threshold levels (70 ppb, 65 ppb and 60 ppb). Zero episode days exceeding current NAAQS were recorded at TCEQ sites while one episode day was recorded at the urban site – CAMS 660 (03/13/2013; 5/29/2014), downwind site – CAMS 664 (7/1/2013) and upwind site – CAMS 659 (April 29, 2014).

As shown in Figures 43 through 46 ozone concentrations below 40 ppb were observed during early morning hours with the lowest being between 4:00 AM to 6:00 AM (CST). With the increase in emissions from the morning rush hour traffic between 7:00 AM to 9:00 AM (CST), increase in photochemical reactions with increased temperature during mid-day along with evening rush hour traffic between 4:00 PM through 6:00 PM (CST) a constant increase in the ozone concentrations was noted can be noted from 7:00 AM through 6:00 PM (CST).

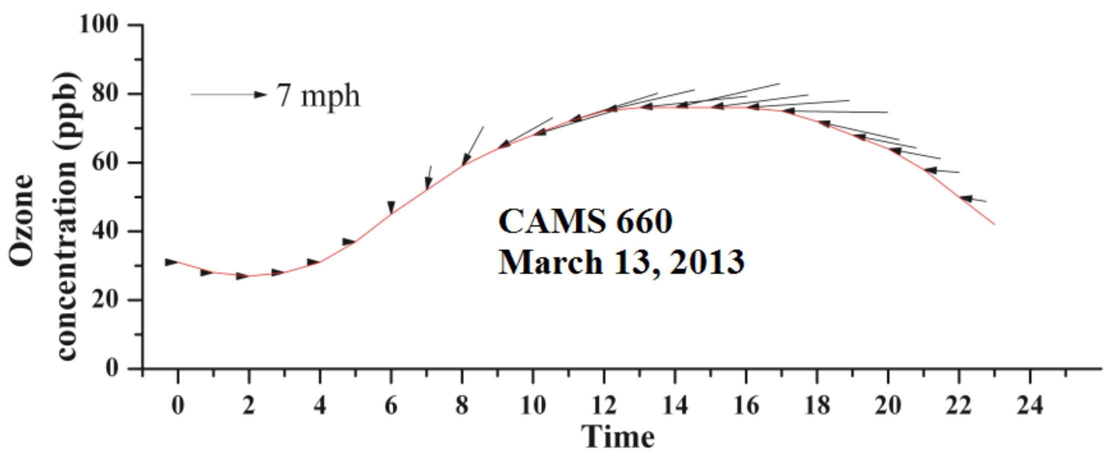

Figure 43. Diurnal trend of hourly ozone concentrations observed during March 13th, 2013 at the urban site.

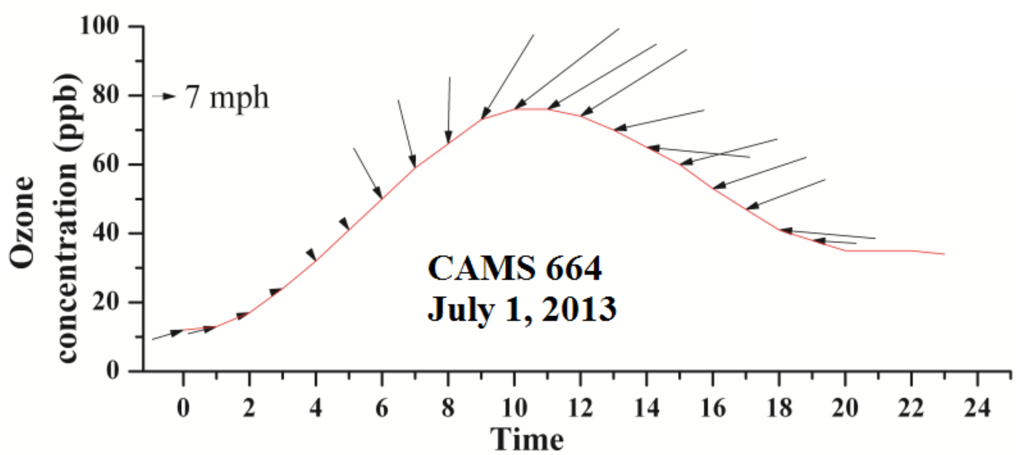

Figure 44. Diurnal trend of hourly ozone concentrations observed during July 1st, 2013 at downwind site – CAMS 664.

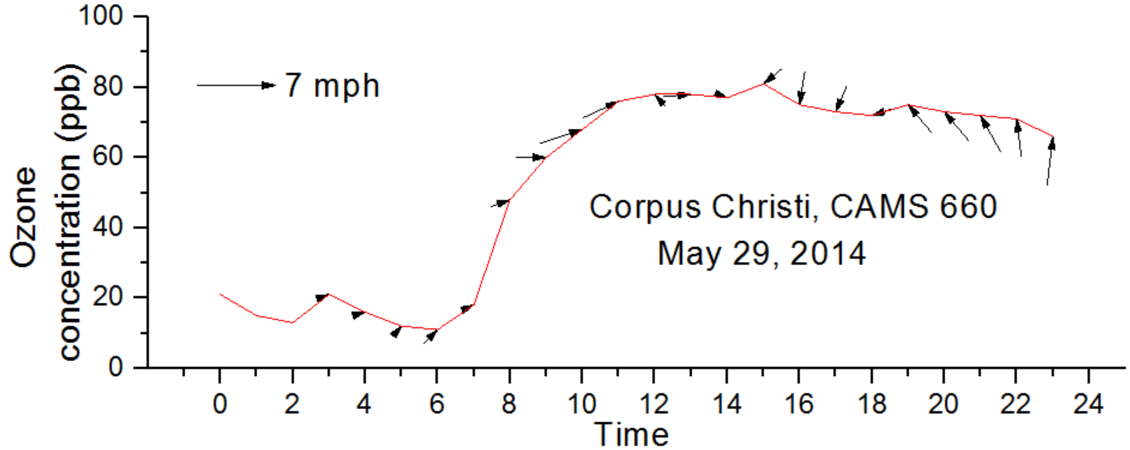

Figure 45. Diurnal trend of hourly ozone concentrations observed during May 29th, 2014 at downwind site – CAMS 660.

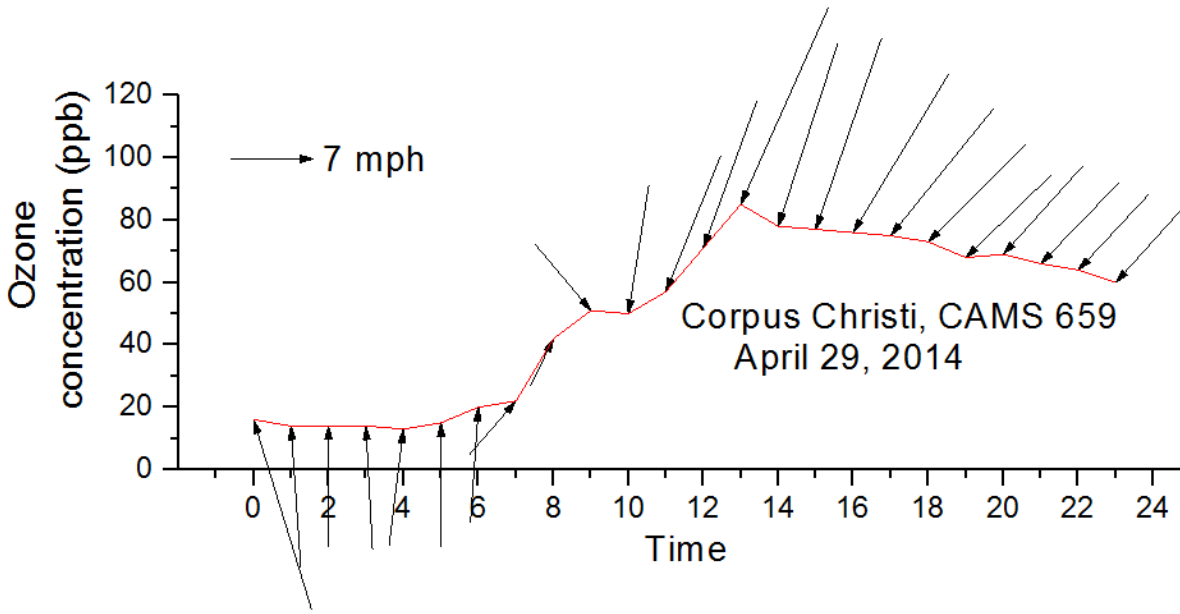

Figure 456. Diurnal trend of hourly ozone concentrations observed during April 29th, 2014 at downwind site – CAMS 659.

Dominant north and northeasterly winds were observed during early morning hours till 12:00 PM (CST) transporting the polluted air parcels from industrialized areas of Texas including Houston Galveston and surrounding states including Louisiana and Mississippi river valley. With the increased local emissions and photochemical modeling along with the polluted air parcels an increase in the ozone concentrations was observed during 2:00 PM through 6:00 PM (CST) with a shift in the dominant wind directions from northeast to southeast. .

5.0 REFERENCES

1. Texas Commission on Environmental Quality (TCEQ), *url: www.tceq.state.tx.us*. (Last accessed January 2012).

2. U.S. Environment Protection Agency (EPA) Guidance on the Use of Models and Other Analysis to Demonstrate Attainment of Air Quality Goals for Ozone and $PM_{2.5}$ and Regional Haze (2007), *url: http://www.epa.gov/scram001/guidance/guide/draft_final-pm-O3-RH.pdf*.

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4. National Climatic Data Center, National Oceanic and Atmospheric Administration, *url: http://www.ncdc.noaa.gov/temp-and-precip/time-series/, accessed on April 11th, 2013.*

APPENDIX

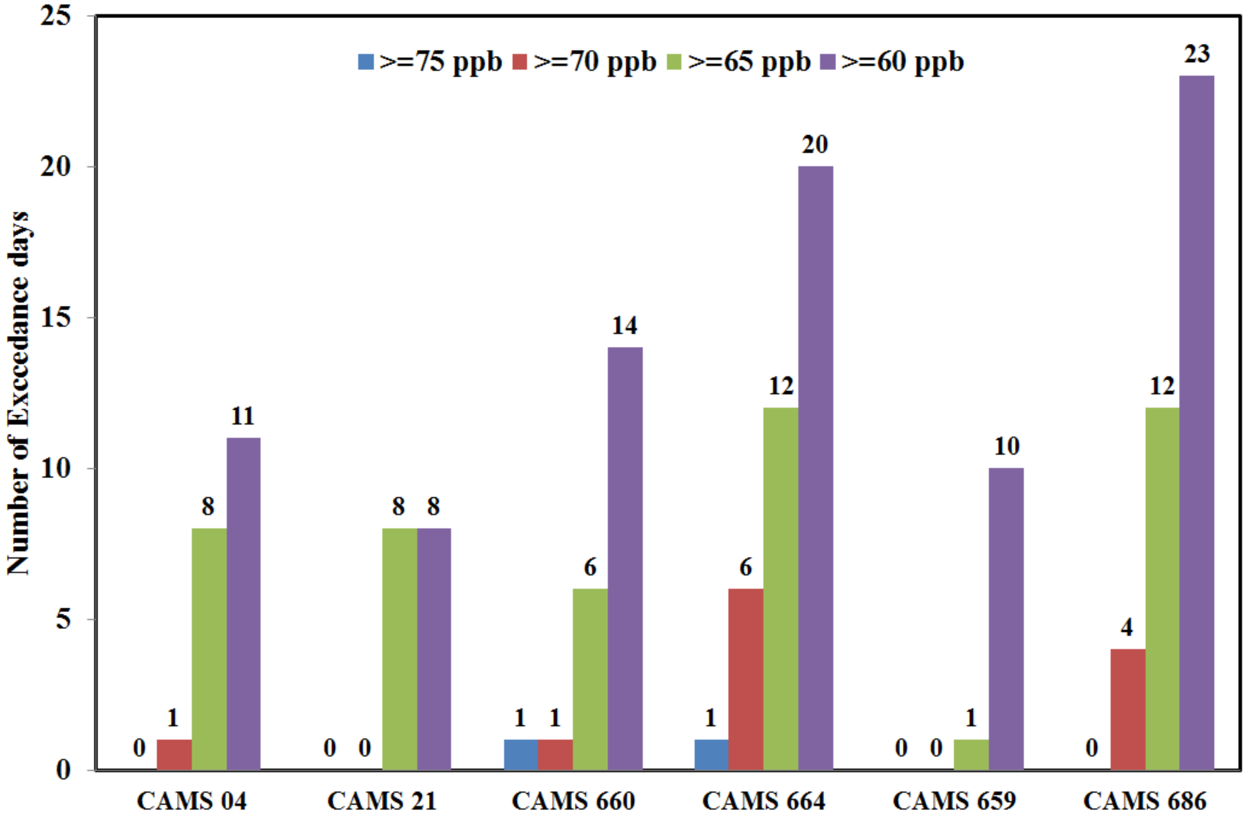

Figure A- 1. Annual frequency of ozone exceedances measured at both TCEQ and TAMUK maintained monitoring stations during 2013.

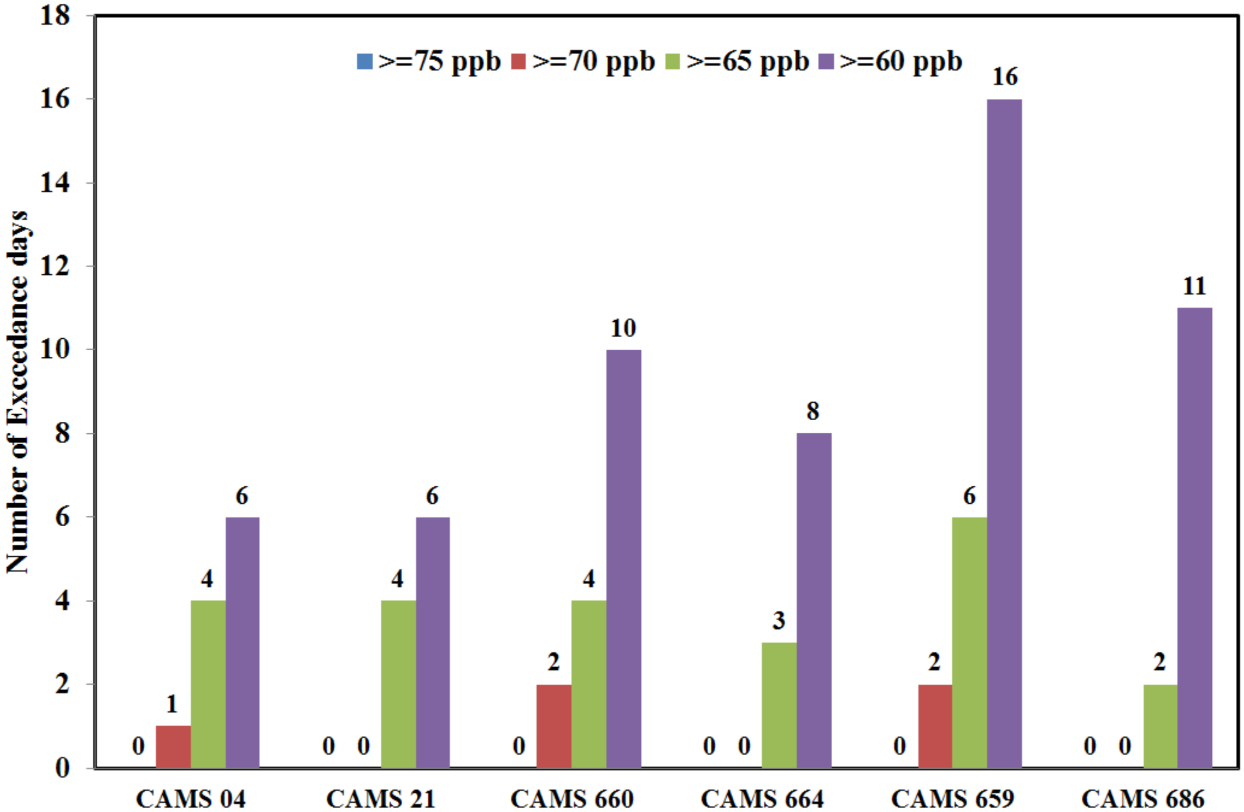

Figure A- 2. Annual frequency of ozone exceedances measured at both TCEQ and TAMUK maintained monitoring stations during 2014.

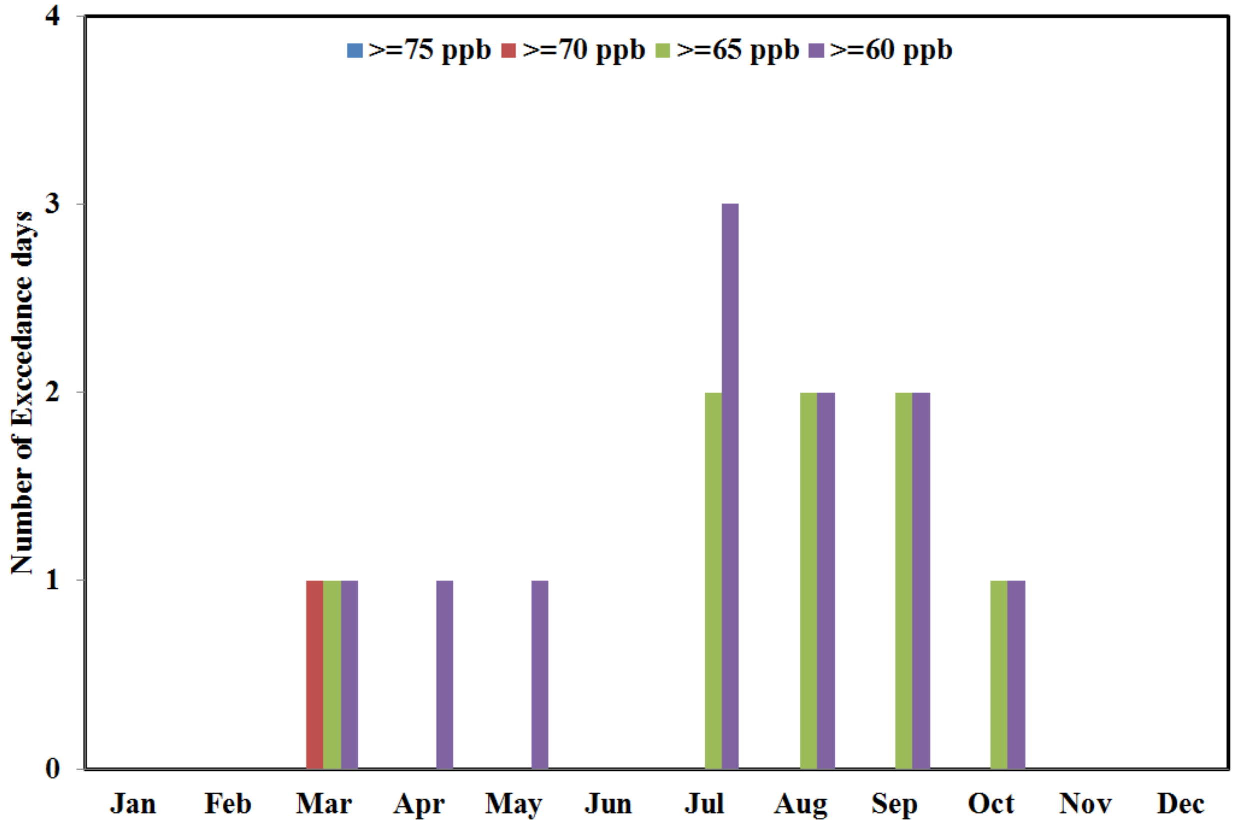

Figure A- 3. Monthly variations in frequency of exceedance days observed at CAMS 04 during 2013 considering the current NAAQS and three threshold levels.

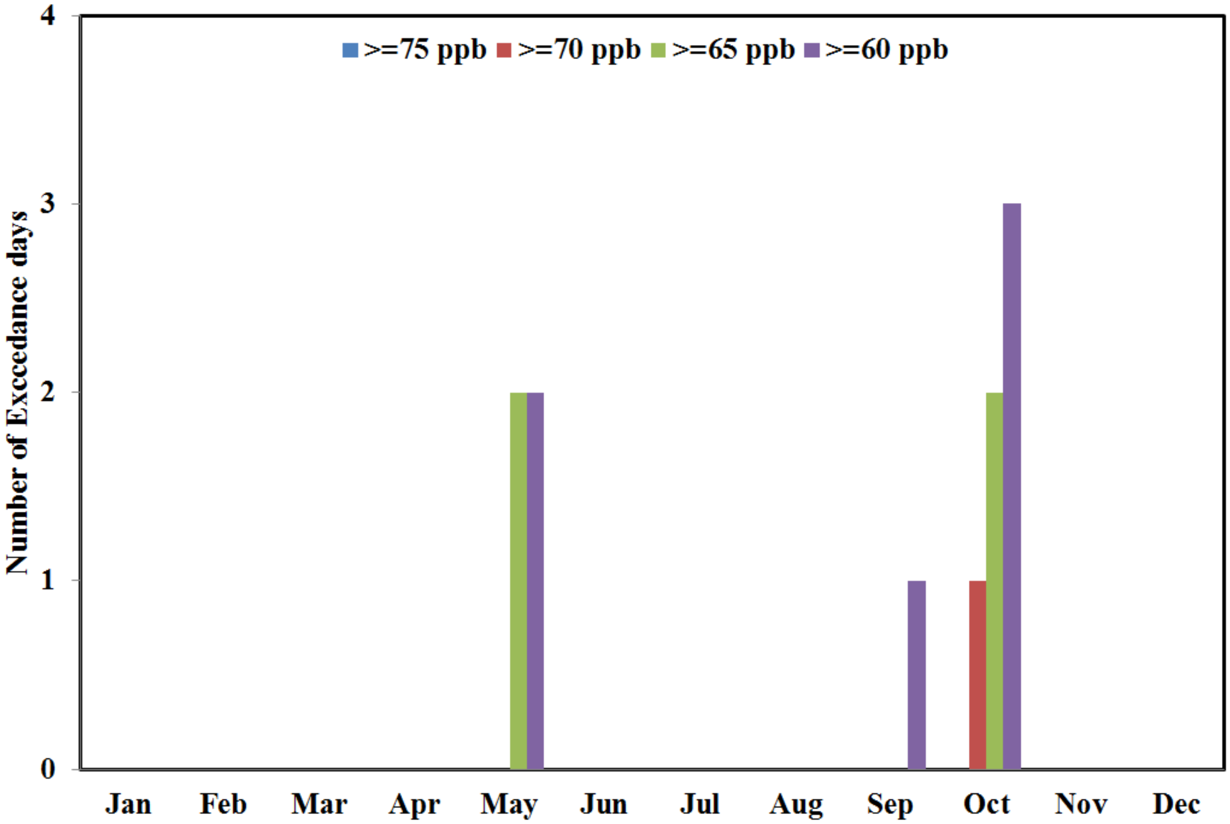

Figure A- 4. Monthly variations in frequency of exceedance days observed at CAMS 04 during 2014 considering the current NAAQS and three threshold levels.

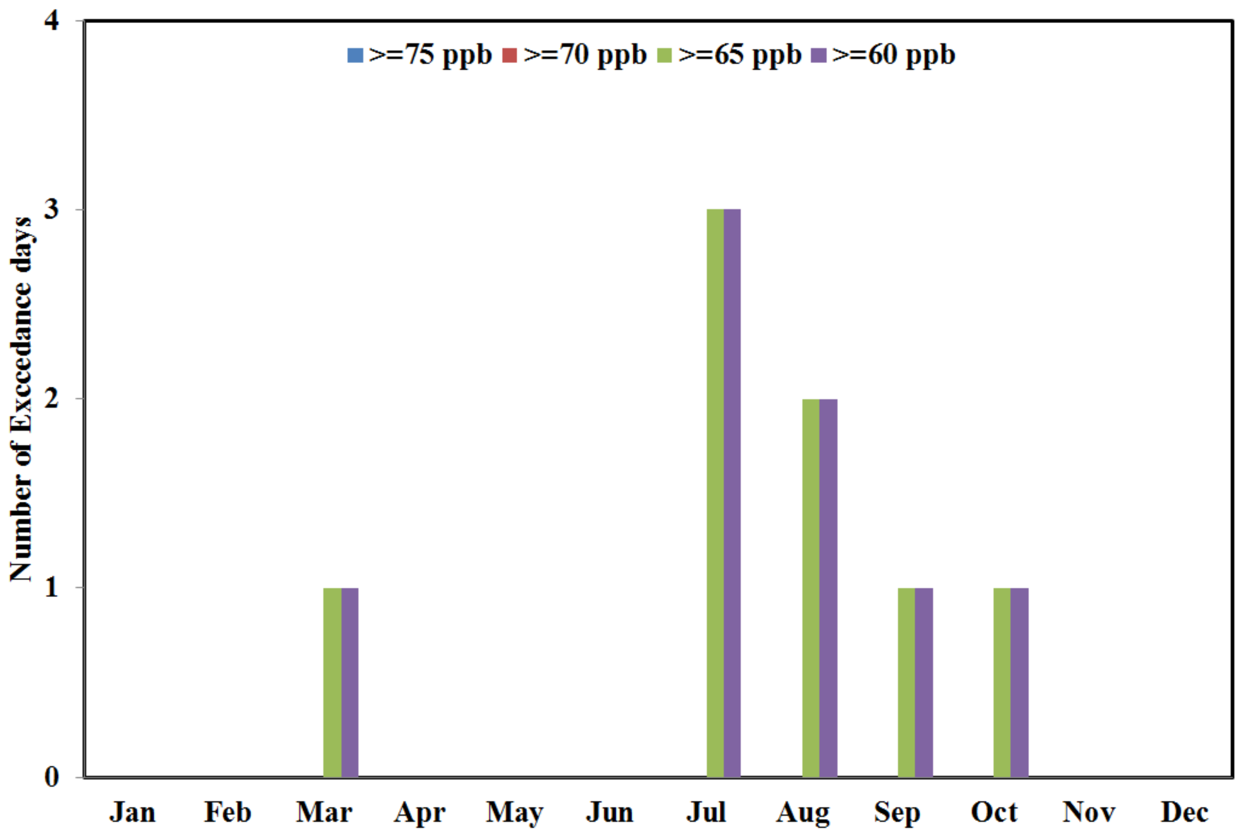

Figure A- 5. Monthly variations in frequency of exceedance days observed at CAMS 21 during 2013 considering the current NAAQS and the three threshold levels.

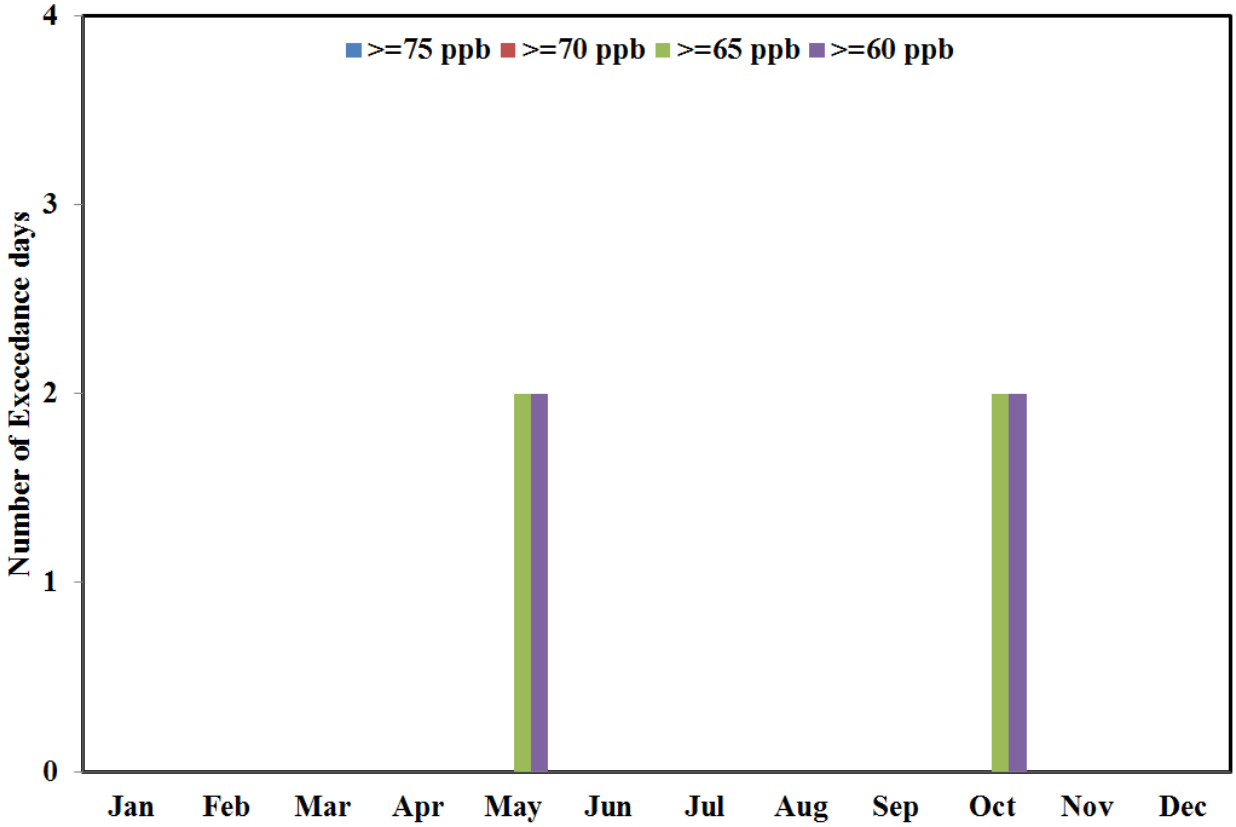

Figure A- 6. Monthly variations in frequency of exceedance days observed at CAMS 21 during 2014 considering the current NAAQS and the three threshold levels.

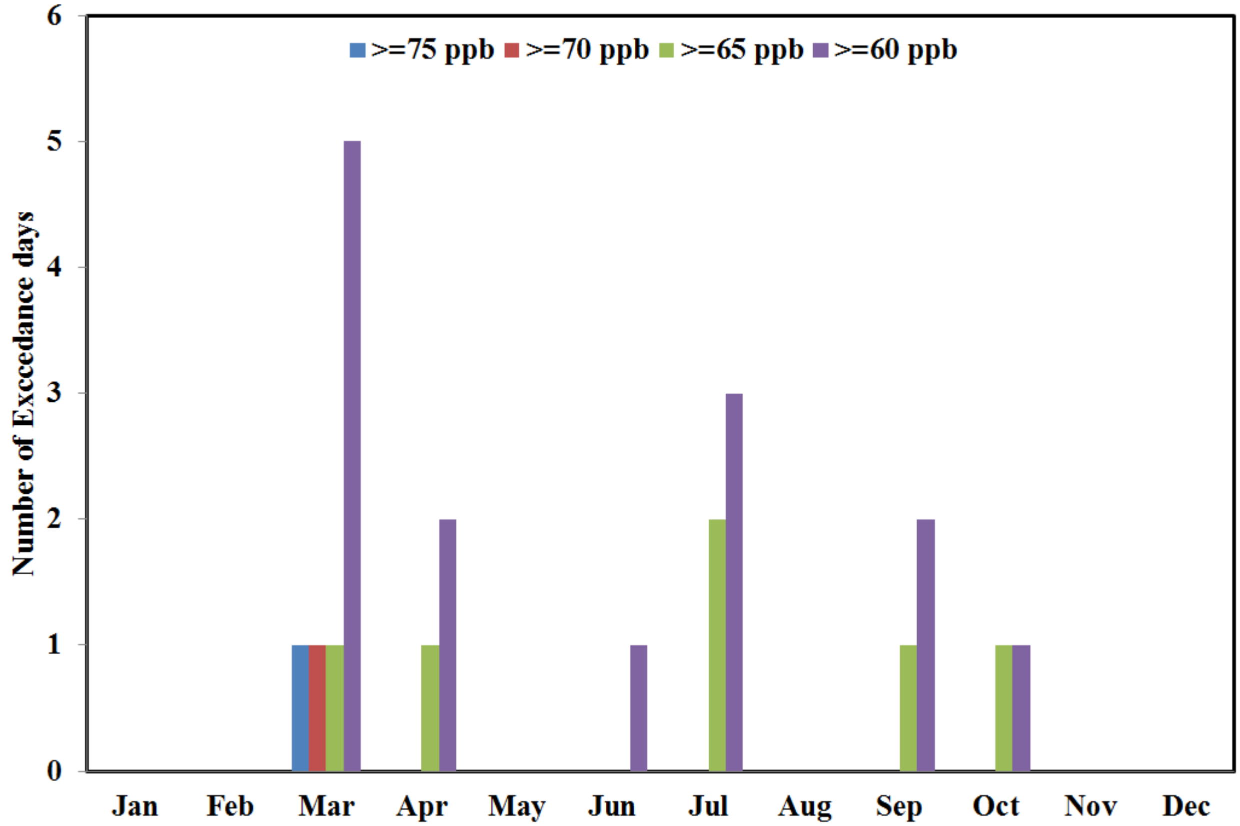

Figure A- 7. Monthly variations in frequency of exceedance days observed at CAMS 660 during 2013 considering the current NAAQS and threshold levels.

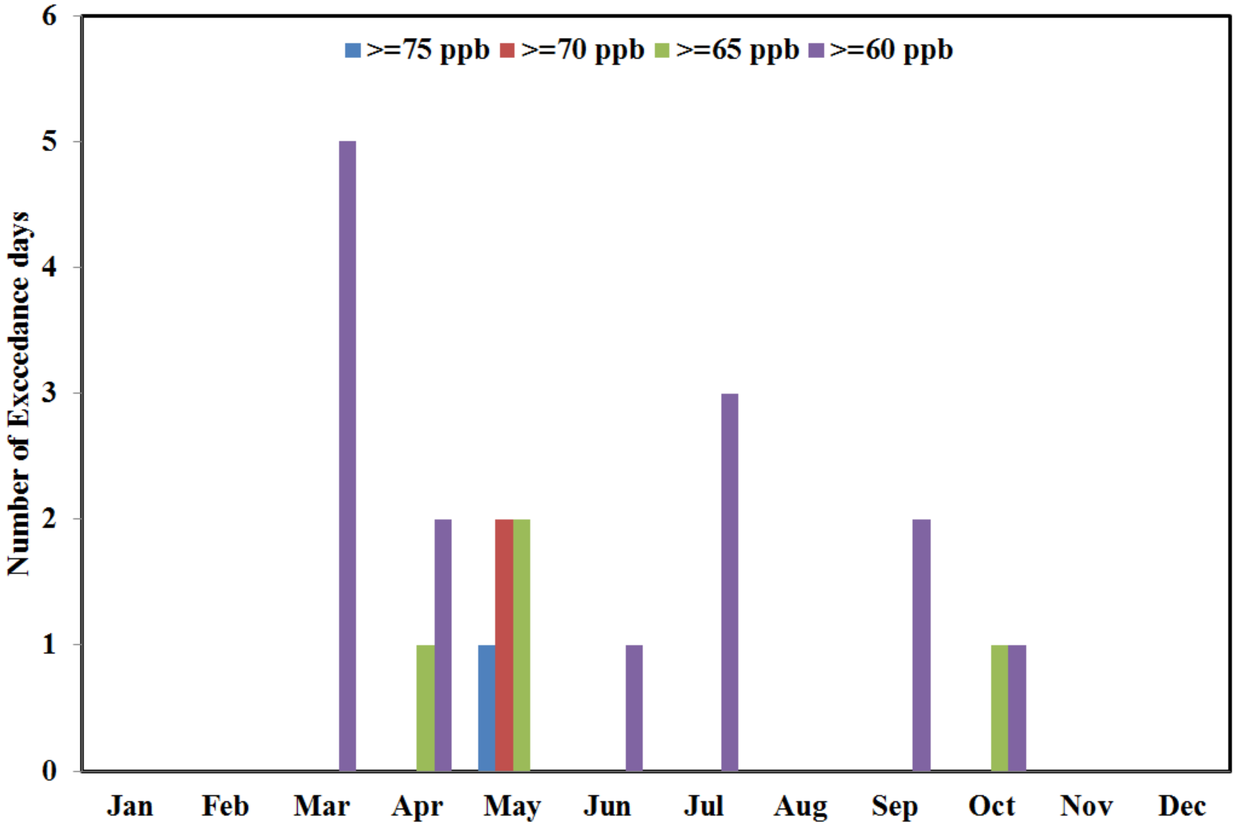

Figure A- 8. Monthly variations in frequency of exceedance days observed at CAMS 660 during 2014 considering the current NAAQS and threshold levels.

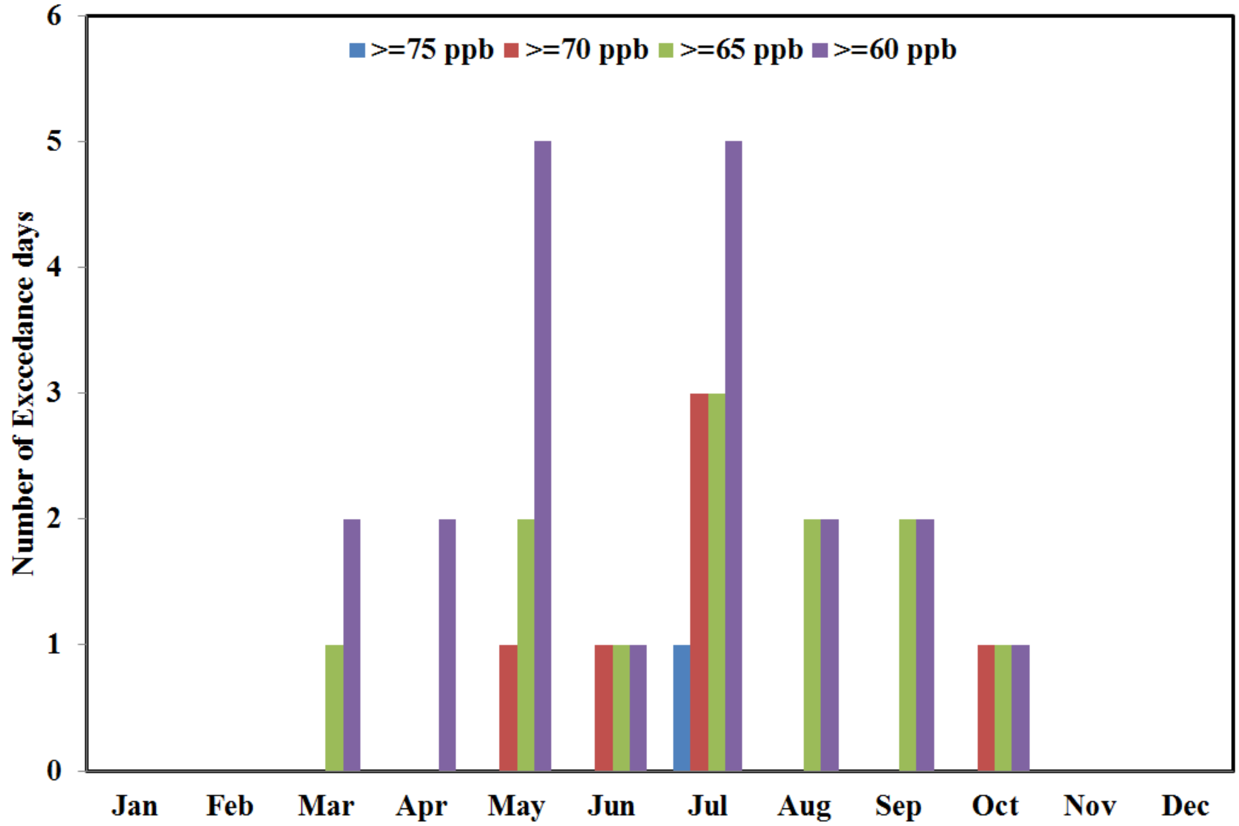

Figure A- 9. Monthly variations in frequency of exceedance days observed at CAMS 664 during 2013 considering the current NAAQS and the threshold levels.

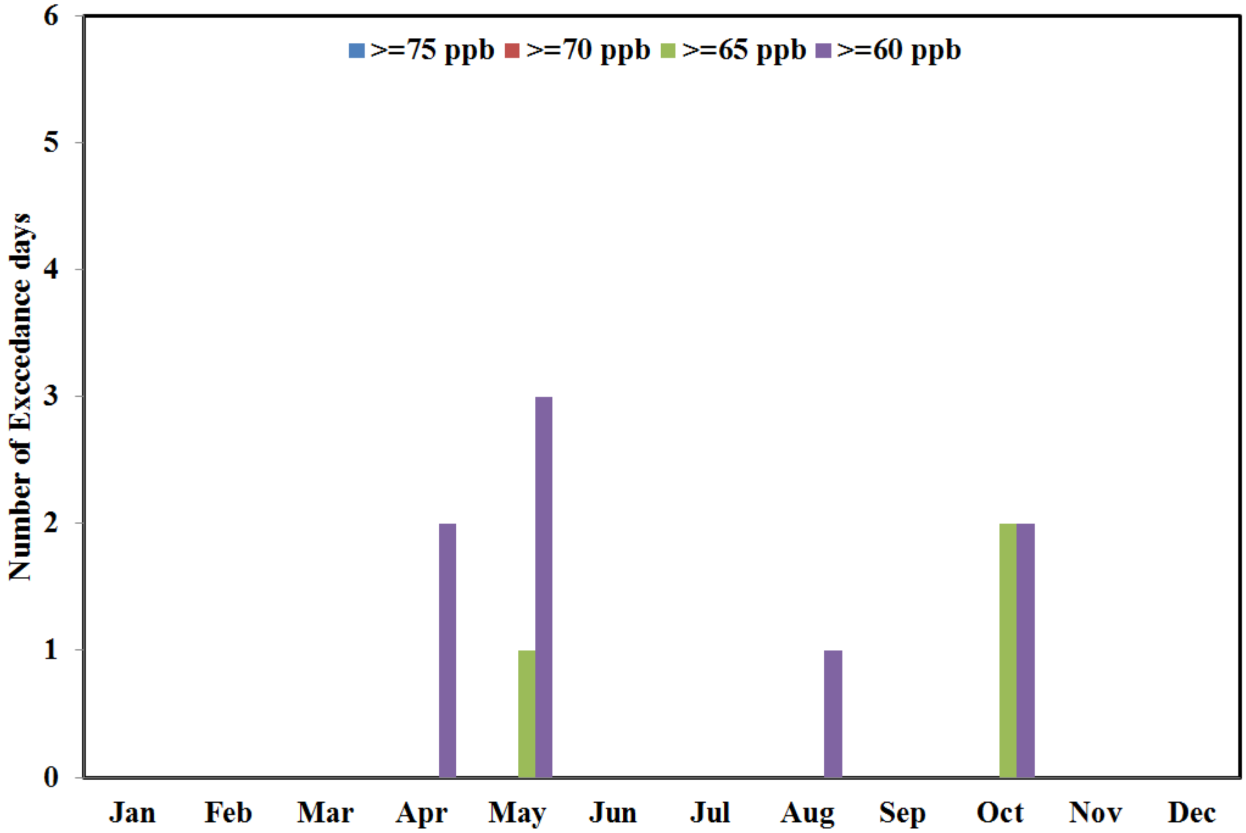

Figure A- 10. Monthly variations in frequency of exceedance days observed at CAMS 664 during 2014 considering the current NAAQS and the threshold levels.

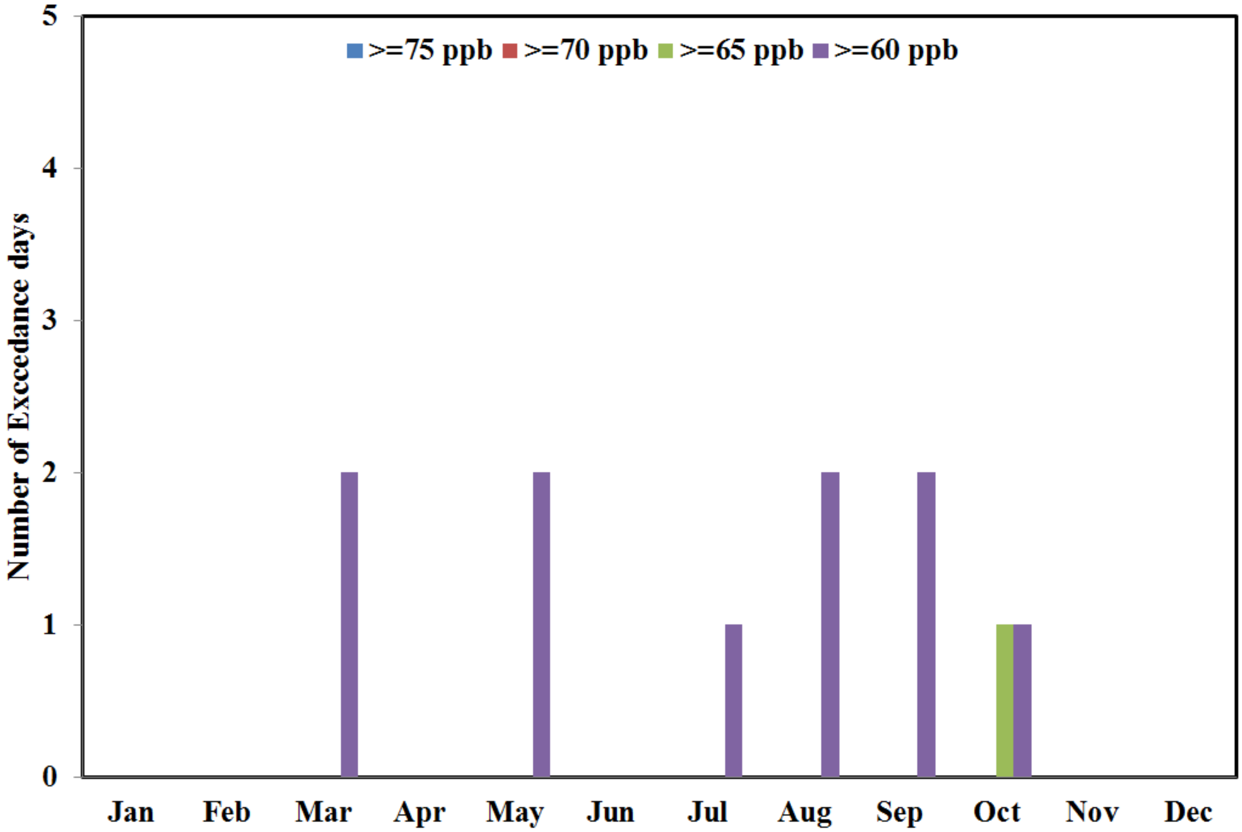

Figure A- 11. Monthly variations in frequency of exceedance days observed at CAMS 659 during 2013 considering the current NAAQS and the threshold levels.

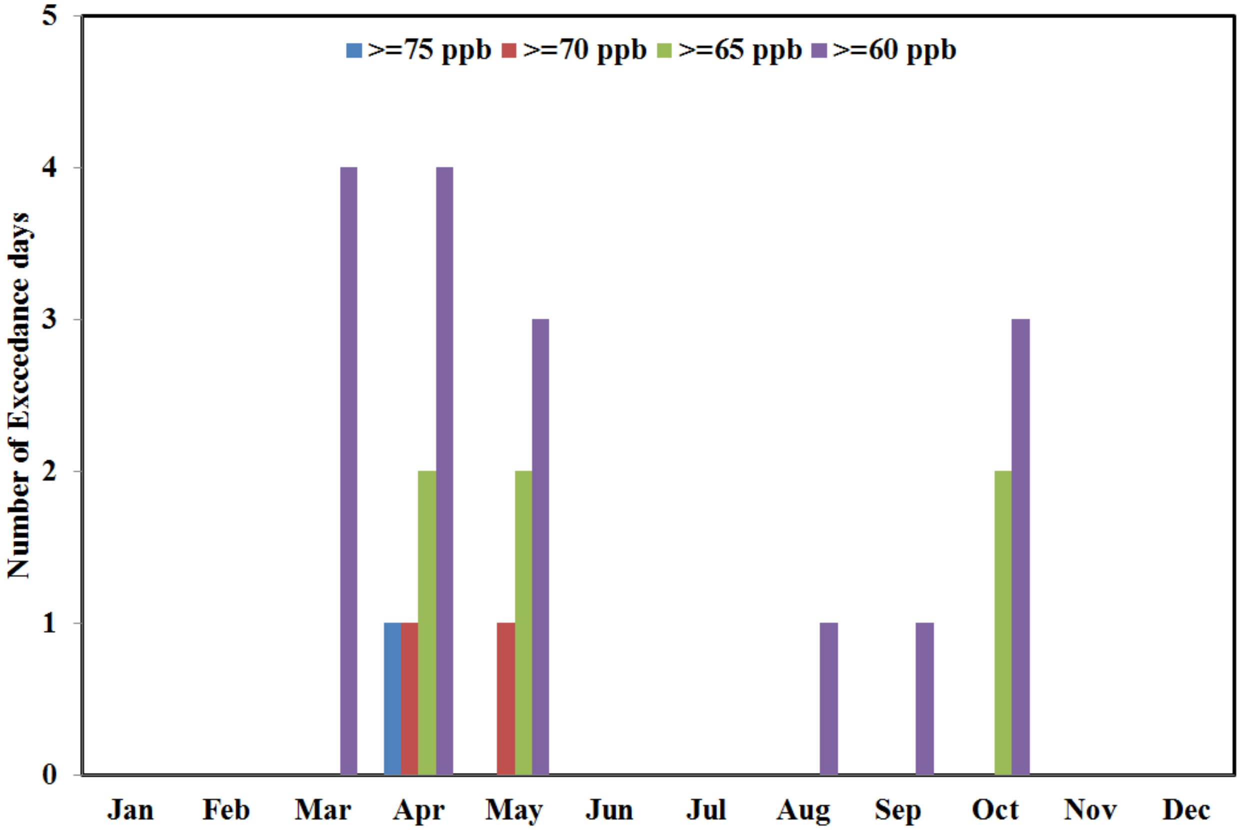

Figure A- 12. Monthly variations in frequency of exceedance days observed at CAMS 659 during 2014 considering the current NAAQS and the threshold levels.

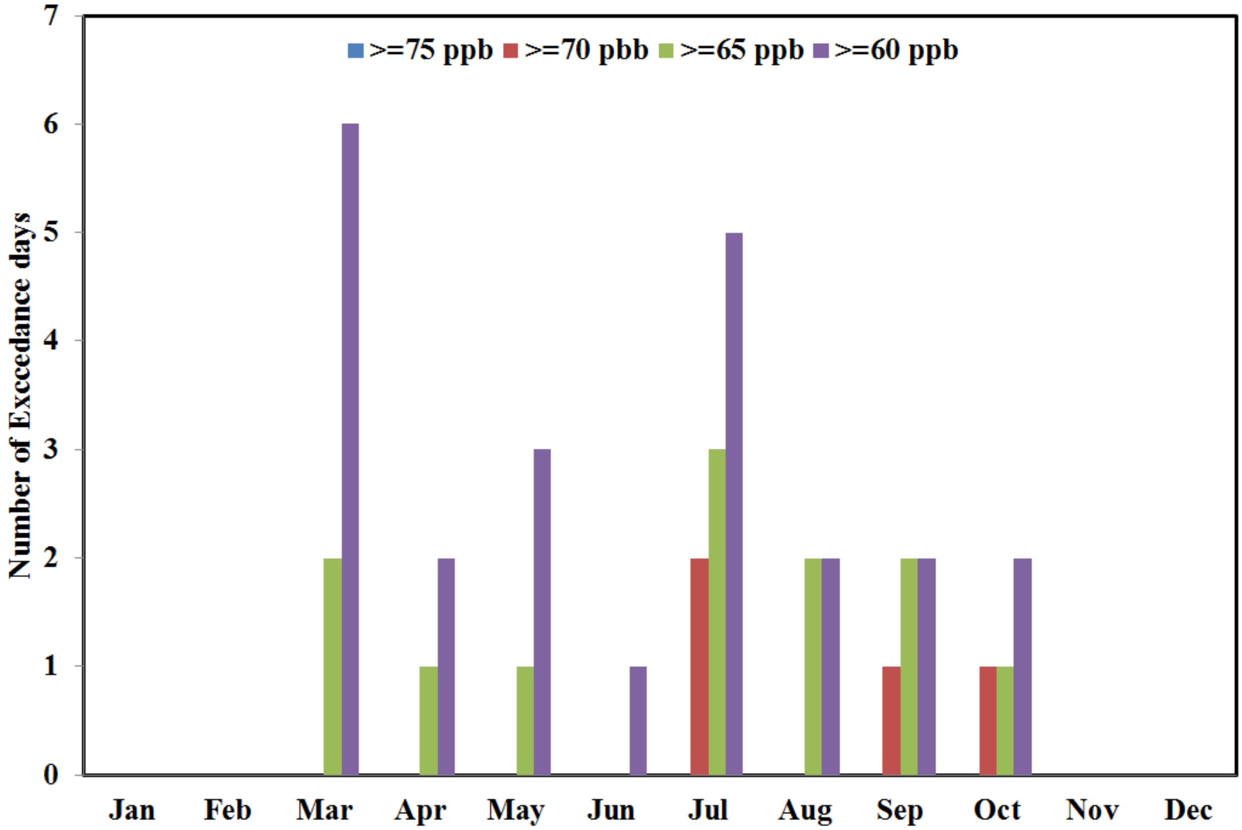

Figure A- 13. Monthly variations in frequency of exceedance days observed at CAMS 686 during 2013 considering the current NAAQS and the threshold levels.

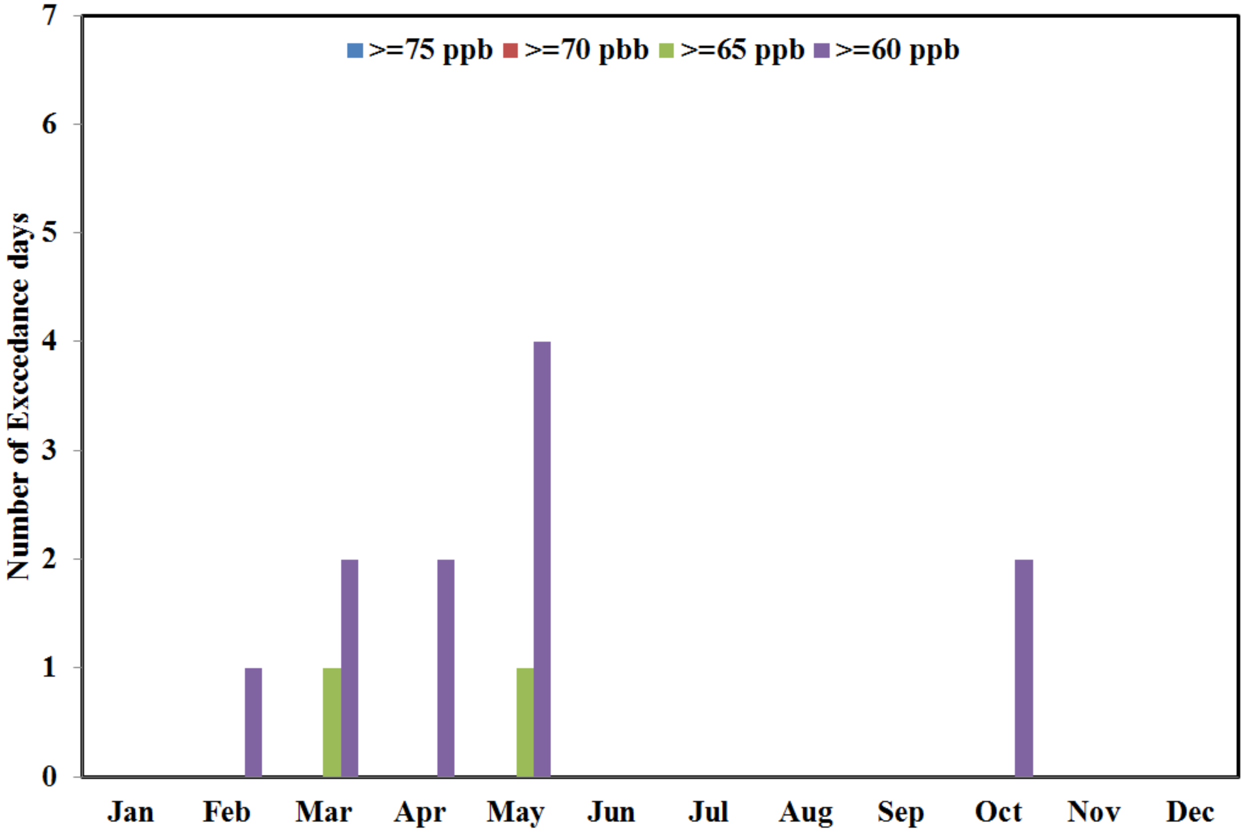

Figure A- 14. Monthly variations in frequency of exceedance days observed at CAMS 686 during 2014 considering the current NAAQS and the threshold levels.

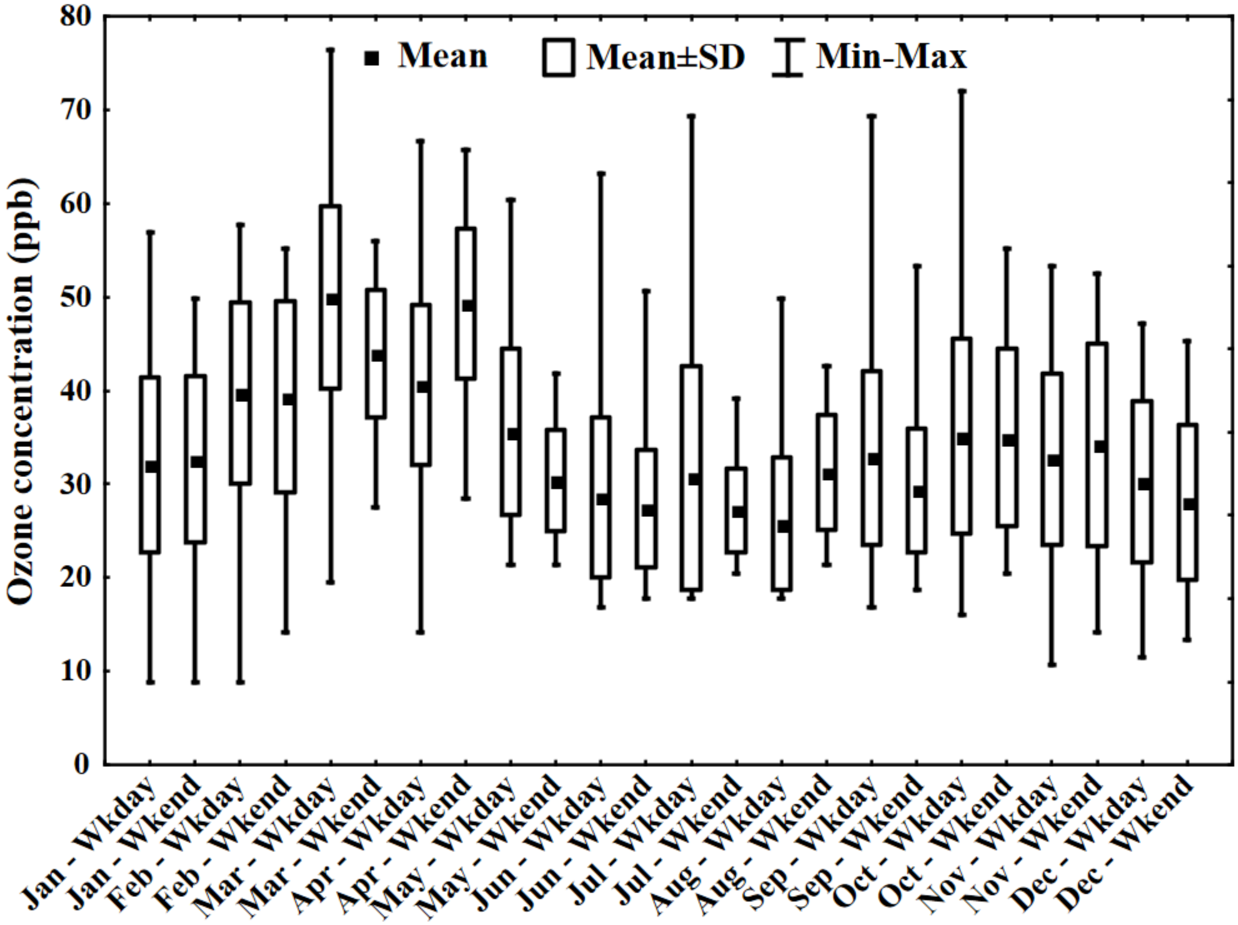

Figure A- 15. Monthly variations in the weekday/weekend ozone concentrations observed at CAMS 660 during 2013.

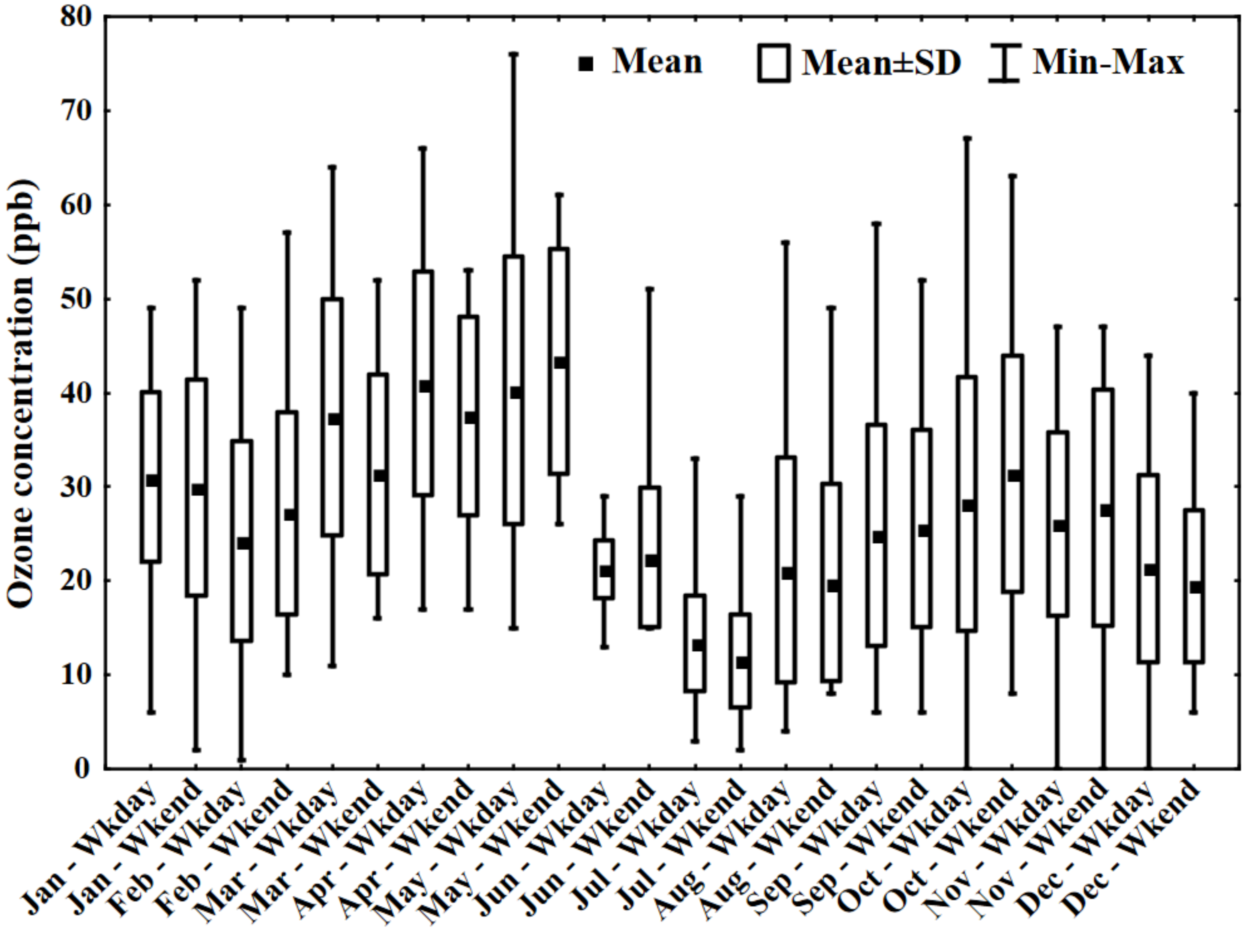

Figure A- 16. Monthly variations in the weekday/weekend ozone concentrations observed at CAMS 660 during 2014.

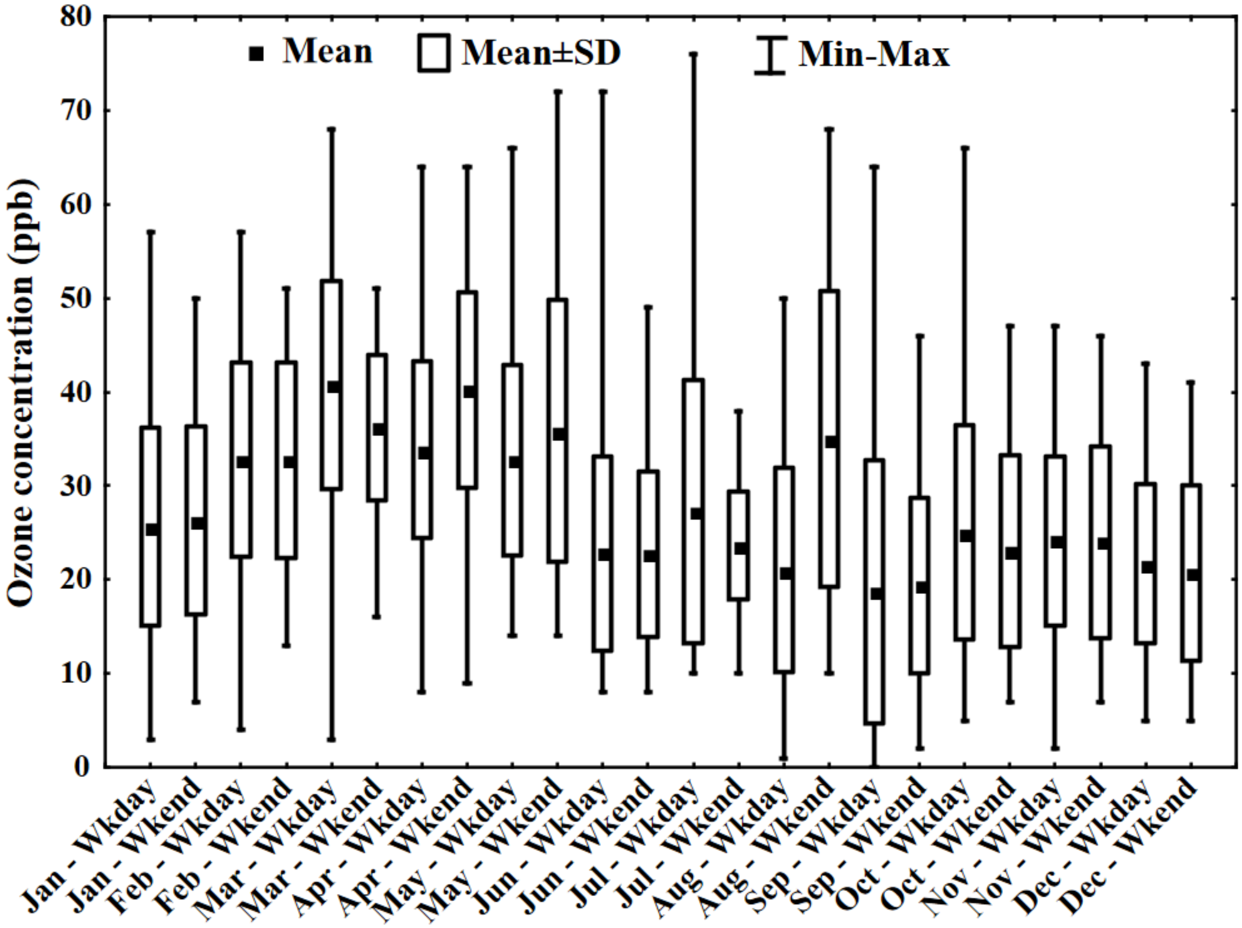

Figure A- 17. Monthly variations in the weekday/weekend ozone concentrations observed at CAMS 664 during 2013.

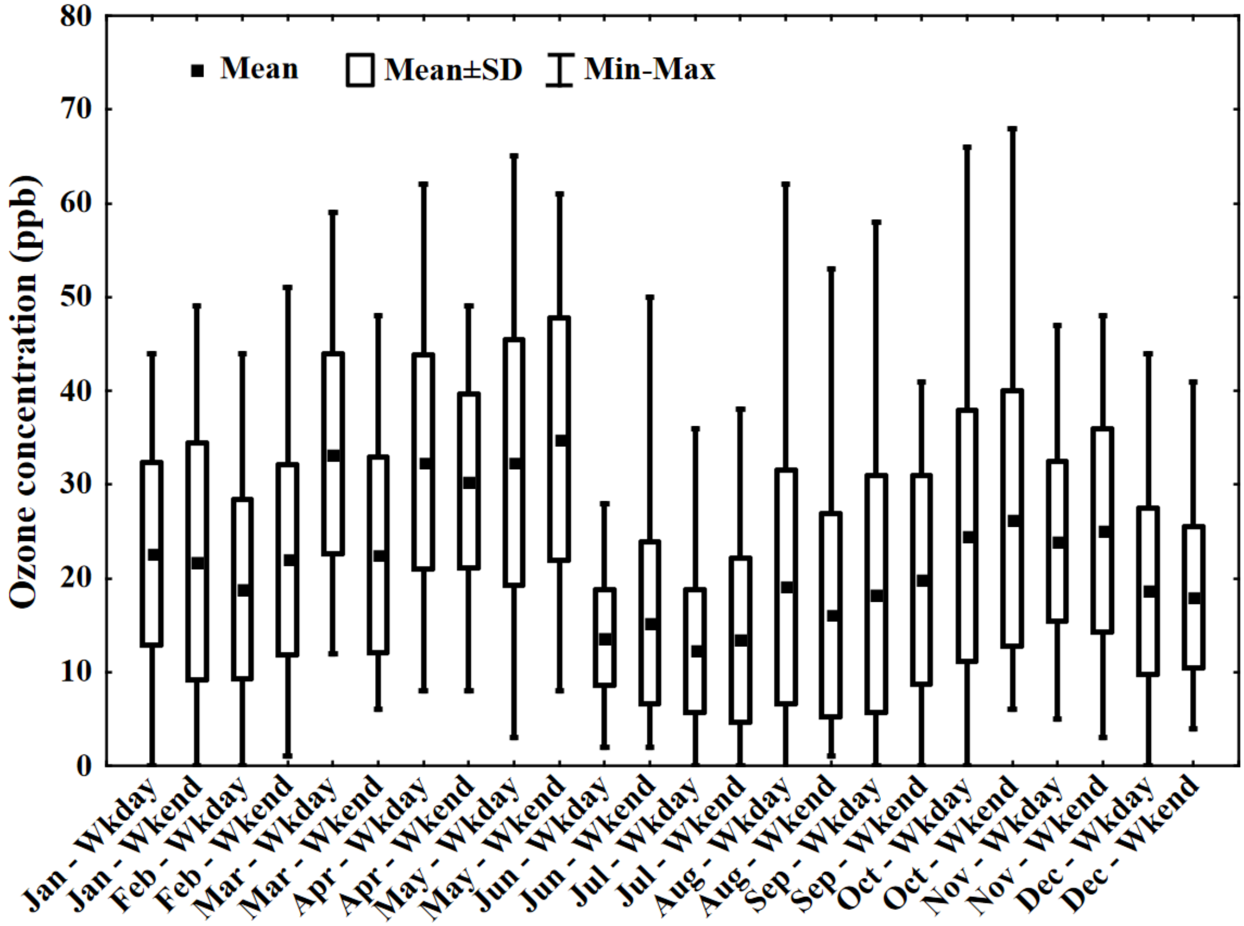

Figure A- 18. Monthly variations in the weekday/weekend ozone concentrations observed at CAMS 664 during 2014.

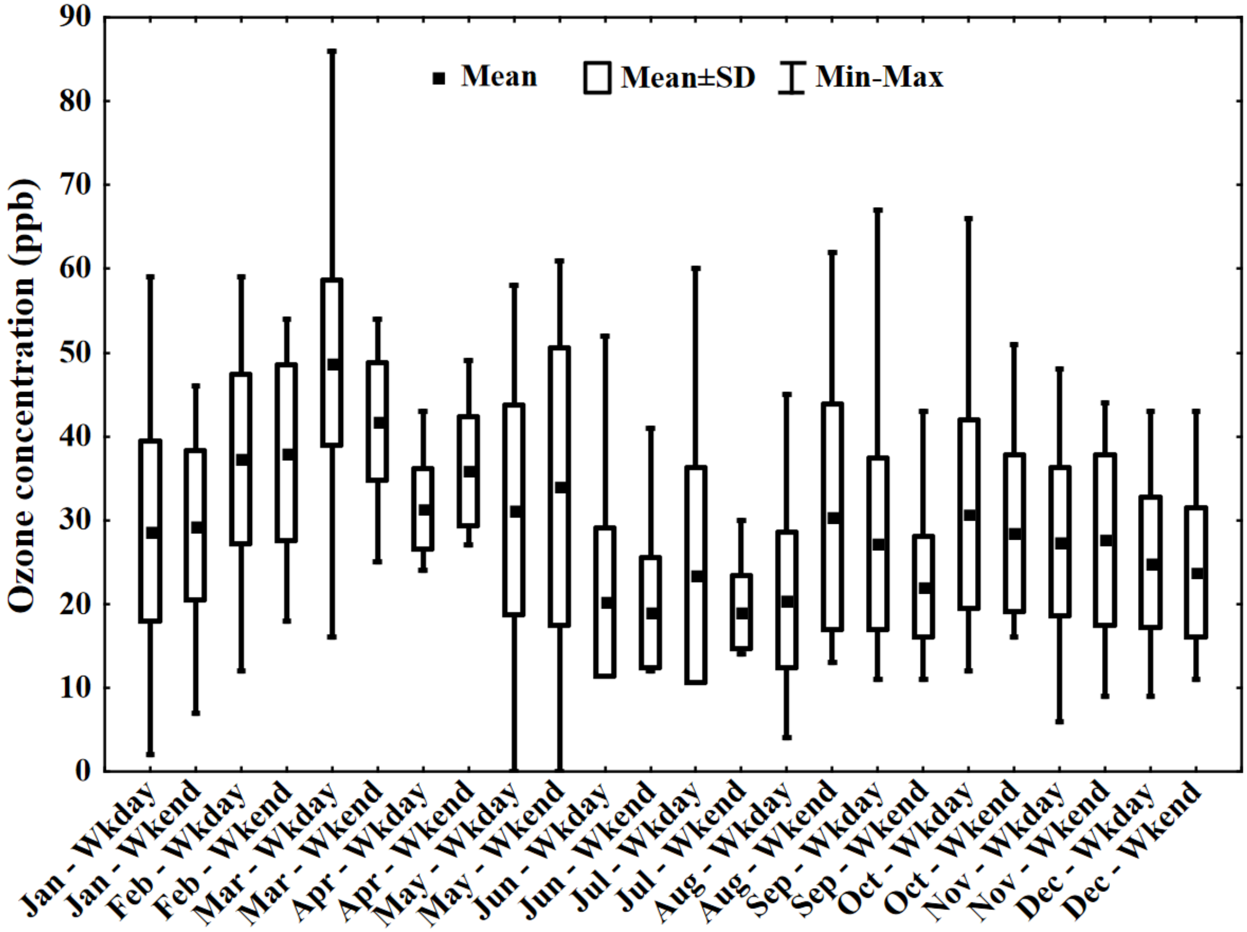

Figure A- 19. Monthly variations in the weekday/weekend ozone concentrations observed at CAMS 659 during 2013.

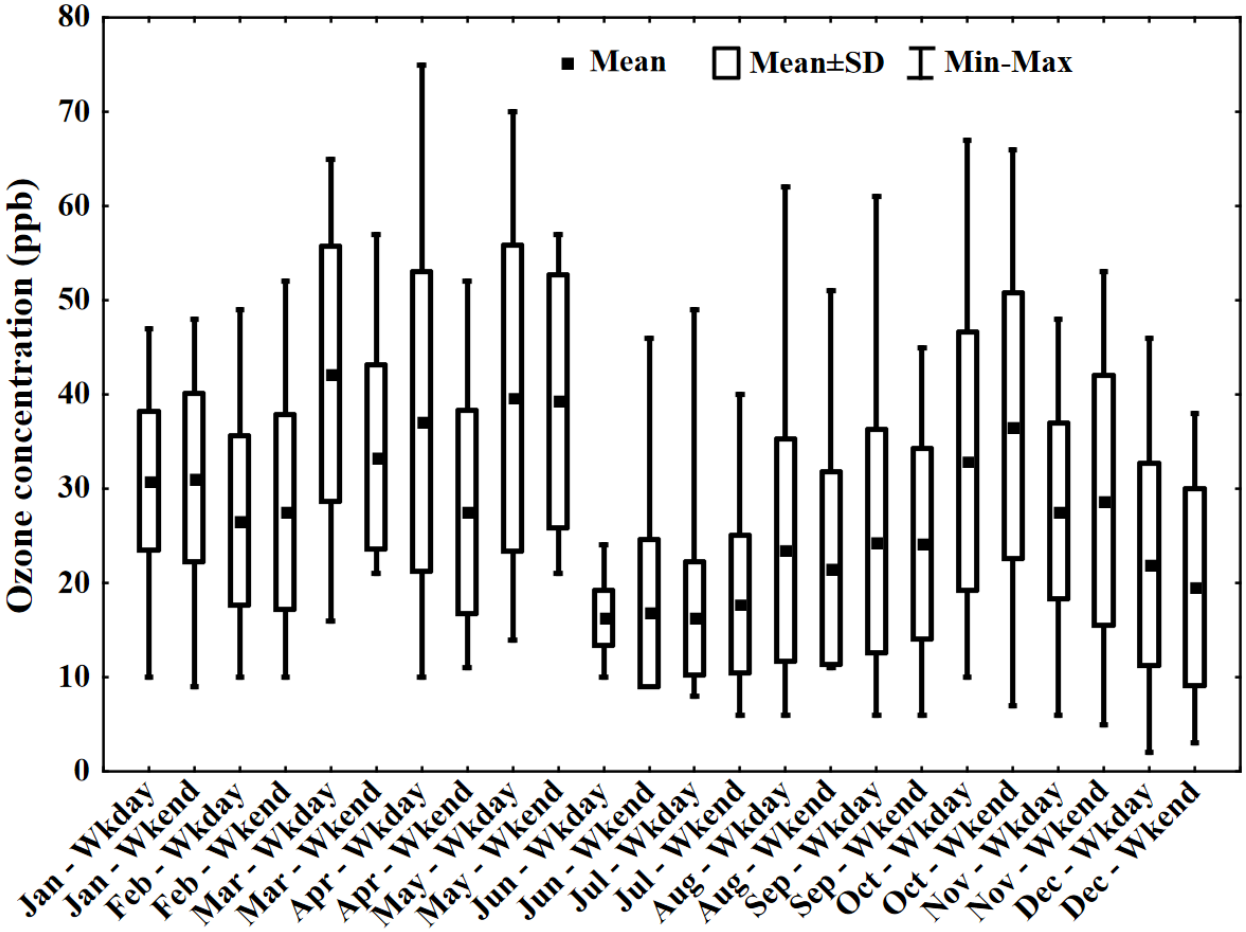

Figure A- 20. Monthly variations in the weekday/weekend ozone concentrations observed at CAMS 659 during 2014.

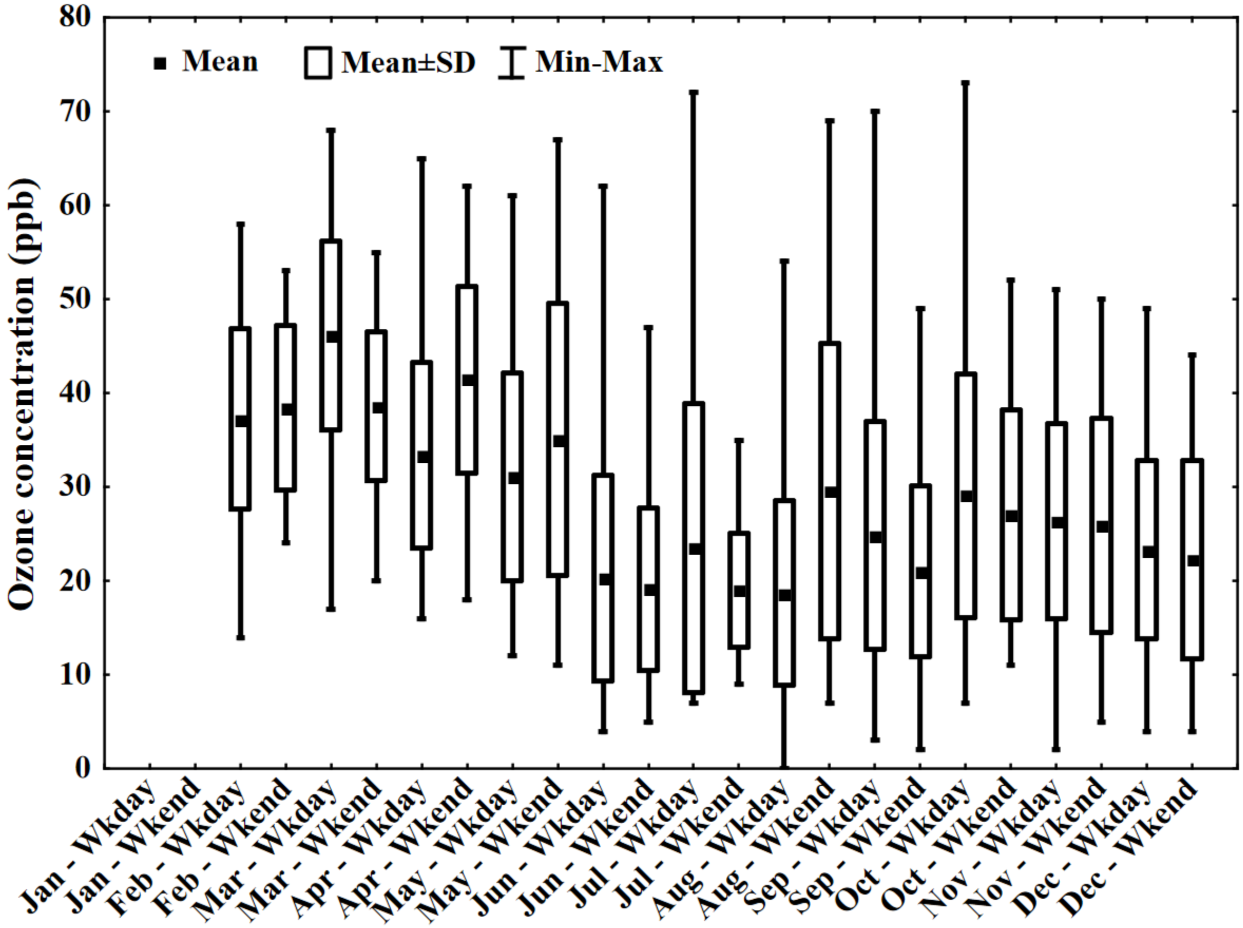

Figure A- 21. Monthly variations in the weekday/weekend ozone concentrations observed at CAMS 686 during 2013.

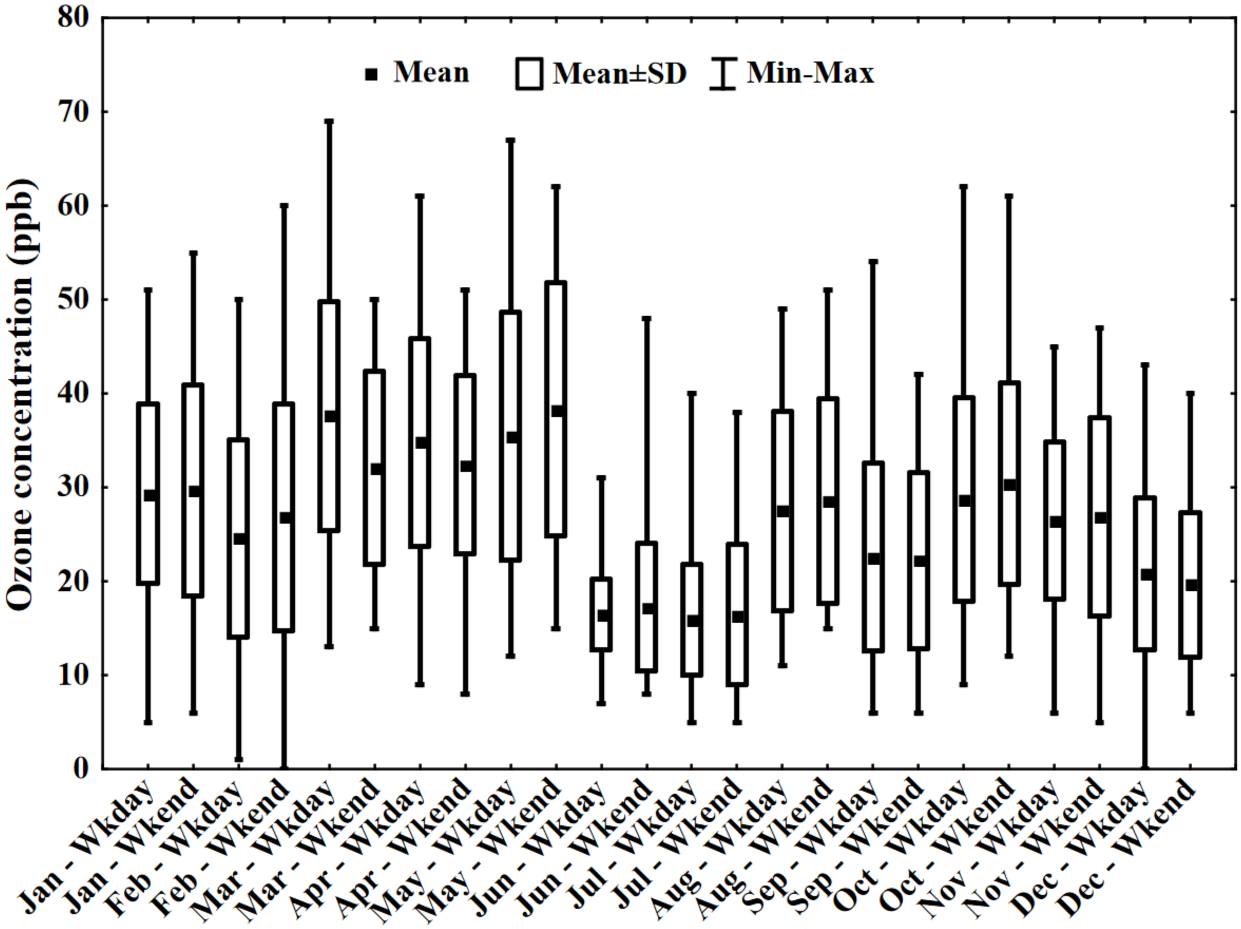

Figure A- 22. Monthly variations in the weekday/weekend ozone concentrations observed at CAMS 686 during 2014.