2012-01-01

Evaluation of Ozone Trends and Distribution in the Paso del Norte Region using TCEQ's CAMS Data and Ozone Data Collected at Two Supplemental Sites

Adrian Michael Sandoval
University of Texas at El Paso, amsandoval2@miners.utep.edu

EVALUATION OF OZONE TRENDS AND DISTRIBUTION IN THE PASO DEL NORTE REGION USING TCEQ'S CAMS DATA AND OZONE DATA COLLECTED AT TWO SUPPLEMENTAL SITES

ADRIAN MICHAEL SANDOVAL

Department of Civil Engineering

APPROVED:

Wen-Whai Li, Ph.D., P.E., Chair

John Walton, Ph.D., P.E.

Norris J. Parks, Ph.D., DABR

Benjamin C. Flores, Ph.D.
Dean of the Graduate School

EVALUATION OF OZONE TRENDS AND DISTRIBUTION IN THE PASO DEL NORTE REGION USING TCEQ'S CAMS DATA AND OZONE DATA COLLECTED AT TWO SUPPLEMENTAL SITES

by

ADRIAN MICHAEL SANDOVAL, Bachelors of Science in Civil Engineering

THESIS

Presented to the Faculty of the Graduate School of

The University of Texas at El Paso

in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE IN ENVIRONMENTAL ENGINEERING

Department of Civil Engineering

THE UNIVERSITY OF TEXAS AT EL PASO

December 2012

ACKNOWLEDGEMENTS

This study was supported by a grant from the Texas Commission of Environmental Quality (TCEQ) through the El Paso Metropolitan Planning Organization (MPO). This research project would not have been possible without the support of many people. The author wishes to express his deepest gratitude to supervisor Professor Wen-Whai Li, who offered invaluable assistance. Deepest appreciation is also due to Professor John Walton and Professor Norris J. Parks, members of the supervisory committee. Many thanks to Joe Castro from TCEQ for making accessible the Continuous Ambient Monitor Station near UTEP for quality assurance purposes. Thanks to the following individuals for assisting with the deployment of the ozone monitor: Jesse Moncada at Fort Bliss Directorate of Public Works-Environmental, Rick Venegas at City of El Paso-Environmental Services and Brad Wise, the superintendent of Butterfield Trail Golf Club Services. Finally, a special thanks to graduate friends and colleagues Sofia Escajeda and Mayra Chavez specifically for their ongoing assistance with monitoring and data processing.

ABSTRACT

The purpose of this research was to determine whether the city of El Paso will continue to be in attainment if the Environmental Protection Agency (EPA) revises the National Ambient Air Quality Standards (NAAQS) of 8-hour average ozone concentration from 0.075 parts per million (ppm) to 0.070 ppm. For the duration of El Paso's ozone season, June-September 2012, two 2B Technology Ozone 202 monitors were deployed at proposed locations, not previously monitored. This was done in order to quantify concentration of ozone. In addition, ozone and meteorological data was downloaded from several Continuous Ambient Monitoring Stations (CAMS) in the Paso del Norte (PdN) region operated and maintained by Texas Commission of Environmental Quality (TCEQ). Daily maximum 1-hour and 8-hour average ozone concentrations were analyzed at each of all El Paso and Juarez CAM stations, and both supplemental sites. Both supplemental sites recorded high concentrations of ozone, demonstrating a potential need for an additional CAM station. The results did not exceed the allowable 8-hour average ozone level of 0.075 ppm but if the standard was lowered to 0.070 ppm the city will potentially be designated nonattainment.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1 INTRODUCTION

1.1 Paso del Norte Ozone Problem

Though air quality has gradually improved over the past 10 years, the Paso del Norte (PdN) region remains the worst along the U.S.-Mexico border, thus being a concern for the welfare of the community. The PdN region is made up of three cities: El Paso, TX, Sunland Park, NM and Ciudad Juarez, Chihuahua, Mexico. "Air pollution in the Paso del Norte region does not respect national borders. Airborne pollutants, regardless of their origin, are easily transported back and forth across the border" (PdN Task Force 1998). Natural factors and anthropogenic activities contribute to formation of ozone in El Paso. Natural factors such as dry climate, high elevation and surrounding mountains in the PdN region. Anthropogenic activities in the PdN region include unpaved roads, open burning, fireplaces and wood-burning stoves are factors of ozone formation.

"Temperature inversions occur during the fall and winter months when a layer of warm air in the upper atmosphere holds cooler, pollution-laden air near the ground. When this occurs, pollutants released in the air are unable to disperse, so they become increasingly concentrated in a brown cloud covering the floor of the air basin. In addition, the hot, sunny days of summer and early fall create ideal conditions for ozone-creating photochemical reactions" (PdN Task Force 1998).

Public health is a concern in the PdN region. As ozone concentrations increase more people experience health effects and are admitted to the hospital for respiratory problems. Health effects from ozone can contribute to: irritation of the respiratory system, lung function reduction, asthma aggravation, it can inflame and damage the lining of the lung and other effects that have yet to be discovered (EPA 1999). These effects tend to be more susceptible to sensitive groups that include children and the elderly.

1.2 Study Objective

This study was performed by the author in 2012 to understand the nature of ozone pollution. In 2011 UTEP created a conceptual model (Li et al, 2011) for ozone that found potential areas in El Paso that could highly contribute to the ozone problem PdN is experiencing. This study was conducted to

ensure if El Paso would continue to meet the current 8-hour National Ambient Air Quality Standard (NAAQS) for ozone, by analyzing the data collected from Continuous Ambient Monitoring Stations (CAMS) and two supplemental sites not previously monitored. Being that there is a possibility the Environmental Protection Agency (EPA) lowers the allowable 8-hour ozone standard this study will provide detailed information if El Paso abides by the current and future proposed standard. By recognizing and analyzing trends of ozone pollution, the city of El Paso will be able to design local control strategies to minimize the concentration levels of ozone.

1.3 Contents of Thesis

Chapter 2 discusses the background information that is necessary to understand the contents of this report. This Section includes a brief description of the PdN region, the Rider 8 Program and the State Implementation Plan (SIP). This study was created from the findings and suggestions of the conceptual model (Li et al, 2011) created in 2011. In order to understand the extent of importance of El Paso being nonattainment the history of El Paso ozone attainment status is also included in this chapter.

In Chapter 3 the author provides a literature review to discuss and demonstrate the photochemical reaction of ozone formation in the atmosphere. In addition the weekend/weekday trends are analyzed using a study conducted in Los Angeles to determine a potential reason why there is higher ozone concentration values collected on weekends rather than weekdays. The weekend/weekday ozone trends for El Paso from 2001-2010 were also included in this Section.

Chapter 4 describes the design for operation and maintenance of two non-regulatory ozone monitors. Both monitors are owned by UTEP. UTEP worked with Texas Commission on Environmental Quality (TCEQ) and El Paso Metropolitan Planning Organization (MPO) to recognize, monitor and analyze ozone pollution levels in the PdN region. Existent networks (CAMS) and non-existent (supplementary) are included. Ozone (O_3) data retrieved from supplemental sites were examined using two 2B Technology Model 202 monitors. These monitors measured five-minute averages and were processed into an hourly average. Monitoring was continuous during the ozone season, with the exception of ozone monitor removal from service for data retrieval, calibration or

repairs. In addition to ozone monitoring indoor temperature throughout the monitoring season was monitored through utilization of a Professional Weather Station, provided by TYCON Power systems. Use of the station was to ensure ozone and indoor temperature maintained TCEQ Quality Assured/Quality Controlled (QA/QC) specifications.

Chapter 5 includes results and trends for measured ozone throughout the duration of ozone season. Ozone data recorded from two monitors deployed at two supplemental sites was compared to that recorded at six CAM stations in El Paso and three in Cd. Juarez. Two 2B Monitors were deployed at Fort Bliss from May until the first week of July. One monitor was then removed from Fort Bliss and deployed at Butterfield Trail Golf Club for the remainder of the ozone season. Data obtained from the 2B monitors deployed at El Paso CAMS stations, Juarez CAMS stations and two additional sites are separated in different figures containing daily maximum 1 and 8-hour averages. A linear regression analysis and t-test was also conducted to demonstrate if the two supplemental sites recorded higher ozone then the existing CAM stations in the PdN region. Wind roses and isopleth maps were then created to help visualize the spatial distribution of daily maximum 1 and 8-hr ozone concentrations.

The trends found after monitoring ozone can be found in Chapter 6. Weekly and diurnal trends were described for the current ozone standard (75 ppb) and potential future standard (using 60, 65 and 70 ppb 8-hour standard).

CHAPTER 2 BACKGROUND

2.1 Paso del Norte Region

The Paso del Norte, translated Pass of the North, is located at approximately the midpoint of the 1,500-mile border shared by the United States and Mexico (Regional Stakeholders Committee, 2009). El Paso is located southwest of Texas at the westernmost tip, west of New Mexico and north of the Mexican state of Chihuahua. As of December 2008, El Paso was rated the 21^{st} largest populated city in the United States (Regional Stakeholders Committee, 2009). El Paso contain mountains called the Franklin Mountains that rise taller than 3,000 feet, range 23 miles long and less than 5 miles wide (Harbour, 1972). "Nicknamed the "Sun City", El Paso receives an average of 7.9 hours of sunshine in December and 12.8 hours of sunshine during June with 85.8% of possible sunshine per annum." The average temperature ranged from 57.2 °F to 32.9 °F in January, 95.3°F in June and 72°F in July (Li et al, 2011).

2.2 MPO Rider 8 Program

This study was performed under the Rider 8 program managed by the El Paso Metropolitan Planning Organization (MPO) and funded by Texas Commission of Environmental Quality (TCEQ). The Rider 8 is a state and local air quality planning program that is managed by TCEQ. This program was created in 1995 to support metropolitan areas to attain ozone set by NAAQS. In 2009 El Paso was granted the funds for a Rider 8 program being there is future possibility of the ozone 8-hour standard reducing to a more stringent value (TCEQ 2012).

2.3 Conceptual Model

In order to demonstrate exceedences in air pollution, EPA requires the enforcement of conceptual models. The conceptual model was heavily referenced as a base for this research. The model provides thorough explanation about the dynamics of ozone formation. It does so by characterizing trends, precursors, formation, transport and other variables potentially involved in the

formation of the criteria pollutant of a particular geographic area. Data for the conceptual model was collected and analyzed from six CAMS in El Paso, three in Cd. Juarez and six in southern Dona Ana County. The report describes time and location of ozone formation, local ground level, mesoscale meteorological conditions and long term (10 year) atmospheric conditions observed in the PdN.

The development of a conceptual model in the PdN region (Li et al, 2011) came about to determine compliance of El Paso, TX with the proposed National Ambient Air Quality Standard (NAAQS) for ozone. This model also examines elements related to high ozone in El Paso and the PdN region. "Mesoscale meteorological modeling using a limited-area, non-hydrostatic, primitive-equation weather forecasting model WRF and backward air trajectory analysis using the National Oceanic and Atmospheric Administration (NOAA) HYSPLIT software were performed to understand the meteorological factors and synoptic conditions during the ozone seasons and to identify the source regions that transport ozone may impact El Paso" (Li et al, 2011). Multi-year ozone averages, ozone-season trends, monthly, weekly, and diurnal air quality conditions are described in Chapter 5. The trends outlined in the conceptual model were examined in this study for current ozone data at both designated locations, six CAMS in El Paso and three in Cd. Juarez. CAMS from Dona Ana County were not included.

The conceptual model aims to establish probable attainment in El Paso under the circumstance that NAAQS drops from 75 ppb to 70 ppb. If considered nonattainment for ozone, El Paso would be required to design control strategies to reduce local emissions.

2.4 State Implementation Plan

The EPA must designate areas as meeting (attainment) or not meeting (nonattainment) the NAAQ standard. The Clean Air Act (CAA) requires states to develop a general plan to attain and maintain the NAAQS in all areas of the country. A specific plan is developed to attain the standards for each area designated nonattainment for a NAAQS. These plans, known as State Implementation Plans or SIPs, are developed by state and local air quality management agencies and submitted to EPA for approval (EPA 2012).

The CAA is enforced by the U.S. EPA, which provides the legal foundation required for development of control strategies. When such areas are designated nonattainment these strategies further described in the SIP ensure attainment of each NAAQS for any of the six criteria pollutants: Carbon Monoxide, Lead, Nitrogen Dioxide, Ozone, Particulate Matter and Sulfur Dioxide.

2.5 TCEQ Air Quality Network

The network monitoring air quality in the PdN is deployed throughout three regional jurisdictions. Chihuahua, New Mexico and Texas operate their own air monitoring networks. New Mexico operates as a single network. Whereas, the networks of El Paso and Juarez are united into the TCEQ air quality monitoring system commonly known as the Leading Environmental Analysis and Display System (LEADS) (TCEQ 2011a). The networks contain both continuous monitors and non-continuous samplers. CAMS contain equipment that observes ambient gaseous materials and particulate matter. Gas monitors measure ambient concentration of ozone, carbon monoxide and oxides of nitrogen. Particulate matter is measured in two fractions: PM_{10} (less than 10 microns in aerodynamic diameter) and $PM_{2.5}$ (particles with an aerodynamic diameter of 2.5 microns or less). Non-continuous monitoring observes gases and particulate matter. This process is examined by using 5-liter stainless steel summa canisters. On a specified schedule, air samples are pulled into these canisters for analysis of targeted organic compounds by a laboratory operated by TCEQ. El Paso operated 8 non-continuous $PM_{2.5}$ samplers for only 4 years since El Paso complied with the $PM_{2.5}$ NAAQS standard (JAC 2010). The conceptual model solely focused on continuous ozone monitoring and meteorological data throughout the PdN region. The locations of the CAMS in the PdN region are shown in Figure 2.1. The following table is a description of the CAMS and included measured parameters. Rather than the use of three air-monitoring networks this study was limited to data retrieved only from TCEQ (both El Paso and Juarez).

Table 2.1 Station IDs and monitored parameters in the Paso del Norte Region

List of Paso del Norte CAMS and Monitored Parameters													
Station ID	Site Name	City, State	O3	NO	NO2	NOx	CO	WS	WD	UV	SLR	Data Range
C12	UTEP	El Paso, TX	✓	✓	✓	✓	✓	✓	✓	✓	✓	1999-2010
C37	Ascarate	El Paso, TX	✓	✓	✓	✓	✓	✓	✓			2000-2010
C41	Chamizal	El Paso, TX	✓	✓	✓	✓	✓	✓	✓			2000-2010
C49	Socorro	El Paso, TX	✓	✓	✓	✓	✓	✓	✓			2000-2010
C72	Skyline	El Paso, TX	✓	✓	✓	✓	✓	✓	✓			2000-2010
C414	Ivanhoe	El Paso, TX	✓				✓	✓	✓			2002-2010
C661	Advanced	Juarez, Chih	✓				✓	✓	✓			2003-2010
C662	20-20 Club	Juarez, Chih	✓				✓	✓	✓			2003-2010
C663	SEC	Juarez, Chih	✓				✓	✓	✓			2003-2010
6CM	Anthony	Anthony, NM						✓	✓			2006-2010
6O	La Union	La Union, NM						✓	✓		✓	2004-2010
6ZK	Chaparral	Chaparral, NM	✓					✓	✓		✓	2001-2010
6ZG	SPCY	Sunland Park, NM	✓					✓	✓		✓	2001-2010
6ZM	Desert View	Sunland Park, NM	✓	✓	✓	✓		✓	✓		✓	2001-2010
6Z H	Santa Teresa	Santa Teresa, NM	✓	✓	✓	✓		✓	✓		✓	2001-2010

Ozone (O3), Nitric Oxide (NO), Nitrogen Dioxide (NO2), Oxides of Nitrogen (NOx), Carbon Monoxide (CO), Wind Speed (WS), Wind Direction (WD), Ultraviolet Radiation (UV), Solar Radiation (SLR). Note that the meteorological data set available through C5004 at the National Weather Service Station is more extensive:
(Li et al, 2011)

Figure 2.1. Locations of CAM stations in the Paso del Norte Region (Li et al, 2011)

2.6 Attainment Status

A single ozone exceedance is described as a day the ozone standard set by NAAQS is exceeded at one or more sites among every monitoring station in a city. For example, if six stations in El Paso exceeded an 8-hour rolling average of 75 ppb in one day, only one exceedance was recorded for that day. A day that ozone exceeds 75 ppb does not constitute ozone nonattainment for the city. A city could be in attainment if the fourth daily maximum 8-hour average of every site in El Paso does not exceed the standard. Every site is allowed to exceed the standard three days out of the year in order to be considered attainment.

As a result of the Federal Clean Air Act amendments of 1990, El Paso County was designated nonattainment of the one-hour ozone NAAQS of 0.12 parts per million (ppm). El Paso County was classified as a serious nonattainment area with a FCAA-mandated schedule for attainment of the ozone NAAQS by November 15, 1999. From 1993 to 1994 El Paso created and submitted a SIP to attain ozone by reducing volatile organic compounds (VOC) emissions (a precursor of ozone) by 15 percent. In order to demonstrate the El Paso area, Texas Natural Resource Conservation Commission (a predecessor to the TCEQ) adopted Section 818 in September of 1994. Section 179B was included in Section 818 of the 1990 FCAA amendments. Special provisions for nonattainment areas affected by emissions beyond the United States are found in the latest Section. Section 818 specifies that under the condition a plan can achieve timely attainment of the NAAQS, the EPA will then approve a SIP revision for the El Paso area. Based on modeling, El Paso on the United States side of the border would be able to attain the proposed 15 percent reduction in VOC emissions, outlined by NAAQS for ozone (TCEQ 1994). A shielding eight-hour ozone standard replaced the one-hour standard as of 1997. The form of the primary standard was altered to an annual fourth-highest daily maximum 8-hr average concentration and averaged over three years. "The daily maximum 8-hr values are found by first calculating running or moving 8-hr values for all 24 hours in a day (for example, averaging the 1-hr concentrations from 1:00am to 8:00 am, then average the 1-hr values from 2:00am to 9:00 am, etc.). Then the maximum value for each day is found (note that any 8-hr time period that starts in a day is assigned to that day). On an annual basis, the fourth highest of these values is summarized" (EPA-452R-07-003, 2007). The

one-hour standard has been revoked in all areas of the U.S., although some former one-hour ozone nonattainment areas have continuing obligations to comply with the anti-backsliding requirements described in 40 CFR 51.905(a).

The U.S. EPA reinforced the primary and secondary eight-hour ozone standard on March 27, 2008 from 0.080 ppm to 0.075 ppm. The EPA announced reconsideration of the 2008 NAAQS in September of 2009. NAAQS then proposed to lower the primary ozone standard on January 19, 2010 which ranged from 0.060-0.070 ppm. The secondary seasonal average ozone concentration was also propositioned to be lowered. This would help to increase the protection of children and other “at risk” populations, according to the EPA (CFR Parts 50 and 58), against various O_3-related adverse health effects. Further description of the adverse health effects such as lung function and increased respiratory symptoms are outlined by the EPA. An increase in emergency room visits and hospital admissions for respiratory causes are a few of the serious indicators of respiratory morbidities. Other considerable adverse health effects are cardiovascular-related morbidity, total non-accidental and cardiopulmonary mortality. On September 2, 2011, President Obama confirmed a request to withdraw the proposed reconsidered ozone standard. Based on the conceptual model, El Paso currently attains the ozone standard of 0.075 ppm (Li et al, 2011). Since deployment of two monitors in areas not previously monitored, the current research found El Paso to attain the standard unless it is lowered to 0.070 ppm.

CHAPTER 3 LITERATURE REVIEW

3.1 Ozone Photochemistry

Ozone occurs in the stratosphere and troposphere, is composed of three oxygen atoms and is also categorized as a gas. Because of its ability to shield high Ultraviolet (UV) rays the stratosphere is better known as the "good ozone". The genetic information within skin cells (DNA) can suffer damage directly from high levels of UV (UV-A 320-400nm and UV-B 280-320nm) and potentially cause skin cancer (Clinuvel, 2012). Ozone in the troposphere is created naturally and by chemical formation from anthropogenic activities. It occurs naturally as a result of downward mixing directly from the stratosphere. The stratosphere contains much higher concentrations of ozone which decrease from the top of the troposphere to ground level (Sillman, 2003). In the troposphere precursors such as oxides of nitrogen (NO_x) and Volatile Organic Compounds (VOC) are emitted from anthropogenic sources and react in the presence of sunlight to chemically form ozone. Emissions from anthropogenic activities that include Industrial/Commercial/Residential Fuel Combustion, Consumer Solvents, Motor Vehicles and Utilities (EPA, 2011) are major sources of NO_x and VOCs.

"The key chemical processes that lead to O_3 production and destruction are driven by reaction cycles involving free-radical intermediates, which are formed mainly from the photolysis of O_3 itself reaction (1)" (The Royal Society, 2008). The process of breaking down molecules into smaller units through the absorption of light is a chemical one, known as photolysis. For example UV wavelengths smaller than 320 nm produce electronically excited oxygen O (^{1}D) atoms and oxygen (O_2) molecules in reaction (1). The oxygen atoms being excited react with either water vapor (H_2O) or an inert molecule (labeled M), most commonly Nitrogen (N_2) (reaction (3) and (4)) to produce hydroxyl (OH) radicals (reaction (2)) or a ground state oxygen atom (O^3P) (reaction (3)):

$$O_3 + h\nu \rightarrow O(^1D) + O_2 \qquad (1)$$

$$O(^1D) + H_2O \rightarrow OH + OH \qquad (2)$$

$$O(^1D) + M \rightarrow O(^3P) + M \qquad (3)$$

$$O(^3P) + O_2 + M \rightarrow O_3 + M \qquad (4)$$

The existing temperature and relative humidity essentially determines the rate of reaction from (2) and (3). The excited oxygen and water vapor will yield OH radicals or $O(^3P)$ atoms given the meteorological parameters assist to drive the concentration of water vapor in air. "For example, in air saturated with water at atmospheric pressure, the fraction of $O(^1D)$ atoms proceeding via reaction (2) increase from about 9% at 10°C to about 12% at 15°C" (The Royal Society, 2008). If O (^3P) is eventually created it can react with an O_2 and an inert molecule M to form ozone (reactions (3) and (4)).

The main carbon-containing precursors of ozone formation in the troposphere are methane (CH_4) and carbon monoxide (CO) (EPA, 2006). The major component for these compounds and formation to occur is OH. The reaction cycle is initiated by CH_4 and CO to react with OH radicals, produce and remove ozone. NO quickly inter-converts to NO_2 once it is released into the atmosphere. The group of oxides and nitrogen (NO_x) are assembled together secondary to being common and forming well with one another. According to the Royal Society, the level of NO_x concentration is dependent upon the impact of O_3 explained in three different regimens (I = Low NO_x, II = Intermediate NO_x, III = High NO_x).

Remote regions that emit less than 20 parts per trillion (ppt) of NO_x is related to the first regime. The South Pacific Region is included with a regime characterized by net O_3 removal. Formation of the peroxy radicals, CH_3O_2 and HO_2 are created by the reactions of OH, CH_4 and CO. These can be removed by their mutual reactions and O_2 (reaction (5) and (6)) to form methyl hydroperoxide, (CH_3COOH) and hydrogen peroxide (H_2O_2). When HO_2 reacts directly with O_3 to regenerate OH radicals and two oxygen molecules (reaction (7)) ozone removal occurs.

$$CH_3O_2 + HO_2 \rightarrow CH_3COOH + O_2 \qquad (5)$$

$$HO_2 + O_2 \rightarrow H_2O_2 + O_2 \qquad (6)$$

$$HO_2 + O_3 \rightarrow OH + 2O_2 \qquad (7)$$

Although reduction of O_3 concentrations is small, this regime has an important global impact as it applies to a large proportion of the troposphere (The Royal Society, 2008).

Characterization of the second regime is by O_3 formation whereby the amount of NO_x concentrations varies and O_3 increases with increasing NO_x concentrations. Most rural areas of industrialized countries are best related to this regime. The peroxy radicals created from OH, CH_4 and CO can react with NO to oxidize CH_3O_2 to form NO_2. NO can also react with another peroxy radical to produce a hydroxyl radical and NO_2. NO_2 will then absorb sunlight to produce O_3 (reaction (8) – (10) followed by reaction (4)):

$$CH_3O_2 + NO \rightarrow CH_3O + NO_2 \qquad (8)$$

$$HO_2 + NO \rightarrow OH + NO_2 \qquad (9)$$

$$NO_2 + h\nu \rightarrow NO + O(^3P) \qquad (10)$$

Reactions (8) and (9) can continuously generate cycles of O_3 before being stopped by a radical termination reaction. In this regime NO_x levels remain low allowing reactions (5) and (6) to be the major radical sink. This type of ozone formation in this regime is often referred to as 'NO_x limited' or 'NO_x sensitive', because O_3 formation rate increases with increasing NO_x concentrations. The reason NO_x is limited in this regime is because reactions (5) and (8) are competing to yield either CH_3COOH with O_2 or CH_3O with NO_2. Reactions (6) and (9) are also competing to form H_2O_2 with O_2 or OH with NO_2.

The third regime dominates reactions (8) and (9). This essentially dominates both CH_3O and HO_2 to yield an increase in NO_x. On the contrary, O_3 formation can be withdrawn by further increases of NO_x. Meaning the free radicals are being terminated by the reaction of OH with NO_2 to form HNO_3 (reaction (11)).

$$OH + NO_2 + M \rightarrow HNO_3 + M \qquad (11)$$

Though increases in NO_x decreases the number of free-radicals that create O_3 forming cycles, CH_4 and CO allow the free radicals to compete with reaction (11) to increase the generation of O_3.

“Consequently, emissions of anthropogenic VOC (e.g. from road transport or solvent evaporation) and biogenic VOC (most notably isoprene) lead to a general increase in the formation rate of O_3” (The Royal Society, 2008). Urban areas are examples of regime III since they are areas with close sources of pollution. CH_3O resulting from reaction (4) can lead to oxygenated product formaldehyde (HCHO) by reacting with O_2 to form both HCHO and HO_2. Its further oxidation is partially initiated by photolysis, which contributes to radical generation, as follows:

$$HCHO + h\nu \rightarrow HCO + H \quad (12)$$

$$HCO + O_2 \rightarrow HO_2 + CO \quad (13)$$

$$H + O_2 + M \rightarrow HO_2 + M \quad (14)$$

“As a result, the formation of HCHO has an impact on the rates of the oxidation cycles described above, through secondary radical generation. It should also be noted that HCHO oxidation generates CO, with the oxidation of CH_4 (via HCHO) being the major source of atmospheric CO” (The Royal Society 2008).

3.1.1 Urban Ozone

Important to ozone formation in the urban area are VOCs and CO. Alkanes, alkenes, aromatic hydrocarbons, carbonyl compounds, alcohols, organic peroxides and halogenated organic compounds are categorized under VOC (EPA, 2006).

Cities such as Los Angeles and Mexico City most frequently produce severe air pollution events secondary to meteorological conditions that favor rapid formation of ozone (high sunlight, warm temperatures, and low rates of dispersion) (Sillman 2003). When temperatures are above 20 °C significant ozone is formed in excess. Temperatures of 30 °C or higher are usually associated with smog events. Ozone levels exceed 80 ppb approximately 30-60 days per year in the major cities of northeastern USA and northern Europe. A mixture of cool temperatures and/or clouds can aid to prevent ozone formation regardless of the level of precursor emissions. When the mixture of light winds

and suppressed vertical mixing prevents the dispersion of pollutants from an urban center, the most severe pollution events can occur. Several hours are typically required for the process of ozone formation which takes place only at times of bright sunlight and warm temperatures. Peak ozone values are most commonly found downwind of major cities rather than in the urban center for the reason mentioned. High ozone concentrations are more likely to occur closer to the city center during severe events with light winds (Sillman 2003).

3.1.2 Regional Pollution Events and Long-distance Transport

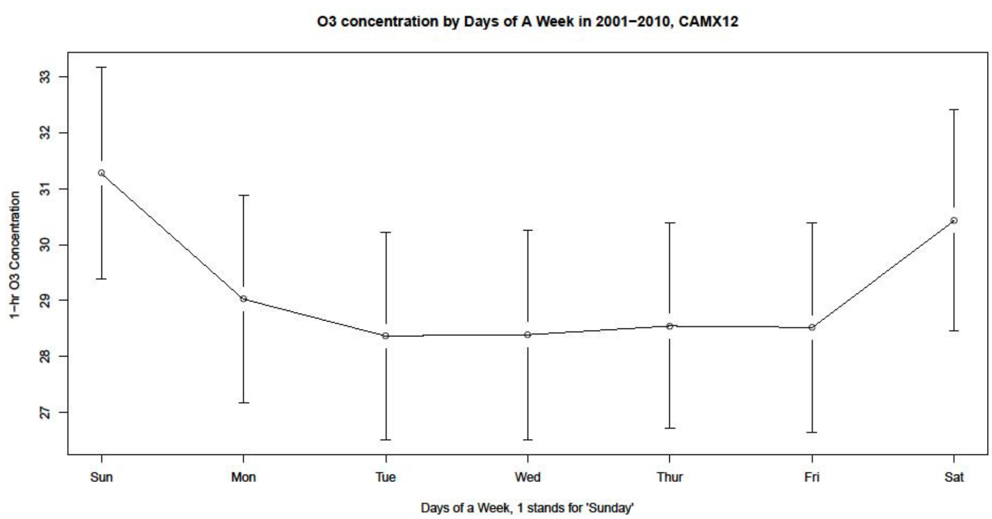
50-100 km downwind of the city center of urban plumes where peak ozone is most commonly formed and found has an effective lifetime of approximately three days. As a result, urban plumes with high ozone concentrations can travel great distances. The lifetime of ozone extends to three months in the middle and upper troposphere and transport is also longer. Plumes with high ozone have regularly been observed at distances 300 km or more from their source regions, however peak ozone most commonly occurs 50-100 km downwind from urban centers. Regular observation of ozone exceeding 150 ppb in Cape Cod, Massachusetts attributes to emissions 400 km away in the New York metropolitan area. NO_x emissions that are similar to the summed emission rate from a city as large as Washington D.C. are rated by the largest power plants because of relatively low emissions of CO or VOCs where the rate of ozone formation is slower and peak ozone occurs further downwind (100 – 200 km) (Sillman 2003).

3.2 Weekday/Weekend Effects

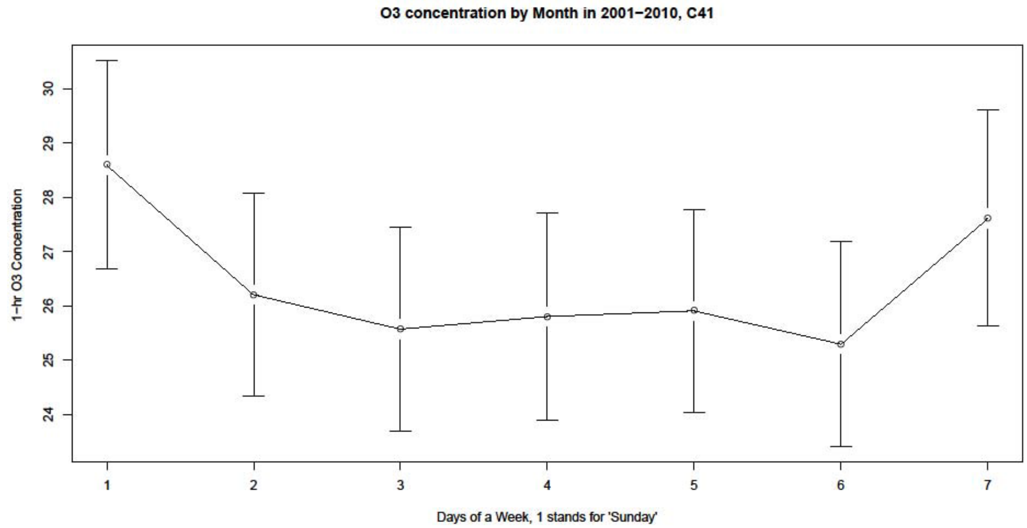
Species whose main source is direct emissions in the atmosphere or external introduction best refer to primary pollutants. These species are compared with secondary pollutants, whose main source is photochemical production within the atmosphere. Theoretically useful is the distinction between primary and secondary pollutants because the dependent species usually show noticeably different patterns of diurnal and seasonal variation in polluted regions of the atmosphere (Sillman 2003).

Controlled largely by proximity to emission sources and rates of dispersion are the ambient concentrations of primary species. Nighttime, early morning and during winter in northerly locations tend to be the highest concentrations of the species secondary to the slowest of atmospheric dispersion rates (Sillman 2003). Atmospheric conditions that favor photochemical production can be associated with high concentrations of secondary species or ozone. The afternoons, summer (in mid-latitudes) and/or dry season (in the tropics) continue to produce the highest concentrations of ozone occurrence (Sillman 2003).

The day of the week variation is a significant trend in El Paso. In 2001-2010 CAMS 12 and 41 produced higher levels of ozone concentration on the weekend than on weekdays as proven by analysis of trend through the Conceptual Model (refer to Figure 3.1 and 3.2). Likely to be the cause are variations in local emissions of ozone precursors between weekdays and weekends; more specifically, the difference in pattern of traffic and volume. It is supposed that the VOC/NOx ratio on weekends may differ from that on weekdays.



3.1 Ten-year averages of ozone concentrations by day of the week at C12 (the bars above and beneath the data point indicate the 95% CI of the mean). (Li et. al 2010)



3.2 Ten-year averages of ozone concentrations by day of week at C41 (the bars above and beneath the data point indicate the 95% CI of the mean) (Li et. al 2010)

Under comparable meteorological conditions, Los Angeles recorded as much as 55% higher levels of ozone concentrations on weekends than weekdays, in 2000 and 2001 (Coe et all). Being that ozone precursors are lower on weekends than weekdays signifies the trend as contradictory. Los Angeles residents and small businesses were surveyed by Sonoma Technology in regards to frequencies and timings of activities related to various emissions (Coe et all). Residential and/or commercial uses of lawn, garden equipment, barbecues, fireplaces, solvents, chemicals, internal combustion engines and several others are a few listed activities. Air quality monitoring at fixed locations, air quality monitoring from a vehicle-mounted mobile platform, monitoring of traffic volumes on surface streets, acquisition of freeway-based traffic volume data and acquisition of data from the continuous emissions monitoring systems (CEMS) of major stationary point sources around L.A. were other means of data collected surveys. 21% of Reactive Organic Gas (ROG) (another term for VOC) emissions and 16% of NOx emissions to the South Coast Air Basin's year-2000 summertime emissions inventory were a result of the contributed sources (Coe et all). Improved diurnal and weekly emissions activity profiles used for inputs in air quality models now have a better understanding of weekday to weekend (WD-WE) variations of emission patterns as a result of the contributed surveys. In comparison to weekdays, the residential activities increased on weekends as much as 40% to 140%, while business activities

decreased from 45% to 95%. These WD-WE variables impact the ROG and NOx emissions significantly to conclude that weekend emission patterns, in L.A., favor ozone formation to a greater degree than weekday emissions. The reason being is the decrease of ROG (or VOC) NOx ratios and reduction in morning titration capacity of ozone by NOx (Coe et all). Weekend NOx reductions are extremely larger than corresponding ROG reductions; given by the result of suggested factors analyzed from the conclusions of surveys and WD-WE patterns for mobile and point sources. "According to Sonoma Technology, Inc. the expected effects of this are (1) less available NOx for titration and removal of morning ambient ozone (refer back to regime I in Section 3.1) and (2) increased ambient ROG:NOx ratios, which correlate with increased rates of ambient ozone formation."

CHAPTER 4 EXPERIMENTAL SETUP AND DATABASE

4.1 Instrumentation

The monitor used for this experiment is manufactured by 2B Technologies. 2B Technologies manufacture multiple ozone monitors such as nitrogen monoxide, nitrogen dioxide, nitrogen oxide, as well as ozone and NO calibration sources. Figure 4.1 below shows the image of the ozone monitor. The Ozone Monitor Model 202 is the product chosen for the analysis and designated by the EPA as a Federal Equivalent Method (FEM) (EPA, 2010).

Figure 4.1 2B Technology Federal Equivalent Ozone Monitor Model 202

“The 2B Technologies Model 202 Ozone Monitor™ is designed to enable accurate and precise measurements of ozone ranging from low ppb (precision of ~1 ppb) up to 100,000 ppb (0-100 ppm) based on the well established technique of absorption of UV light at 254 nm. The Model 202 Ozone

Monitor™ is light weight (4.7 lb., 2.1 kg.) and has a low power consumption (12V DC, 0.33 amp, 4.0 Watt) relative to conventional instruments and is therefore well suited for applications such as:

- Vertical profiling using balloons, kites, RPVs and light aircraft where space and weight are highly limited
- Long-term monitoring at remote locations where power is highly limited
- Urban arrays of ground-based detectors
- Personal exposure monitoring for studies of health effects of air pollutants
- Environmental health and safety monitoring
- Laboratory studies of the effects of ozone exposure on materials and organisms"

The non-existent networks collecting ozone from the 2B monitors were compared to existent networks in the PdN region run by TCEQ that contain Teledyne-API monitors. Table 4.1 compares the specifications of these 2B monitors with other high precision ozone monitors including the Teledyne-API monitor. The reason the 2B monitors were compared to TCEQ Teledyne-API monitors were to prove that data collected from these two monitors were comparable and sufficient enough to rely on data collected from them the duration they were deployed at supplemental sites. Further investigation will be discussed in Chapter 5 regarding this comparison analysis.

Table 4.1 Comparisons of Specifications for High Ozone Monitors

	2B Tech Model 106-L	2B Tech Model 202	2B Tech Model 205	2B Tech Model 211	2B Tech POM	Teledyne-API Model 400E	Ecotech EC9810	Thermo Model 49i
Optical Bench	Single Beam	Single Beam	Dual Beam	Dual Beam	Single Beam	Single Beam	Single Beam	Dual Beam
Linear Range	0-100 ppm	0-250 ppm	0-250 ppm	0-2 ppm	0-250 ppm	0-10 ppm	0-20 ppm	0-200 ppm
Resolution	0.1 ppb	0.1 ppb	0.1 ppb	0.1 ppb	0.l ppb	0.1 ppb	0.1 ppb	0.1 ppb
Penumatics	Internal diaphragm pump, ~800 cc/min	Internal diaphragm pump, ~800 cc/min	Internal diaphragm pump, ~1600 cc/min	Internal diaphragm pump,~1600 cc/min	Internal diaphragm pump, ~800 cc/min	Internal diaphragm pump, ~800 cc/min	Internal rotary vane pump, ~500 cc/min	Internal diaphragm pump, 1000-3000 cc/min
Filter	Optional external PTFE particle filter	Optional external PTFE particle filter	Optional external PTFE particle filter	Optional external PTFE particle filter	Optional external PTFE particle filter	Internal PTFE particle filter	Optional external PTFE particle filter	Optional PTFE particle filter
Dimensions	3.8 x 7.5 x 8.5 in 10 x 19 x 22 cm	3.5 x 8.5 x 11 in 9 x 21 x 29 cm	3.5 x 8.5 x 11 in 9 x 21 x 29 cm	17 x 14.5 x 5.5 in 43 x 37 x 14 cm	4 x 3 x 1.5 in 10.2 x 7.6 x 3.8 cm	7 x 17 x 23.5 in 18 x 43 x 60 cm	7 x 17 x 26 in 18 x 43 x 65 cm	8.6 x 16.8 x 23 in 22 x 43 x 58 cm
Volume	240 cubic inches	330 cubic inches	330 cubic inches	1,356 cubic inches	18 cubic inches	2,800 cubic inches	3,100 cubic inches	3,300 cubic inches
Weight	4.3 lb, 2.0 kg	4.7 lb, 2.1. kg	4.7 lb, 2.1 kg	14.3 lb, 6.5 kg	0.75 lb, 0.34 kg	28 lb, 13 kg	46 lb, 21 kg	55 lb, 25 kg
Power	4 Watt 100-240 V AC, 50/60 Hz or 12 V DC	4 Watt 100-240 V AC, 50/60 Hz or 12 V DC	5 Watt 100-240 V AC, 50/60 Hz or 12 V DC	9 Watt 100-240 V AC, 50/60 Hz or 12 V DC	3 Watt 100-240 V AC, 50/60 Hz or 12 V DC	250 Watt 100-240 V AC, 50/60 Hz	110 Watt 100-260 V AC, 50/60 Hz or 12 V DC	150 Watt 100-240 V AC, 50/60 Hz
Reporting Units	ppb, pphm, ppm, mg/m^3, $\mu g/m^3$	ppb, pphm, ppm, mg/m^3, $\mu g/m^3$	ppb, pphm, ppm, mg/m^3, $\mu g/m^3$	ppb, pphm, ppm, mg/m^3, $\mu g/m^3$	ppb	ppb, ppm, mg/m^3, $\mu g/m^3$	ppt, ppb, ppm, mg/m^3, $\mu g/m^3$	ppb, ppm, mg/m^3, $\mu g/m^3$
Humidity Control	Nafion tube	Nafion tube	Nafion tube	Nafion tube	Nafion tube	None	None	None
Zero Noise	≤ 2 ppb (rms)	≤ 1.5 ppb (rms)	≤ 1.0 ppb (rms)	≤ 0.5 ppb (rms)	≤ 2.0 ppb (rms)	< 0.3 ppb (rms)	< 0.25 ppb (rms)	0.25 ppb (rms)
Lower Detectable Limit (LDL)	≤ 4 ppb for 10-s avg. ≤ 0.9 ppb for 1-min avg,	≤ 3 ppb for 10-s avg. ≤ 1.3 ppb for 1-min avg.	≤ 2 ppb for 10-s avg. ≤ 0.9 ppb for 1-min avg.	≤ 1 ppb for 10-s avg. ≤ 0.5 ppb for 1-min avg.	≤ 4 ppb for 10-s avg. ≤ 0.9 ppb for 1-min avg,	< 0.6 ppb	< 0.5 ppb	1.0 ppb
Precision	Greater of 2.0 ppb or 2% of reading	Greater of 1.5 ppb or 2% of reading	Greater of 1.0 ppb or 2% of reading	Greater of 0.5 ppb or 1% of reading	Greater of 2.0 ppb or 2% of reading	Greater of 0.3 ppb or 2% of reading	Greater of 1 ppb or 0.5% of reading	1.0 ppb
Zero Drift	≤ 2 ppb per day ≤ 5 ppb per year	≤ 2 ppb per day ≤ 5 ppb per year	≤ 2 ppb per day ≤ 5 ppb per year	≤ 1 ppb per day ≤ 3 ppb per year	≤ 2 ppb per day ≤ 5 ppb per year	< 1 ppb per hour < 1 ppb per 7 days	< 1 ppb per day < 1 ppb per 30 days	< 1 ppb per day < 2 ppb per 7 days
Span Drift	< 1% per day < 3% per year	< 1% per day < 3% per year	< 1% per day < 3% per year	< 1% per day < 3% per year	< 1% per day < 3% per year	< 1% per 7 days	< 0.5% per 30 days	< 1% per 30 days
Rise and Fall Time	20 s	20 s	4 s	4 s	20 s	< 20 s to 95%	30 s to 95%	20 s
Linearity	1% of full scale	1% of full scale	1% of full scale	1% of full scale	1% of full scale	1% of full scale	< 1% of full scale	1% of full scale
Operating Temp.	0-60 °C	0-60 °C	0-60 °C	10-50 °C	0-50 °C	5-40 °C	5-40 °C	20-30 °C
Outputs	0-2.5 V and 4-20 mA for user enterable range, RS232 serial, USB	0-2.5 V for user enterable range, RS232 serial, USB adapter	0-2.5 V for user enterable range, RS232 serial, USB adapter	0-2.5 V for user enterable range, RS232 serial, USB adapter	USB	4 Analog voltage ranges, RS232 serial	3 Analog current ranges, 4 Analog voltage ranges, USB, RS232 serial	4 Analog voltage ranges, RS232/RS485 serial, TCP/IP
Data Logger	32,736 lines; 5 min avg = 3.7 mo	14,336 lines; 5 min avg = 1.4 mo	14,336 lines; 5 min avg = 1.4 mo	14,336 lines; 5 min avg = 1.4 mo	8,192 lines; 5 min avg = 1 mo	None	5 min avg. = 5.8 mo.	None
Options	Battery, Particle Filter	Battery, Flash Memory, GPS, Particle Filter, 4-20 mA Output, Custom	Battery, Flash Memory, GPS, Particle Filter, 4-20 mA Output, Custom	Battery, Flash Memory, GPS, Particle Filter, 4-20 mA Output, Custom	GPS Included	Various communication, calibration and mounting brackets	Various communication, calibration and mounting brackets	Various communication, calibration and mounting brackets
Lag Time	10 s	10 s	2 s	2s	10s	10 s		10 s

(2B Technology, Inc.)

4.1.1 Theory of Operation

This Section is collected directly from the 2B Technologies Inc., Operation Manual Chapter 1. Ozone is measured based on the attenuation of light passing through a 15-cm long absorption cell fitted with quartz windows. Figure 4.2 is a schematic diagram of the ozone monitor. A low-pressure mercury lamp is located on one side of the absorption cell; a photodiode is located on the opposite side of the absorption cell. The photodiode has a built-in interference filter centered on 254 nanometers, the

principal wavelength of light emitted by the mercury lamp. An air pump draws sample air into the instrument at a flow rate of approximately 1 L/min. A solenoid valve switches so as to alternately send this air directly into the absorption cell or through an ozone scrubber and then into the absorption cell. The intensity of light at the photodiode is measured in air that has passed through the ozone scrubber (I_o) and air that has not passed through the scrubber (I). Ozone concentration is calculated from the measurements of I_o and I according to the Beer-Lambert Law:

$$C_{O_3} = \frac{1}{\sigma l} \ln\left(\frac{I_o}{I}\right)$$

where l is the path length (15 cm) and σ is the absorption cross section for ozone at 254 nm (1.15 x 10^{-17} cm^2 $molecule^{-1}$ or 308 atm^{-1} cm^{-1}), which is known with an accuracy of approximately 1%. The 2B Technologies instrument uses the same absorption cross section (extinction coefficient) as used in other commercial instruments.

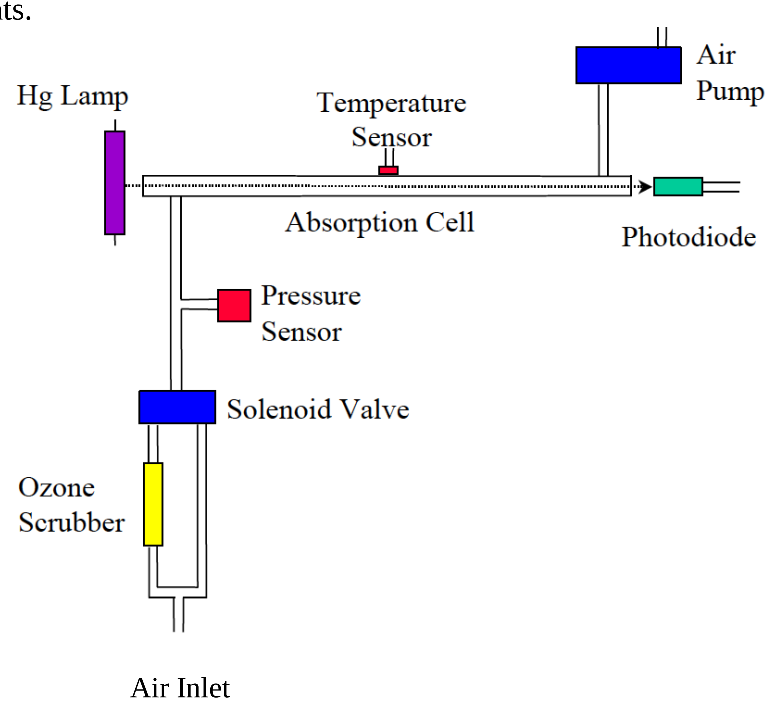


Figure 4.2 Schematic diagram of ozone instrument

4.2 2B Monitor Database

The internal data logger from the 2B technologies ozone monitors was used to monitor ambient ozone concentrations. Data retrieved from the monitors will displayed the log number (16,383 potential

data lines), ozone (ppb, ppm, pphm, ug/m^3 or mg/m^3), internal pressure (mbarr or torr), volumetric flow rate (cm^3/min also referred to as ml/min), date and time. Ozone can be averaged every minute, 5 minutes or hour. In this experiment the monitor recorded ozone in ppb, internal pressure in units of mbar, volumetric flow rate at cm^3/min, with date and time in 24 hour real-time.

Data collected from the ozone analyzers was downloaded weekly, via modem, and managed by the author. The author checked both 2B monitors every two to three days at the designated site. This included an analysis by inspection of the data to determine the equipment is operating efficiently. Data collected from both monitors were in real time (taking into account daylight savings in March 2012).

4.3 TCEQ Database

Data from CAM stations was collected and transferred to a modem using a Zeno data logger, shared with the EPA and available for public viewing on the TCEQ website. Ozone, Wind Direction and Wind Speed totals were collected at the CAM stations throughout the duration of this experiment. Parameters were averaged at the beginning of each hour. For example, values displayed at 1:00 p.m. are based on measurements taken from 1:00 p.m. to 2:00 p.m. The 1:00 p.m. average was not calculated until after 2:00 p.m. Wind direction and wind speed were used to produce Wind Roses to help demonstrate the transport of air pollution in the PdN region. TCEQ CAM stations collect data in local standard time without daylight savings time adjustments. Since the 2B monitors were adjusted to real time, TCEQ parameters were also adjusted to accurately compare the results.

4.4 Selection for Locations

Planning for placement of ozone monitors is a crucial step in the implementation process. Monitoring sites are selected according to a variety of factors. Should high levels of pollution occur monitors are set up in population centers where people are more likely to experience such exposure. The remaining monitors are in areas where pollutant levels are likely to be high. The isopleth map created in the conceptual model determined the two locations for deployment of both 2B Technology

monitors. An isopleth map is a graph that shows the occurrence or frequency of a phenomenon as a function of two variables (Merriam-Webster). This map was produced to examine the distribution of ozone concentration in the PdN region for identification of potential ozone hot spots.

The isopleths were created using the kriging interpolation method available in the R software (Version 2.13.0). The ozone design values used for this map are presented in Figure 4.3. Figure 4.3 compares 1 and 8-hour ozone design values collected from El Paso, New Mexico and Juarez CAM stations for the years 2001-2010. Since ozone monitoring stations do not exist near the Franklin and Juarez Mountains three background ozone concentrations were artificially added (refer back to Figure 2.1 for location) to the conceptual model. The artificial additions at the two Mountains were done in order to avoid overestimation at common low ozone concentration areas. Two reasonably spaced locations along the ridge of the Franklin Mountains (imagining them as two monitoring stations) and vertex of the Juarez Mountains were randomly picked and assigned a regional background ozone design value of 30 ppb (Li et al 2011a). After expressing 1 and 8-hour ozone design values the authors of the conceptual model created Figure 4.4-the 4th highest daily maximum 8-hour average. The authors concluded 2006 and 2008 to be years of the highest 8-hour average ozone within the 10 years they evaluated. They created only two isopleths to demonstrate the distribution of ozone. Figure 4.5 and 4.6 show the 8-hour ozone design value isopleth map for 2006 and 2008. Longitude and Latitude is specified to visualize exact locations of CAM stations. A color scheme represents low to high ozone concentrations in units of ppb.

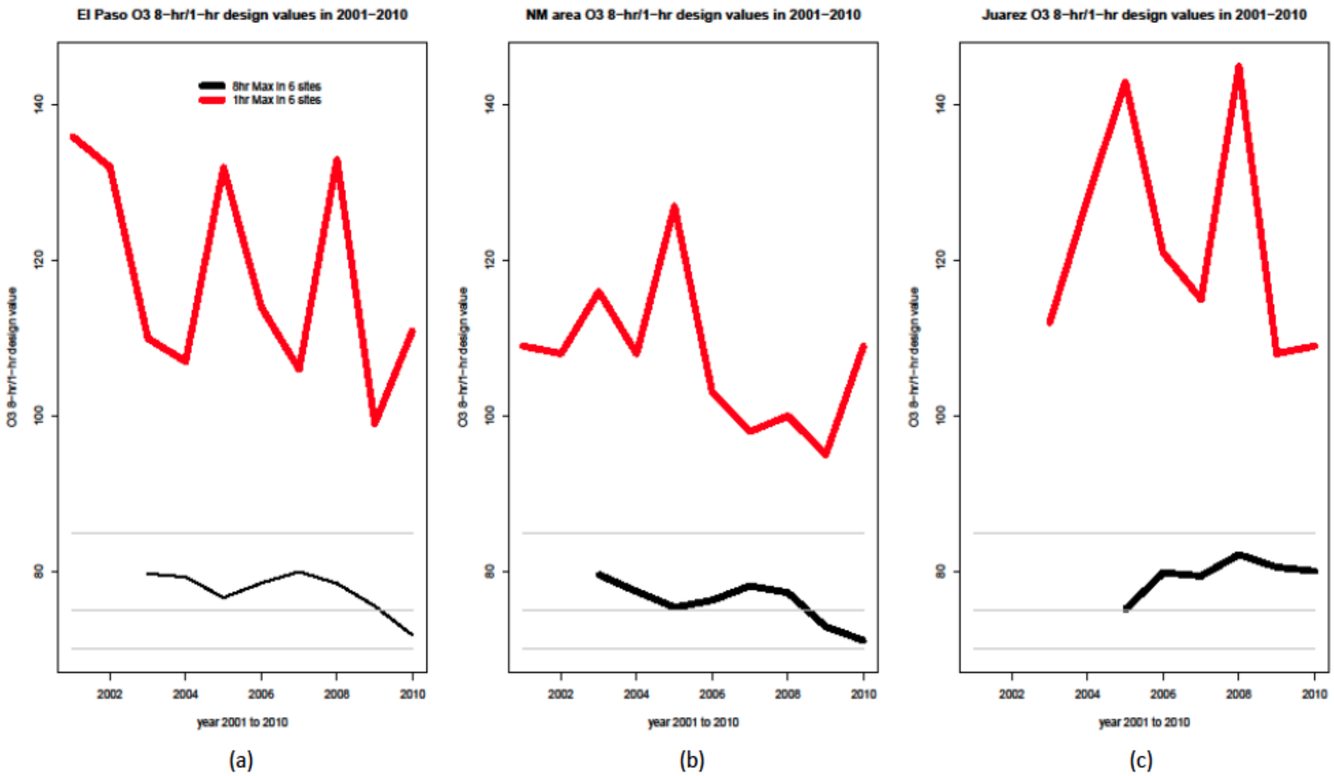


Figure 4.3 8-hour and 1-hour Ozone design values for a) El Paso; b) Sunland Park; and c) Cd. Juarez (Li et al, 2011)

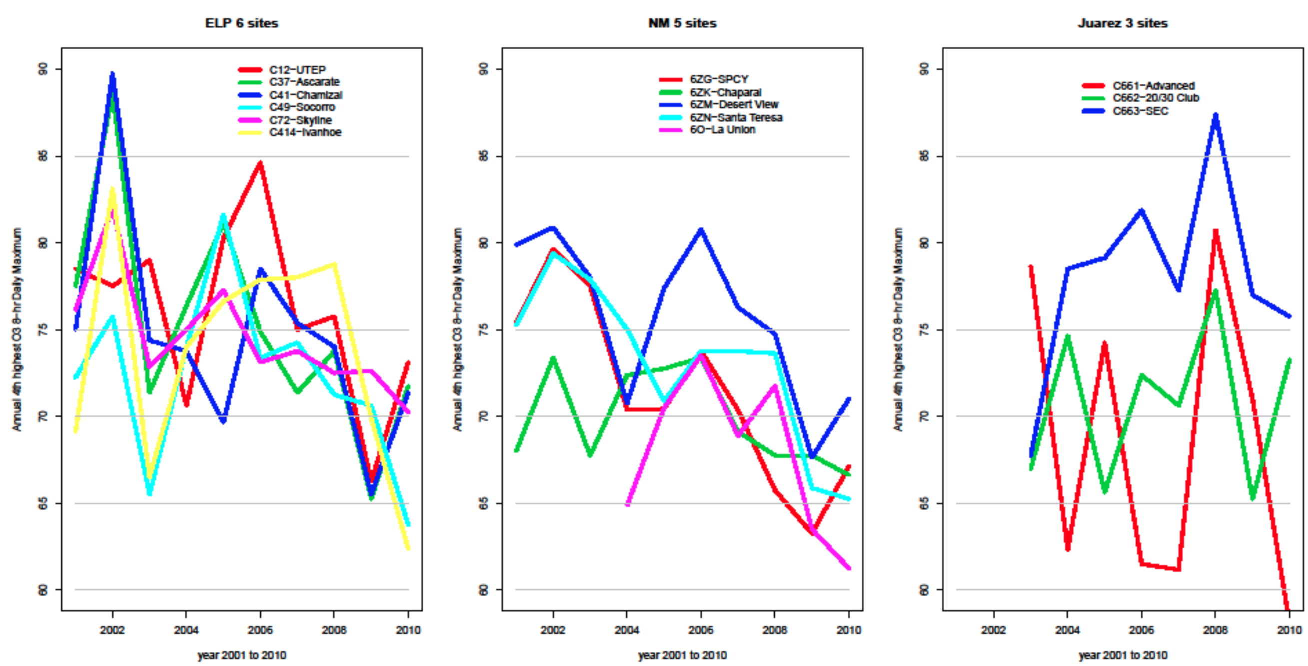


Figure 4.4 4th highest daily maximum 8-hour average ozone concentrations in a year observed at a) El Paso; b) Sunland Park; and c) Cd. Juarez (Li et al, 2011)

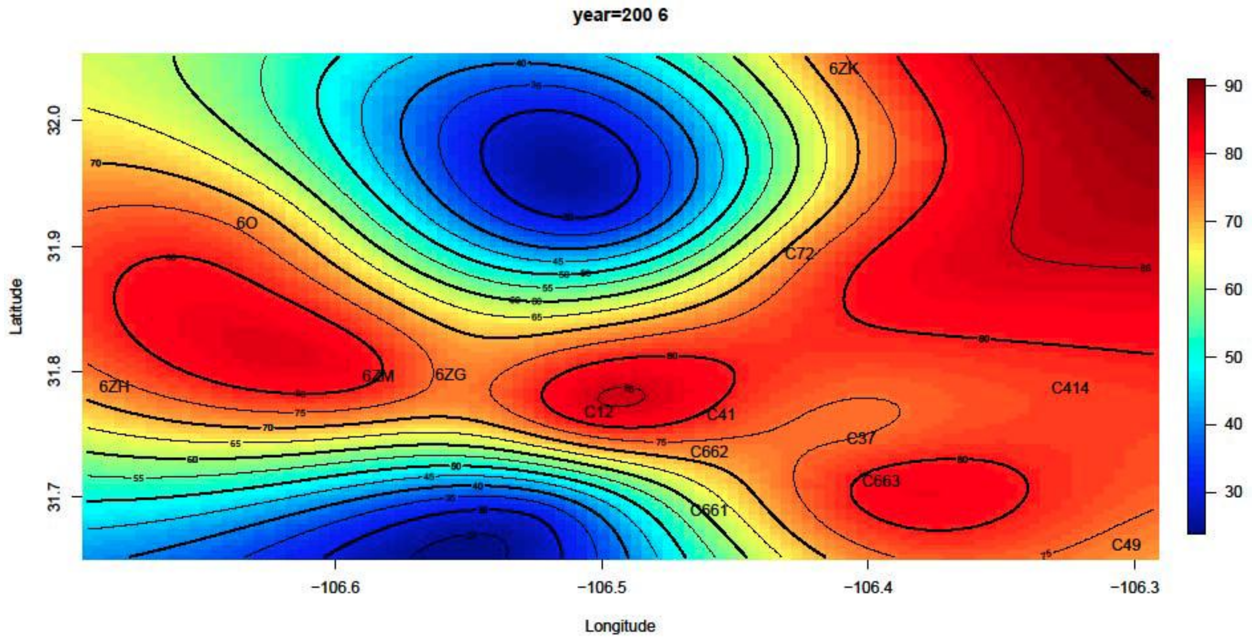


Figure 4.5 8-hour ozone design values (in ppb) for the Paso del Norte region (Li et al, 2011)

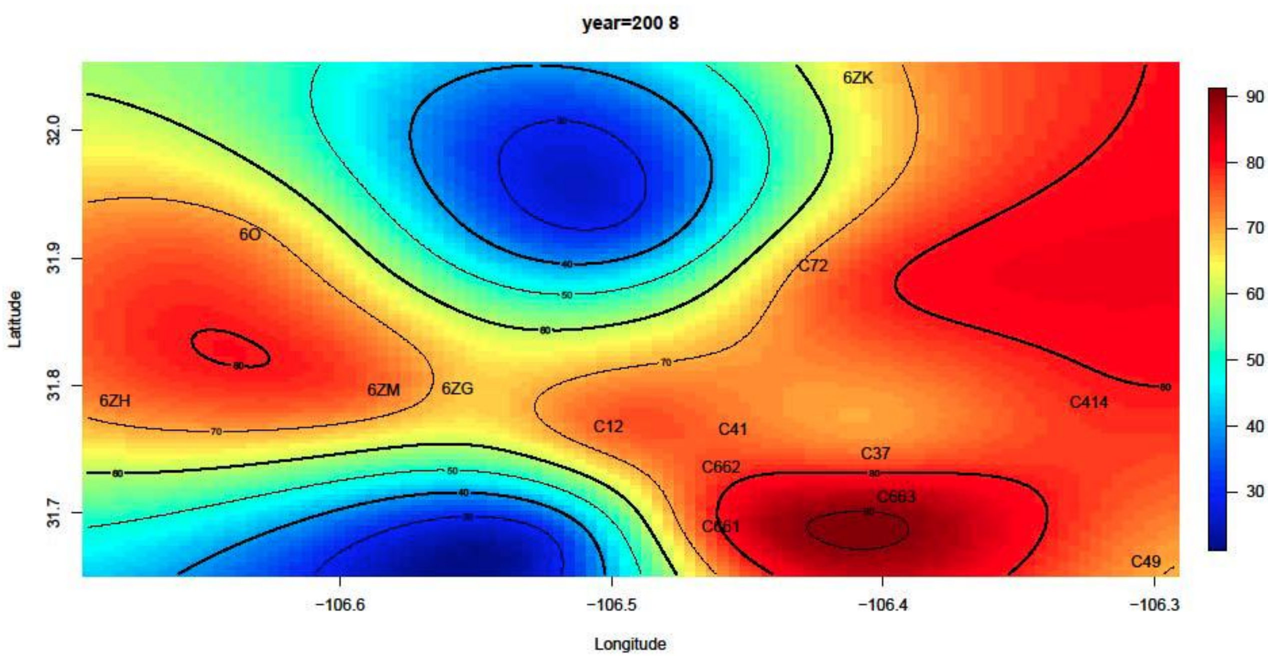


Figure 4.6 8-hour ozone design values (in ppb) in 2008 for the Paso del Norte region (Li et al, 2011)

“Peak ozone concentrations are anticipated to occur along the west-east descending valley (or along the U.S.-Mexico border) in the region. Both figures show the possible need of an additional monitor between the Sunland Park (6ZG) and UTEP (C12) stations for confirming the existence of two local peaks (one in New Mexico and one between Cd. Juarez (C663) and El Paso (C12)). An upwind/downwind/background monitoring station may be needed in the far northeast of El Paso for further confirmation on whether another possible local peak exists in El Paso, East of Skyline (C72) location, or the peak shown in both figures is the result of artificially generated (by inadequate extrapolation of insufficient data) (Li et al, 2011a).”

Both isopleths revealed the possible need for an additional monitor in the far northeast of El Paso, East of Skyline (C72) location. For that reason UTEP concluded deployment of the monitors at Fort Bliss and Butterfield Trail Golf Club. Fort Bliss is a United States Army post in the U.S., of New Mexico and Texas. Because of a dense population throughout the week, weekend and isopleth maps demonstrated this location is best suited for this study. According to the Paso del Norte Region, US-Mexico: Self Evaluation Report “Fort Bliss will realize a net gain of 24,500 active duty population from 2005-2013, the largest gain of any military installation in the world over the same time frame. In addition to the active duty population growth, an estimated 33,000 accompanying family members will also come to the county as result of this expansion” (Regional Stakeholders Committee, 2009). To help distinguish the transport of ozone, Butterfield Trail Golf Club was chosen as the second location. Butterfield is a public golf course located seven miles East of Fort Bliss opened in 2007. Figure 4.9 demonstrates the location of Fort Bliss and Butterfield. In addition to determining additional hot spots, this study will recognize the level of safety for every occupant traveling in and out of Fort Bliss.

TCEQ, UTEP, El Paso MPO, Fort Bliss Directorate of Public Works- Environmental, Butterfield Trail Golf Club and the City of El Paso-Environmental Services Department helped conclude location deployment of 2B technology monitors. The monitor at Fort Bliss is located in the abandoned Recycled Center near the Cassidy entrance. In order to meet the indoor temperature standards set by TCEQ UTEP purchased and installed an air conditioner unit in order to meet the indoor temperature standards. The

monitor located at Butterfield is housed inside a UTEP owned van. Figures 4.8 and 4.9 demonstrate zoomed in locations in El Paso of the 2B ozone monitors.

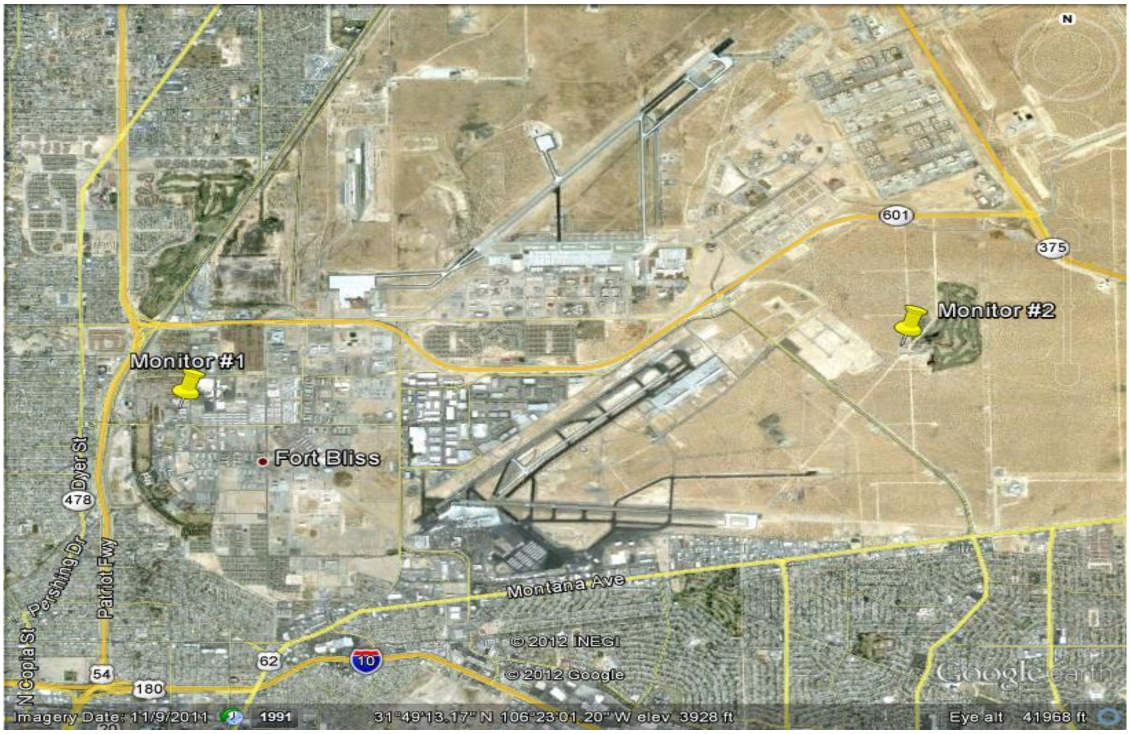


Figure 4.7 Locations of 2B Technology Monitor #1 and #2

Figure 4.8 Recycled Center - Location of Monitor #1

Figure 4.9 Butterfield Maintenance Parking Lot - Location of Monitor #2

Additional photos were taken in order to demonstrate a better sense of the location of both 2B monitors. The photos in Figure 4.10 and 4.11 display each monitor inside both Fort Bliss and Butterfield locations. In Figure 4.10 a) the photo displays both Monitor #1 and Monitor #2 at Fort Bliss Recycled Center when both monitors were initially deployed. This photo also includes an A/C unit that was installed in order to meet QA/QC indoor temperature requirements. Though there are QA/QC requirements for indoor temperature (to avoid potential drifts) at CAM shelters, 2B Technology states these 2B monitors can produce precise measurements in extreme environments. "In March 2010, the Model 202 became the only portable Federal Equivalent Method for ozone recognized by the EPA, with certification over the wide temperature range of 10 to 40 degrees Celsius" (2B Technologies).

In addition to installing an A/C unit, foam board was also used to cover the windows and doors to help insulate the room. Figure 4.10 b) is a different angle of the setup. The Tanabyte calibration monitor is sitting in front of both 2B monitors, and the TYCON weather station and laptop (used to retrieve all the data from the monitor and weather station) is located on the desk displayed to the left.

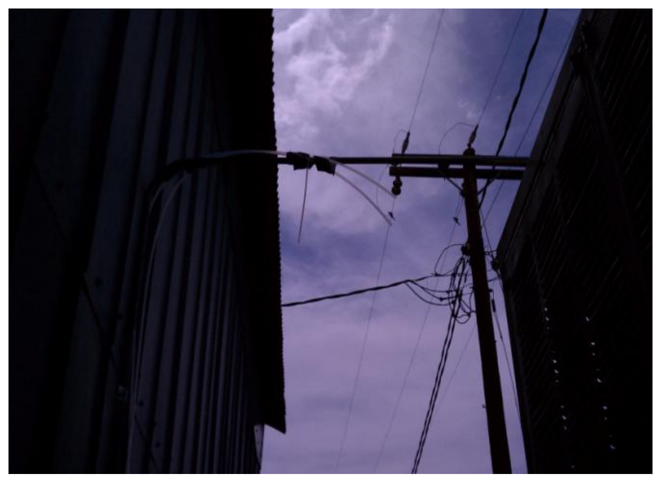
Tubing is connected to the back of the monitor and the other end of the tubing extends outside the room by access from the right side of the window in b). Figure 4.10 c) and d) are photos of the tubing extending outside the room of the recycled center where the monitors were located. There is a small pipe that is located between both windows that extend vertically then attaches to the A/C (non-operational) unit located outside. Figure 4.10 d) is a close up of the tubing that is attached to this pipe. The tubing is facing downward in order to avoid any debris or rain from entering the inlet, preventing contamination.

The best and most convenient way to record ambient ozone when Monitor #2 was deployed at Butterfield was directly from UTEP's air quality van. Figure 4.11 displays the monitor located at Butterfield. Figure 4.11 a) and b) displays the van residing at Butterfield parking lot. The photos show an A/C unit on top of the van with the tube extending outside the van near the unit. Photo c) demonstrates the setup of the monitor inside the van with tubing extending towards the top of the roof exit of the van.

a)

b)

c)



d)

Figure 4.10 Fort Bliss Recycled Center Including Both 2B Monitors, Tanabyte Calibrator and TYCON Weather Station

a)

b)

c)

d)

Figure 4.11 UTEP Van Located at Butterfield Trail Golf Club Containing 2B Monitor #2

CHAPTER 5 RESULTS

5.1 Quality Assured Quality Control

Before delivery to UTEP, the 2B monitors were pre-calibrated at 2B Technologies manufacturing company. A seven-point calibration curve and a calibration certificate (Section 5.1.2 contains details and images of the calibration curve and certificate) were provided upon purchase. To ensure that data recorded by these monitors were consistent with that measured at by a TCEQ compliance monitor, the author deployed both previously calibrated 2B monitors at CAMS 12 for a side-by-side comparison. Data was recorded for eleven days using the 2B Technology (a Federal Equivalent Method (FEM)) and compared to TCEQ's Federal Reference Method (FRM) approved ozone monitor. The side-by-side comparisons were performed at three time periods prior to deployment of the instrument: 3/19/12 - 3/23/12, 4/12/12 - 4/16/12 and 4/26/12 – 4/30/12. Figure 2.1 shows the exact location of CAMS 12 in PdN.

5.1.1 CAMS 12 Field Study

A CAMS is a sufficient shelter to house instruments measuring the amount of pollutants, nutrients and other parameters in the atmosphere or in a body of water (TCEQ, 2012). A small pump from a CAM station extracts external air from several tubes. Ambient air is then distributed to the instruments housed within the shelter. At each station ozone concentrations are monitored continuously and reported in 1 and 8-hour averages. Figure 5.1 displays the site at CAMS 12. It is seen in Figure 5.1 the shelter and the inlet where ambient air was withdrawn into the instrument. Figure 5.2 demonstrates a better sense of the location for the 2B monitor deployed at CAMS 12. For the reasons of security, power access, and prevention of damage from wet precipitation, the monitor is located underneath the CAMS 12 shelter with a Teflon tubing rising approximately six feet high to collect ambient air.

Figure 5.1 CAMS 12 Site (Photo from TCEQ)

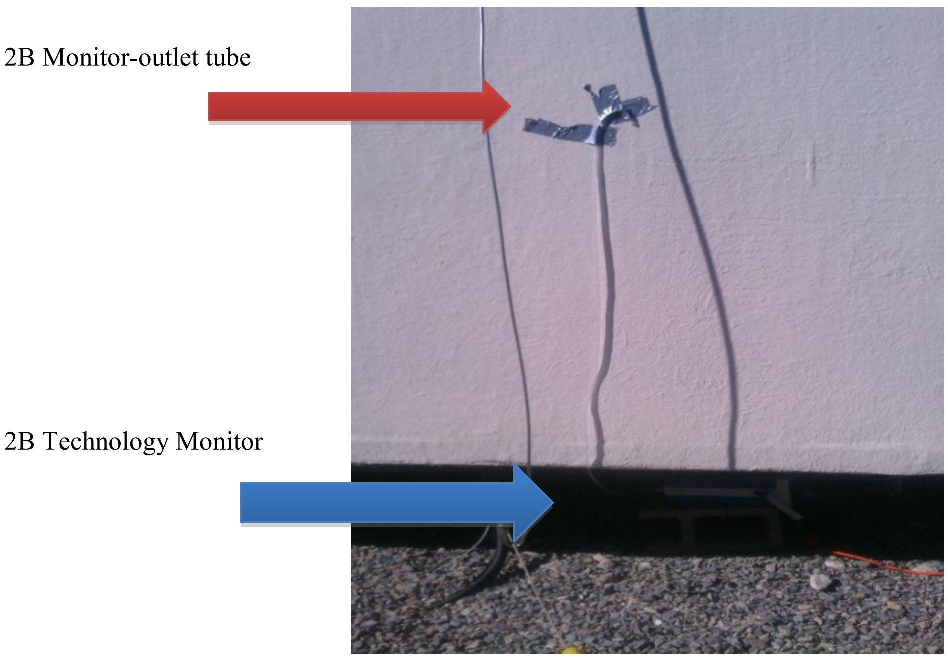


Figure 5.2 2B Monitor Location at CAMS 12

A time series plot was developed with a slope and intercept for each set of measurements collected during the side-by-side comparison. Figures 5.3 to 5.6 shows the time series plots and linear regression analysis of the data obtained from this study. The y-axis of the time plot series (Figure 5.3) represents monitored ozone in ppb. The x-axis represents the recorded day. There is vertical gridlines that represent the 12:00 p.m. and 12:00 a.m. mark. For example the vertical line at 4/28/12 represents

12:00 a.m. and the vertical gridline between 4/28/12 and 4/29/12 represent 12:00 p.m. It is worth noting the highest 1-hour recorded ozone occurs approximately midday between 11:00 a.m. to 6:00 p.m. This trend will be further examined in Chapter 6 discussions along with other trends. Linear regression figures shown in Figure 5.4 throughout 5.6 demonstrate that 2B technology monitors correlate well with one another ($R^2 \geq 0.99$), along with the ozone compliance monitor at CAMS 12. To avoid confusion between monitors; serial number 1131 monitor is designated as 2B Monitor #1, and serial number 1147 monitor as 2B Monitor #2. Figures 5.4 to 5.6 are linear regression models of ozone collected at CAMS 12 and both 2B Monitors. The y-axis for Figure 5.4 represents the ozone collected from 2B Monitor #2 in ppb and the x-axis represents the ozone collected from 2B Monitor #1 in ppb. The regression model in Figure 5.4 demonstrates a great correlation between both 2B monitors since the data points nearly overlap (collecting alike values) and follow the trendline thoroughly. Figure 5.5 compares monitor #1 with CAMS 12. Figure 5.6 compares monitor #2 with CAMS 12. The R^2 values range from 0.988-0.99, slope from 0.978-1.033 and intercept from 0.065-0.117. The data was additionally evaluated with a straight line fit by setting the intercept to zero. The R^2 and slope values were equivalent for this fit. The red line represents a one-to-one ratio of both evaluated monitors.

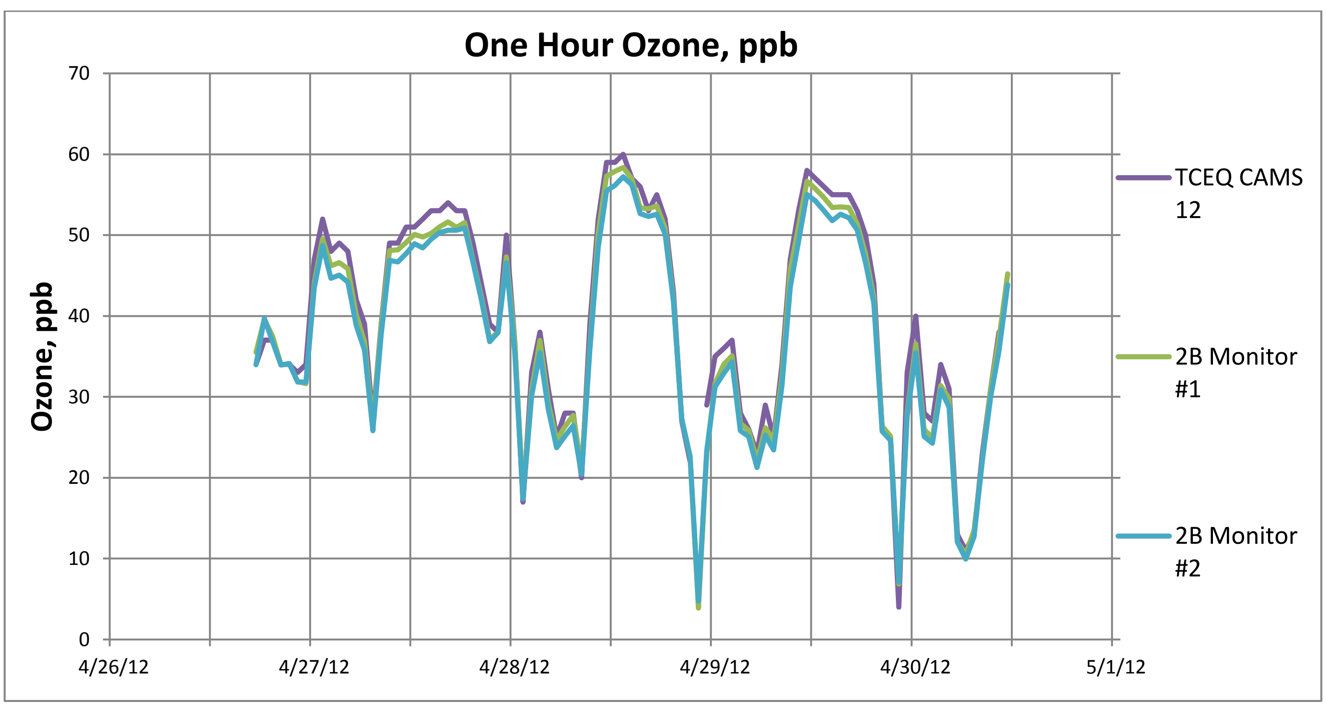


Figure 5.3 1-hour average Ozone of both 2B Monitors and CAMS 12

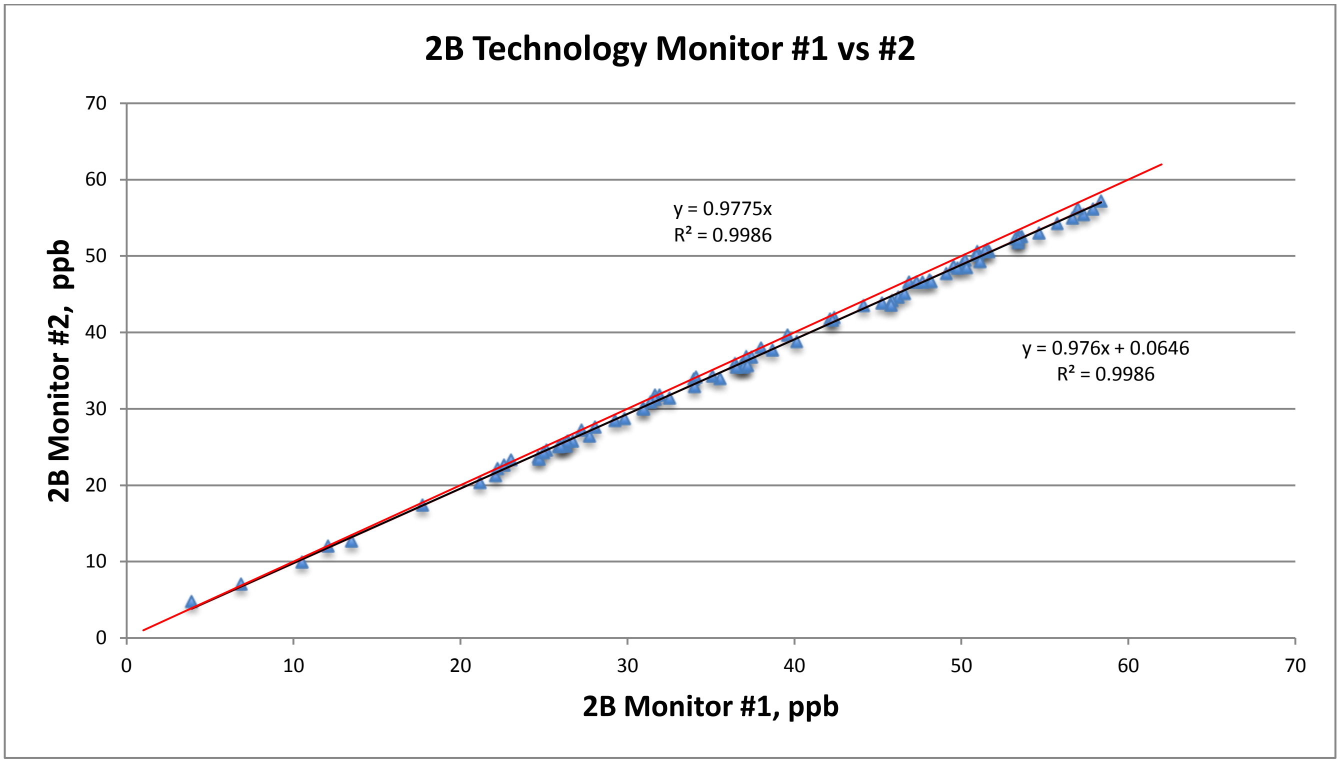


Figure 5.4 Correlation between both 2B Monitors

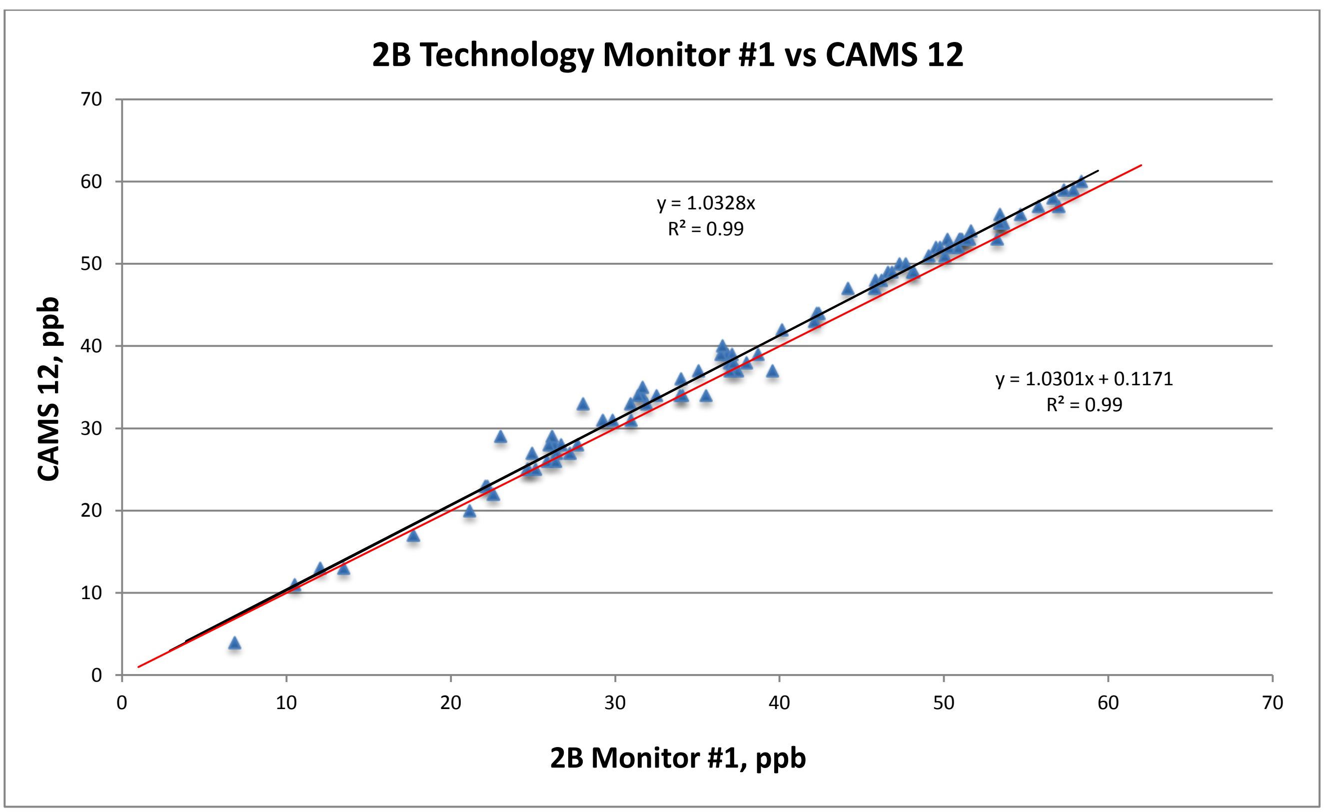


Figure 5.5 Correlation between 2B Monitor #1 and CAMS 12

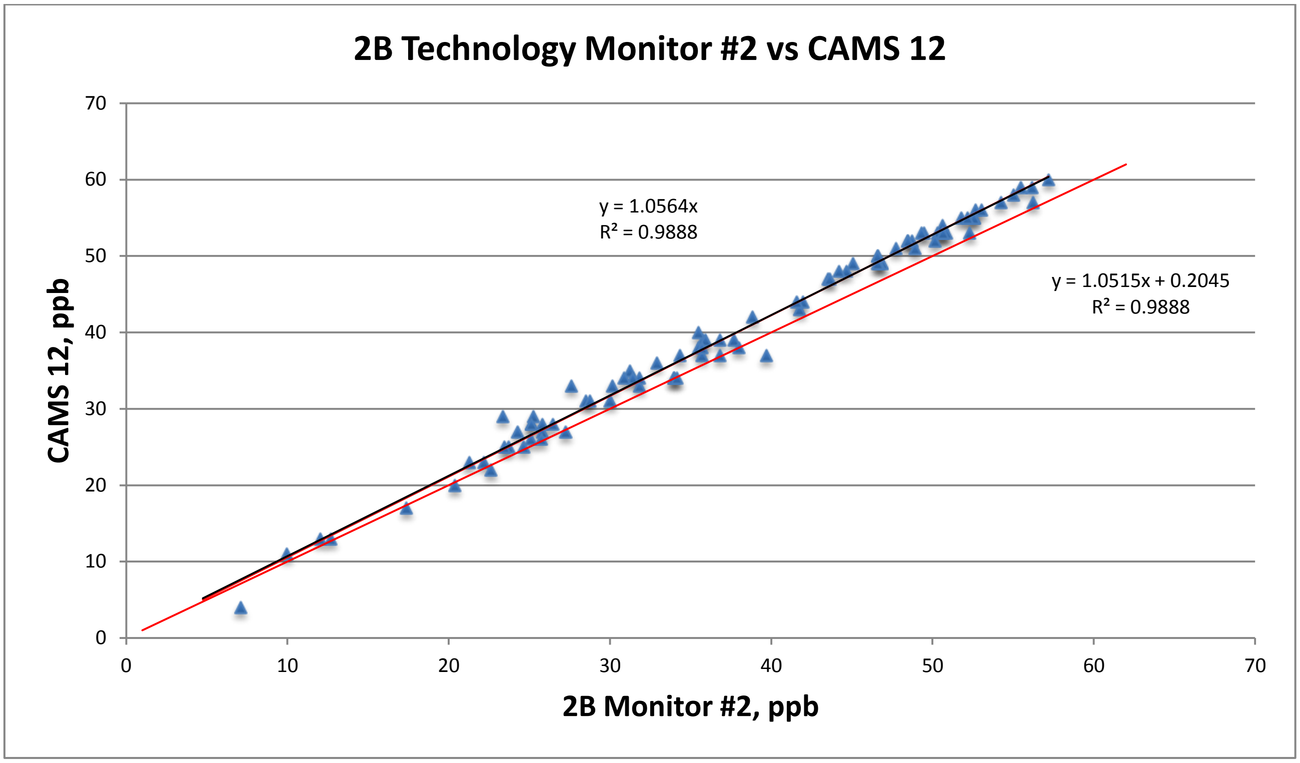


Figure 5.6 Correlation between 2B Monitor #2 and CAMS 12

These assessments demonstrated both 2B technology monitors to be adequate and ready for deployment. The seven-point calibration received from 2B Technologies Manufacturing Company, side-by-side analysis evaluated at CAMS 12 and Performance Evaluations revealed the monitors proven to be highly efficient and reliable during deployment. The Performance Evaluations are further discussed in Section 5.1.2. With the help of the conceptual model both 2B monitors were deployed in areas that yield potential hot spots during the months of highest ozone. Appendix B include the additional graphs for the side-by-side analysis among the 2B Monitor #1, 2B Monitor #2, and CAMS 12 for the other two time periods of calibration: 3/19/12 - 3/23/12 and 4/12/12 - 4/16/12. It is worth noting that both 2B monitors slightly drift below the monitored ozone at CAMS 12.

5.1.2 Maintenance and Performance Evaluation Checks

Startup procedures and maintenance operations were necessary throughout the duration of this study to ensure the monitors were retrieving quality data. The startup procedure for each site includes

confirmation of correctly operating equipment (i.e., internal data logger, ozone analyzer, sample intake line, filter, water trap, modem, UPS power supply). This task suggests replacement of the ozone scrubber, on an "if needed" basis. Calibration schedules during the course of this study are shown in Table 5.1. The CAMS stations were calibrated according to TCEQ schedules and specifications. The transfer standard was also calibrated according to TCEQ specifications, policies and procedures. Both 2B technology monitors at Fort Bliss and Butterfield received a performance evaluation check during months of July – September. Site visits occurred every two to three days and included performance checking of ozone monitor and download of indoor temperature readings (the calibration checks may be performed during these visits). The room was cleaned once a week to avoid any accumulation of dust in and around the monitors.

The data delivery method for the CAMS stations is by modem to TCEQ. Data was continually updated every hour on the TCEQ website for all CAM stations. The monitors located at Fort Bliss and Butterfield were manually retrieved once a week. Every week that data was retrieved the 2B monitors were temporarily shut down from collecting ambient air for at least 10-15 minutes. Other occasions the monitor did not continually retrieve data was when the monitors were undergoing performance evaluations (described further in this section).

TABLE 5.1 SITE MAINTENANCE, DATA VERIFICATION AND SHUTDOWN SCHEDULE

Month ➔ 🡣 Data Check	May	June	July	August	Sept.	Oct.		
3- or 5-point Calibration	N/A	N/A	Twice monthly	Once monthly	Once monthly	N/A		Shutdown Sites by Nov. 1
Simple data verification	Weekly	Weekly	Weekly	Weekly	Weekly	Weekly		
Equipment maintenance check	Every 2-3 days during the period from May 18 through October							

Subject to drift and variation every instrument requires periodic calibration. According to 2B Technologies, the Model 202 requires calibration at least once annually. Before delivery of the

instrument, 2B Technologies calibrate the monitor using the Thermo Electron 49i Primary Standard ozone calibrator. The Primary Ozone Standard is the combination of an ozone generator and ozone monitor based on UV absorbance (a UV photometer). The combination has been setup in accordance with procedures prescribed by the U.S. Environmental Protection Agency (EPA) under Title 40 of the Code of Federal Regulations, Part 50, Appendix D (40 CFR Part 50). The seven-point calibration and certificate included with both 2B monitors is shown in Figures 5.7 and 5.8. The plots in both figures show the comparison between a known concentration (Standard ozone, ppb) from the calibrator and the concentration recorded from the 2B monitors. The data is fit to a straight line (y = mx + b) using the linear regression technique to determine the calibration relationships. The slope of the line is the gain factor (S). The intercept is the offset (Z) requiring application to the ozone monitor response in order for calibration to the primary ozone standard. An intercept range exceeding -10 to 10, or the slope from 0.90 and 1.10, indicates a problem in the calibration setup or the ozone monitor being calibrated.

2B Technologies Model 202 Ozone Monitor™

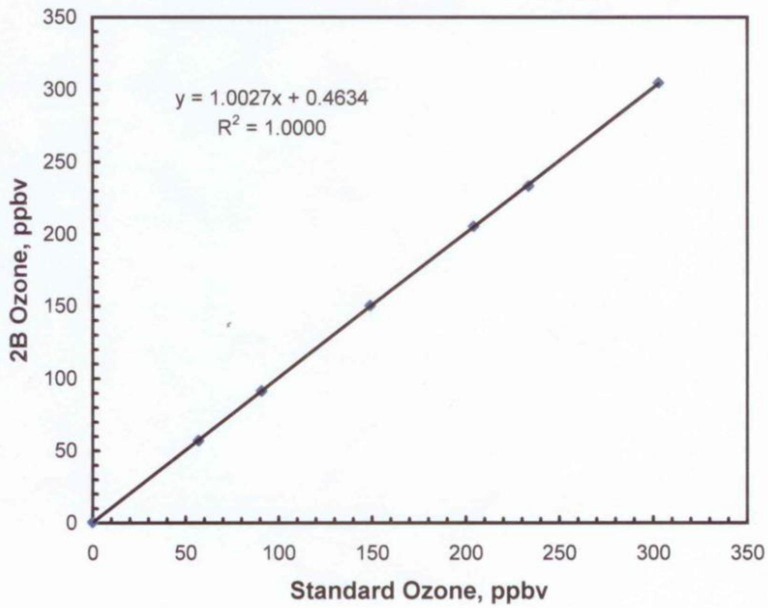
Calibration Data

Serial No. 1131 **15-Nov-11**

2B, ppbv	Std, ppbv	2B, corr	Deviation	% Dev.
298.6	302.9	304.6	1.7	0.6
229.0	233.6	233.5	0.0	0.0
201.6	204.3	205.7	1.4	0.7
147.6	149.1	150.6	1.4	1.0
89.7	90.9	91.5	0.6	0.6
56.1	56.9	57.2	0.3	
0.6	0.0	0.6		

Average Precision, ppbv:	1.4
Avg. Precision at 1 Atm.:	1.2
Cal Parameters Entered During Calibration:	
Z = 0	(Admin use only)
S = 1.00	
New Cal Parameters:	
Z = 0	(To be entered
S = 1.02	into instrument)

Calibration Curve with Cal Factors Applied



Model 202 #1131 & #1133 11_15_11

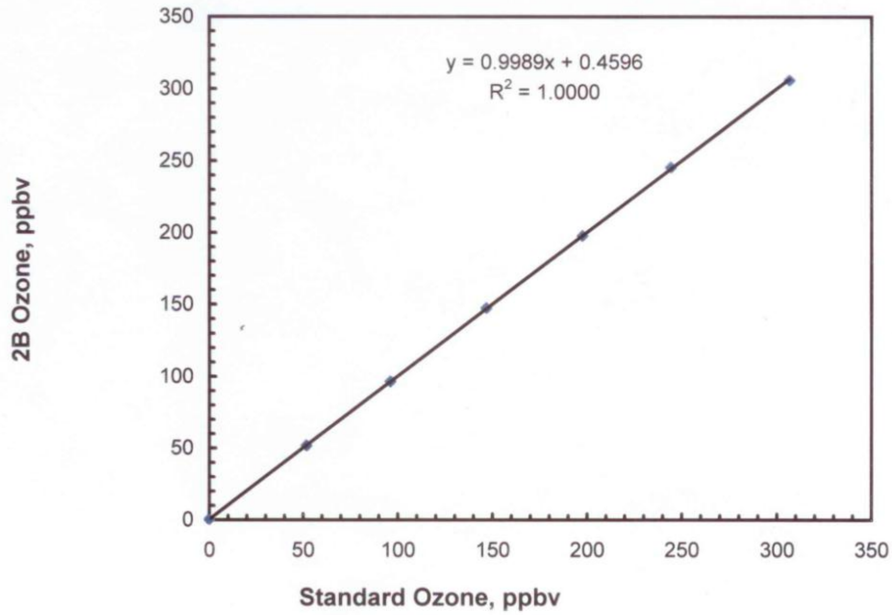
Figure 5.7 Calibration Data - 2B Monitor #1

2B Technologies Model 202 Ozone Monitor™
Calibration Data

Serial No. 1147 **29-Feb-12**

2B, ppbv	Std, ppbv	2B, corr	Deviation	% Dev.		
302.9	306.8	306.0	-0.8	-0.3	Average Precision, ppbv:	1.4
243.1	244.3	245.6	1.3	0.5	Avg. Precision at 1 Atm.:	1.1
196.1	197.8	198.0	0.2	0.1	Cal Parameters Entered During Calibration: Z = 0	(Admin use only)
146.0	146.8	147.5	0.7	0.5	S = 1.00	
95.6	96.3	96.5	0.2	0.3	**New Cal Parameters:**	
51.5	51.8	52.0	0.2		**Z = 0**	(To be entered
0.3	0.0	0.3			**S = 1.01**	into instrument)

Calibration Curve with Cal Factors Applied



Model 202 #1147 02_29_12

Figure 5.8 Calibration Data - 2B Monitor #2

Rather than calibrating each monitor they were instead checked by Performance Evaluations for the duration of this study. A five-point performance evaluation was performed at least once every month during operation to ensure reliable data. The gain factor (S) and offset (Z) were never changed. For this reason this study refers to "Performance Evaluations" instead of calibration checks. This study used a Tanabyte Model 724 Ozone Transfer Standard to verify correct operation of the monitors. The monthly checks are described in Table 5.1. The months of May and June were not evaluated using this technique but both monitors were deployed at Fort Bliss assuring the reliability of recorded ozone. "The Model 724 is configured as an Ozone Transfer Standard Calibrator, with a built-in ozone generator and zero air supply. The U.S. EPA Equivalent Method photometer can either be configured to measure external ozone concentrations or to monitor the ozone generator output in order to precisely control the ozone concentration to a specified set point" (Tanabyte Products Website). The Tanabyte 724 contains two output manifolds that allow simultaneous direction of ozone to the internal photometer and external instrument.

Since the Tanabyte contains both features, the standard concentration and the monitored concentration values were retrieved and compared with the 2B monitors. For example if 100 ppb was chosen as the standard concentration from the Tanabyte calibrator the value of 100 ppb should appear on both the Tanabyte and 2B monitor screen to prove accuracy. Before generating and recording ozone, 2B monitor and the Tanabyte calibrator were turned on for 30 minutes to an hour in order to fully stabilize. The known concentrations used for the performance evaluation were 0, 50, 100, 150 and 200 ppb. Refer to Table 5.2 for exact values retrieved using the given standard concentrations, from the Tanabyte Analyzer and 2B Monitor #1. Figures 5.9 and 5.10 below demonstrate one of the many straight-line fits created from the performance evaluations assessed during the duration of the deployment of these 2B monitors. The R^2 values range from 0.9942-0.9999, slope from 1-1.0944 and intercept from -2.5868 to 5.4482. The performance evaluation demonstrates continuous and accurate readings being that the monitors collected values within the allowable intercept range of -10 to 10 and slope from 0.90 to 1.10. The data was additionally evaluated with a straight line fit by setting the intercept to zero (refer to red line). Appendix A contains the remainder of the tables and figures for these performance evaluations.

Table 5.2 Concentration Values from the Tanabyte Analyzer and 2B Monitor using Standard Concentrations

All Values expressed in ppb		
Standard Concentration, ppb	Tanabyte Analyzer, ppb	2B Monitor #1, ppb
0	6.21	3.6
50	49.95	44.5
100	99.73	95.4
150	149.44	143.7
200	200.56	192.2

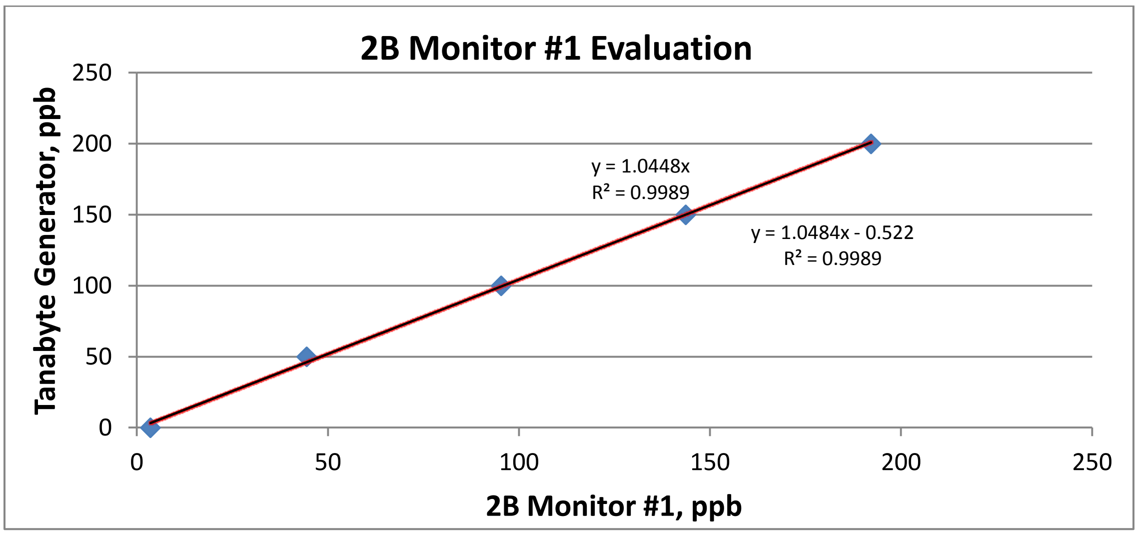


Figure 5.9 Tanabyte Generated Ozone vs. 2B Monitor #1

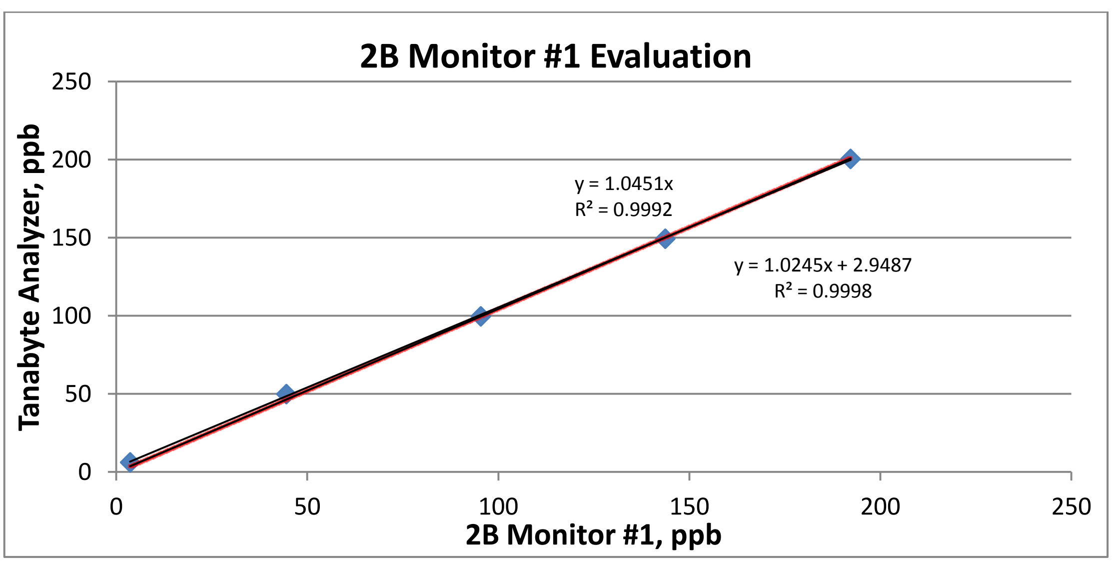


Figure 5.10 Tanabyte Internal Analyzer vs. 2B Monitor #1

5.2 Ozone Measured at Fort Bliss

The 2B monitors give the option to record ozone every 10s, 1m, 5m or 1 hour. For this study ozone was collected from both 2B monitors every 5 minutes and processed into 1-hour averages. Every hour contains 12 different 5-minute readings unless the monitors were shut down for performance evaluations or temporarily stopped for retrieving data. Hourly averages with less than nine available 5-minute averages were not included in this study. Once the hour averages were processed an 8-hour rolling average was processed. The running 8-hour averages were computed for each hour monitored for this entire study and reported at the start of the 8-hour period. For example, the 8-hour averages reported at 1:00 p.m. were averaged from 1:00 p.m. through 9:00 p.m. In order to be valid these 8-hour averages reported contained at least 75% (6-7 hours) of the hourly averages for the 8-hour period (U.S. EPA 40CFR part 50). Any 8-hour averages containing less than 75% of the 8-hour period were ignored. Being that the EPA recognizes only one exceedance per site per day (8-hour average > 75 ppb), only the maximum daily 1 and 8-hour value was used in the time series plots in Figures 5.11 through 5.16.

Figures 5.11 through 5.16 display daily maximum 1 and 8-hour ozone averages dating from May 18th to July 9th for all CAM stations and both 2B monitors. The vertical gridline represents the 12:00 a.m. mark for the day that is displayed in the x-axis. The vertical gridlines are separated every seven days during this period. During this time both 2B monitors were located at Fort Bliss. Section 5.3 includes the figures at the time #2 monitor was deployed at Butterfield. Figures 5.11 and 5.12 demonstrate both monitors still continue to have a great relationship with each other. This proves the data retrieved is very dependable during this period. There is a lag on 7/9/12 in both figures since the 2B Monitor #2 was separated before recording a full day of ozone leading to different daily maximum 1 and 8-hour concentrations. After analyzing the figures you can see much higher ozone concentrations were collected at Fort Bliss as opposed to the other CAM stations in El Paso and Juarez. After comparing the 8-hour ozone rolling averages both 2B monitors at Fort Bliss exceeded 75 ppb (current NAAQS) with values ranging from 78.7 ppb (2B Monitor #2) to 80.4 ppb (2B Monitor #1). The same 8-hour figures for El Paso and Juarez CAMS did not experience a single exceedance. 75.1 ppb recorded at CAMS 41 was the highest point measured for El Paso CAM stations. 75.1 ppb is not considered an

exceedance because the concentration needs to average 76 ppb or higher. 66.1 ppb recorded at CAMS 662 is the highest 8-hour rolling average measured in Juarez CAM stations.

A linear regression was created to further inspect which location measured higher concentration levels of ozone. Since CAMS 12 and 41 appeared to collect the highest values in El Paso and Juarez during this period, they were used for comparison to 2B monitors located at the Fort Bliss site. Since both monitors at Fort Bliss collected almost identical ozone values (R^2=0.94), only one was used to compare to CAMS 12 and 41.

The linear regression Figures 5.17 and 5.18 display daily maximum 1 and 8-hour ozone concentrations for both 2B monitors. Figure 5.19 and 5.20 display that Fort Bliss recorded higher daily maximum 1 and 8-hour values overall. In order to see the direct numerical comparison of the values graphed, the intercept was set to zero. Additionally, to establish a one-to-one ratio for comparison a red line was drawn. The 2B Monitor #1 is graphed on the y-axis and 2B Monitor #2 is displayed on the x-axis for both Figure 5.17 and 5.18. The CAM stations were compared to 2B Monitor #1 and graphed on the x-axis in Figures 5.19 to 5.22. In order for both concentrations to coincide, the y-axis needs to equal the x-axis. In Figure 5.19 y = 1.0282x and 5.18 y = 1.04446x indicating Fort Bliss recorded 2.8% higher ozone than CAMS 12 for daily maximum 1-hour concentrations and 4.4% higher for daily maximum 8-hour concentrations. In Figure 5.21 y = 1.0603x and 5.22 y = 1.082x indicating Fort Bliss recorded 6% higher ozone than CAMS 41 for daily maximum 1-hour concentrations and 8.2% higher for daily maximum 8-hour concentrations.

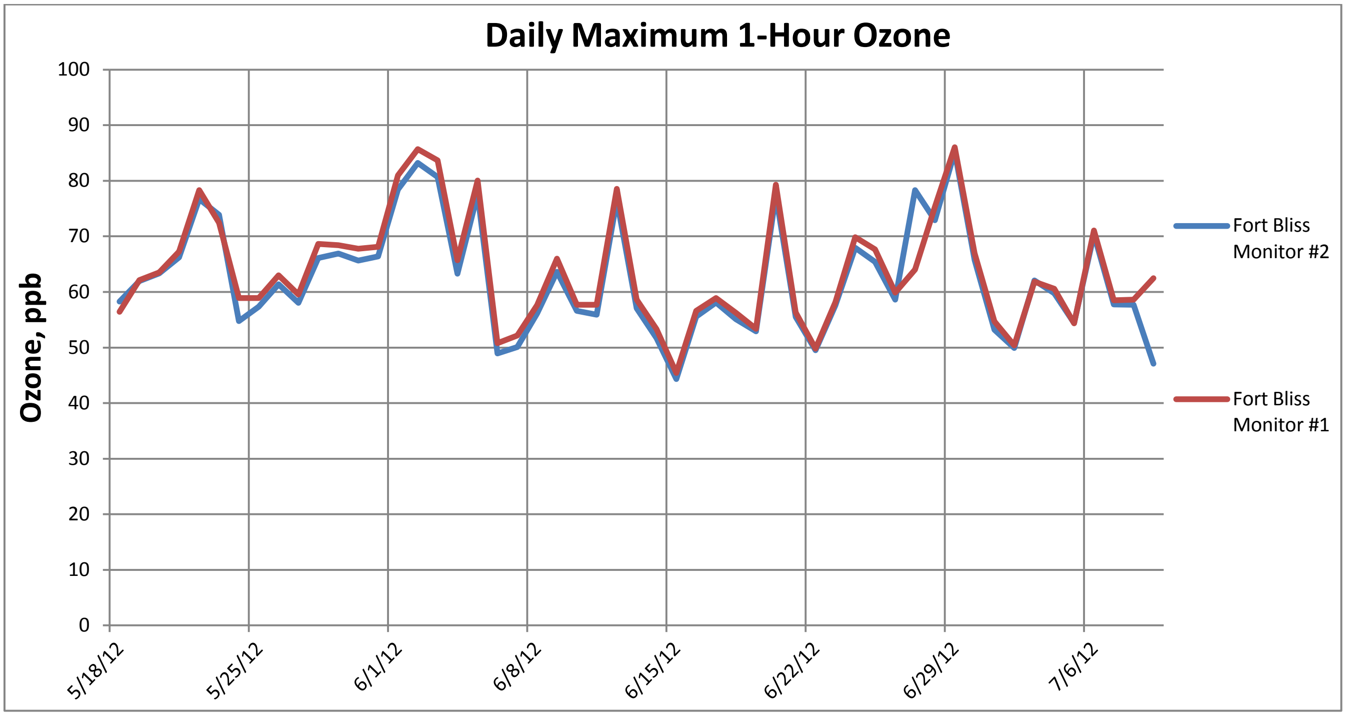


Figure 5.11 Daily Maximum 1-Hour Ozone Recorded at Fort Bliss from both 2B Monitors (May-July)

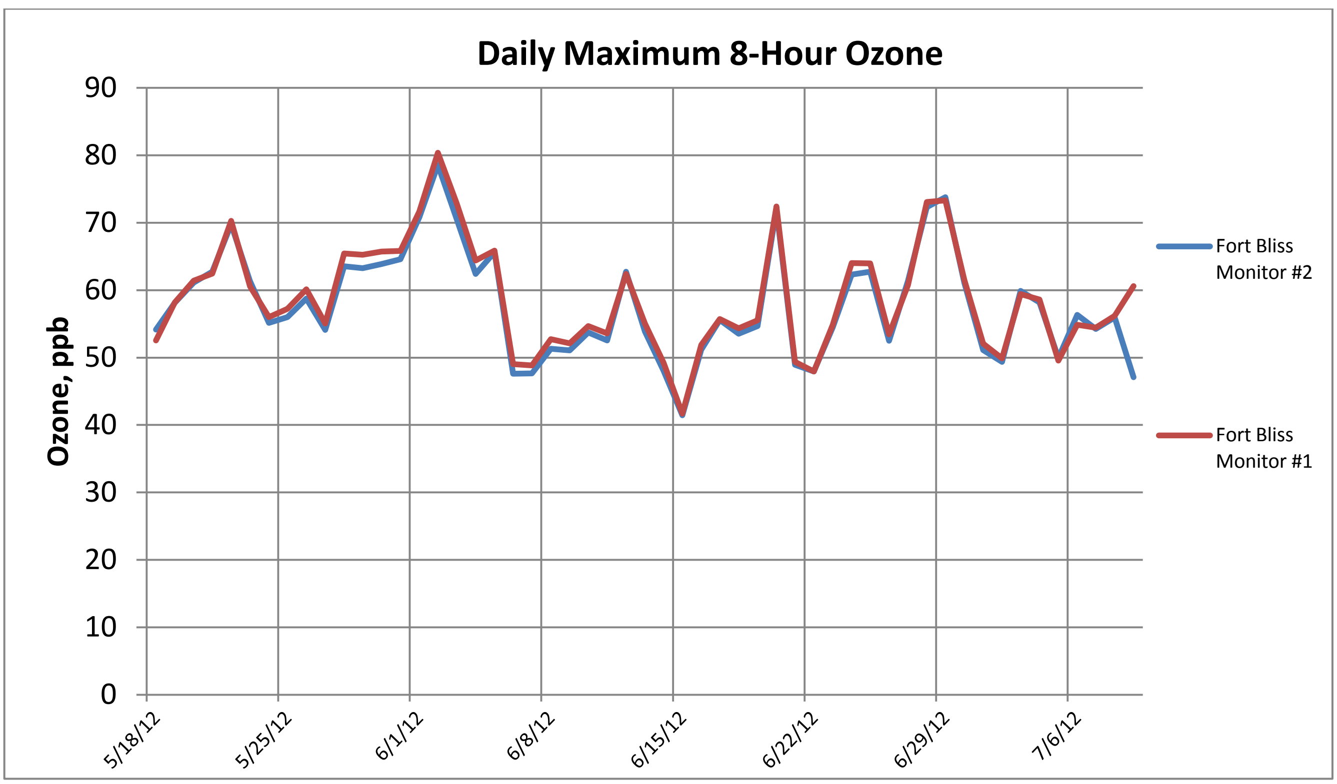


Figure 5.12 Daily Maximum 8-Hour Ozone Recorded at Fort Bliss from both 2B Monitors (May-July)

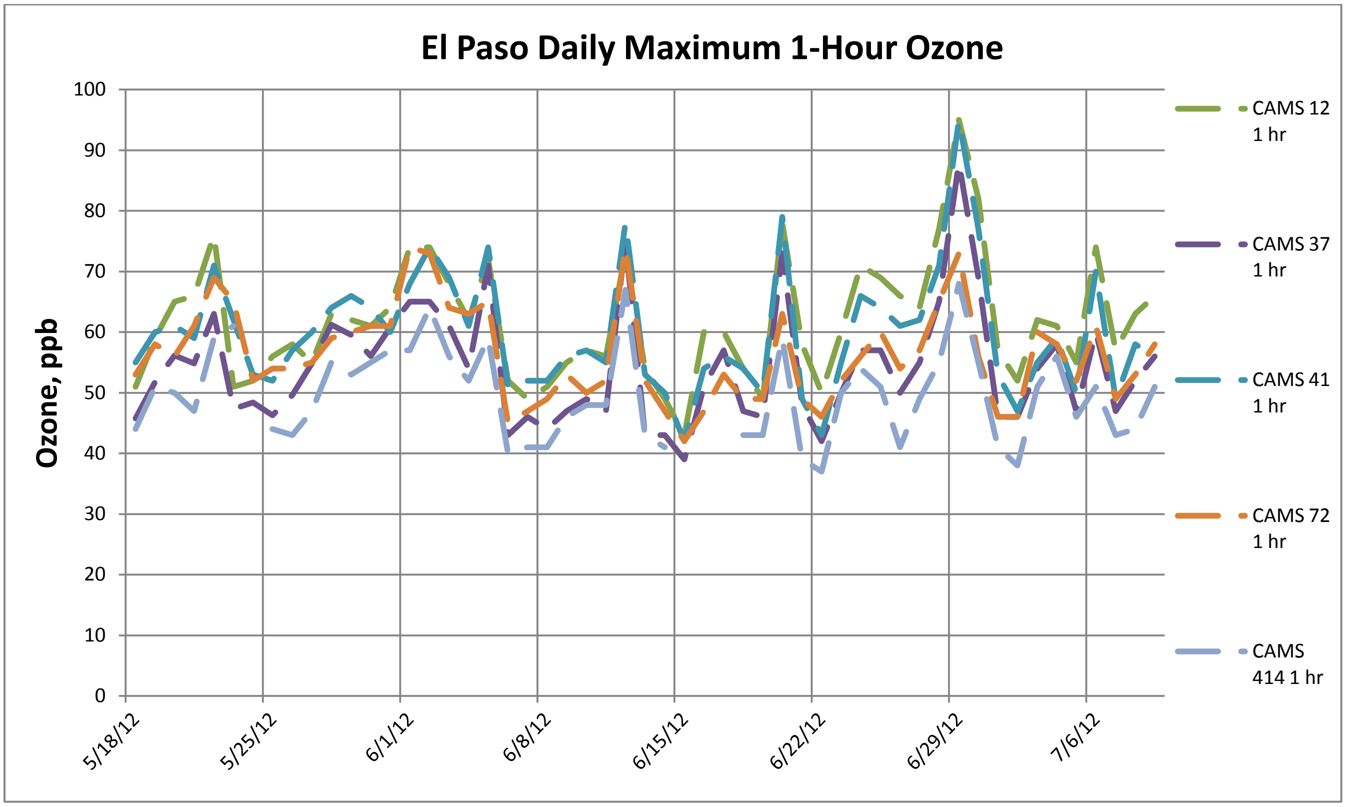


Figure 5.13 Daily Maximum 1-Hour Ozone recorded from CAM Stations in El Paso (May-July)

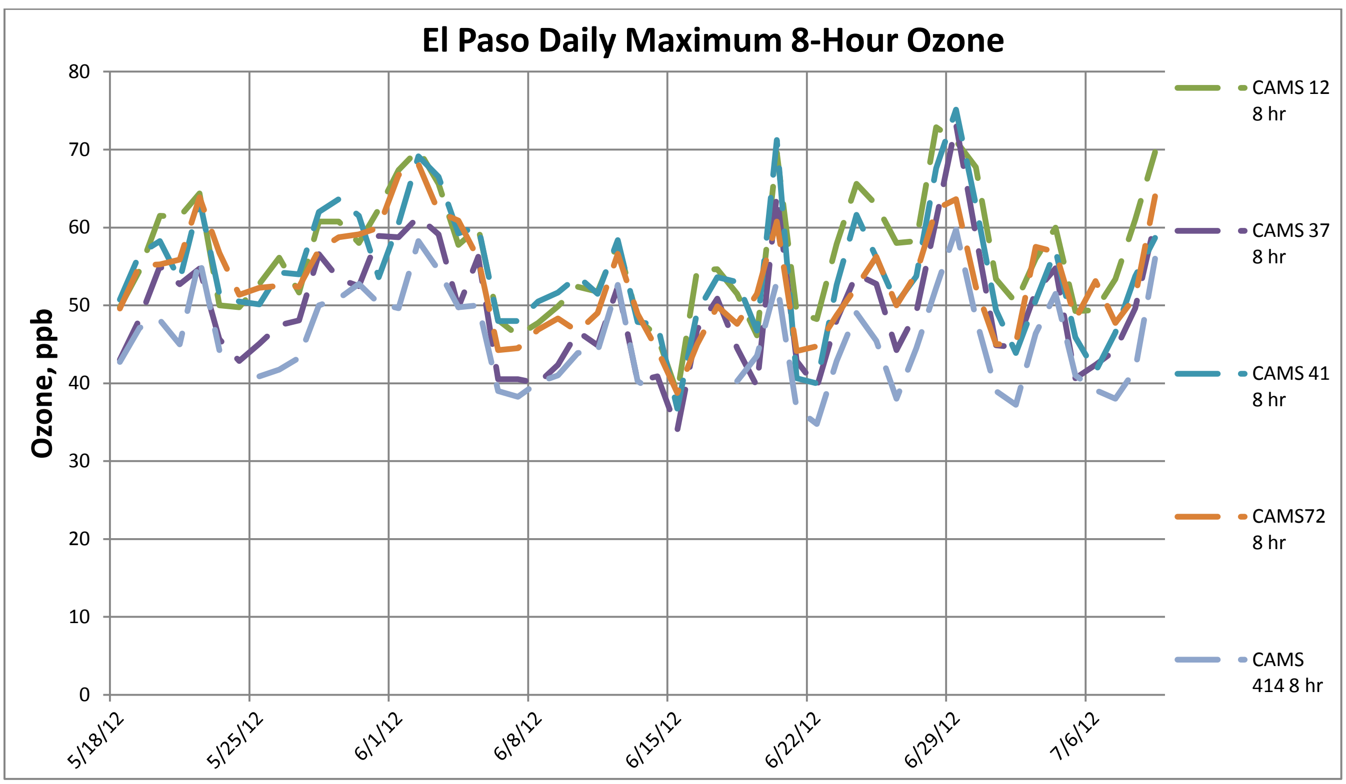


Figure 5.14 Daily Maximum 8-Hour Ozone recorded from CAM Stations in El Paso (May-July)

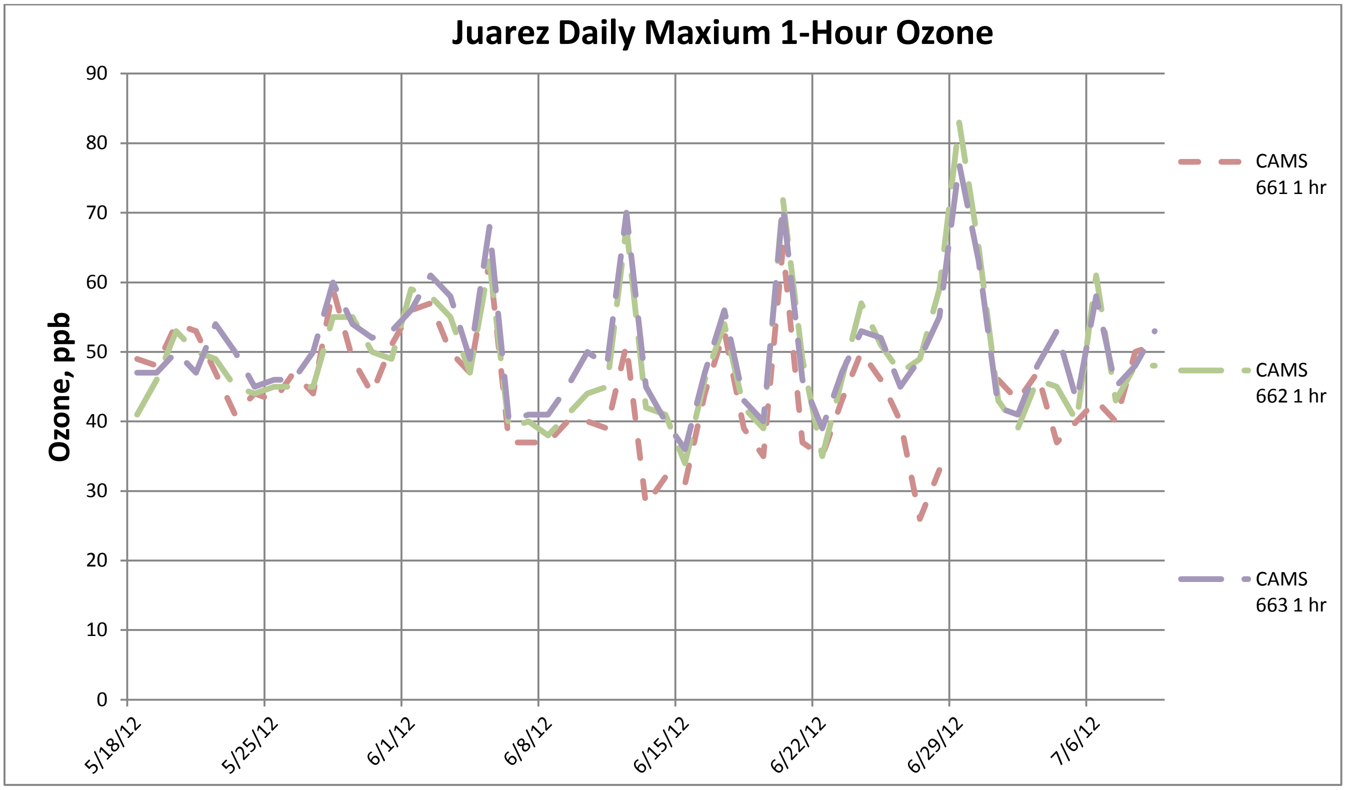


Figure 5.15 Daily Maximum 1-Hour Ozone recorded from CAM Stations in Juarez (May-July)

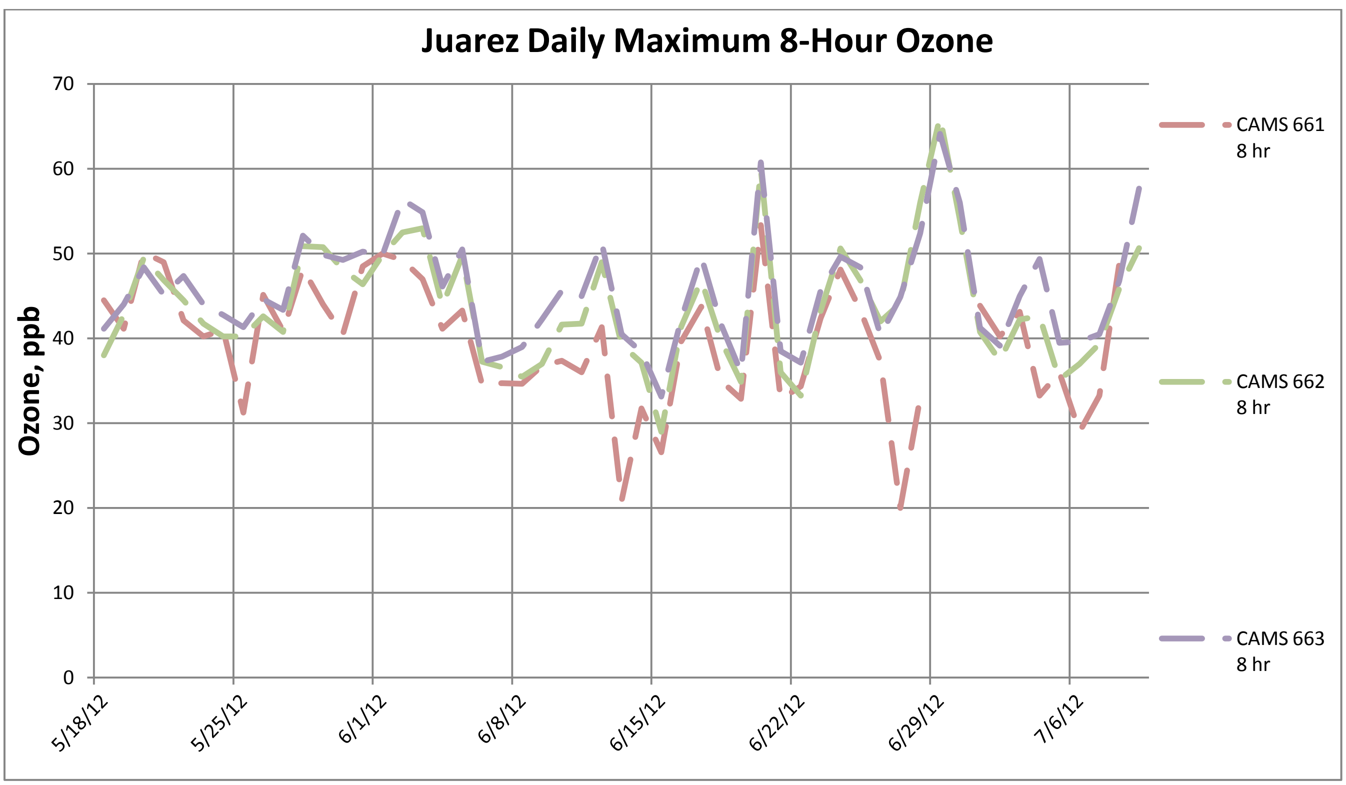


Figure 5.16 Daily Maximum 8-Hour Ozone recorded from CAM Stations in Juarez (May-July)

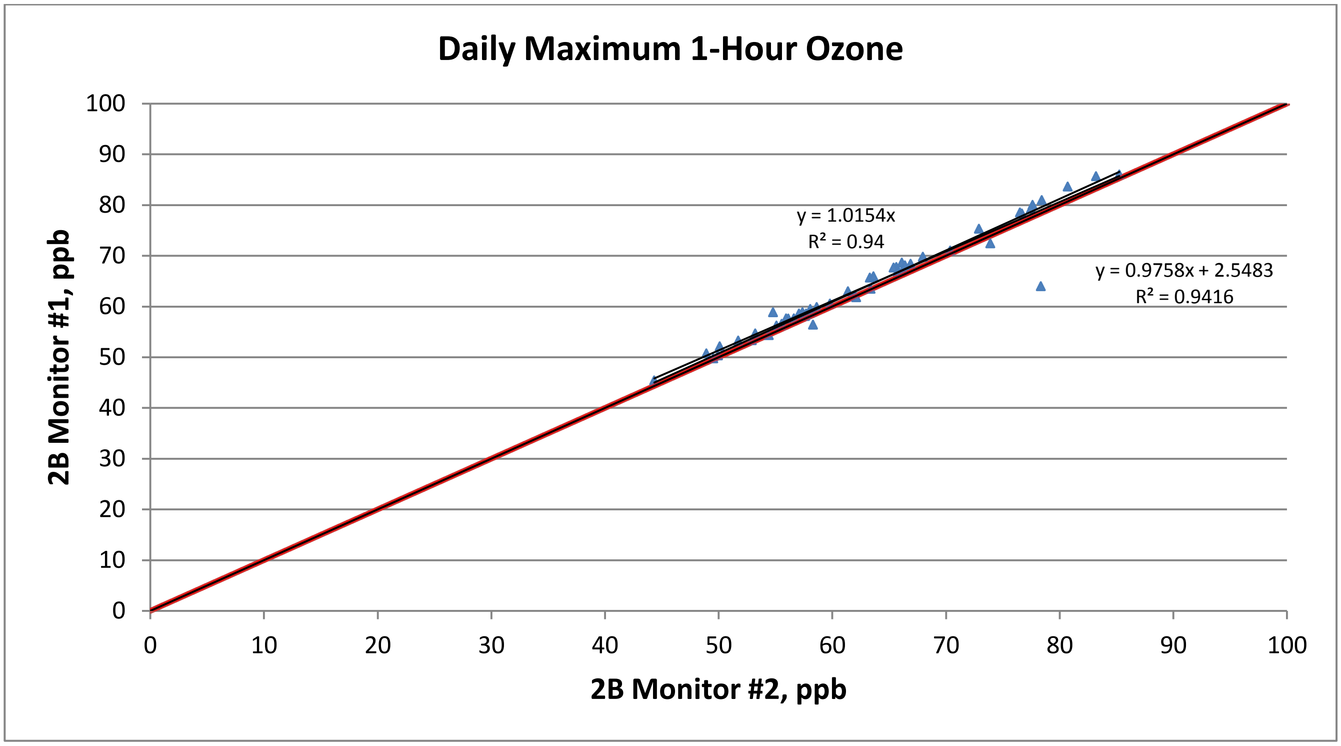


Figure 5.17 2B Monitor #1 and #2 Daily Maximum 1-hour Ozone Linear Regression Model

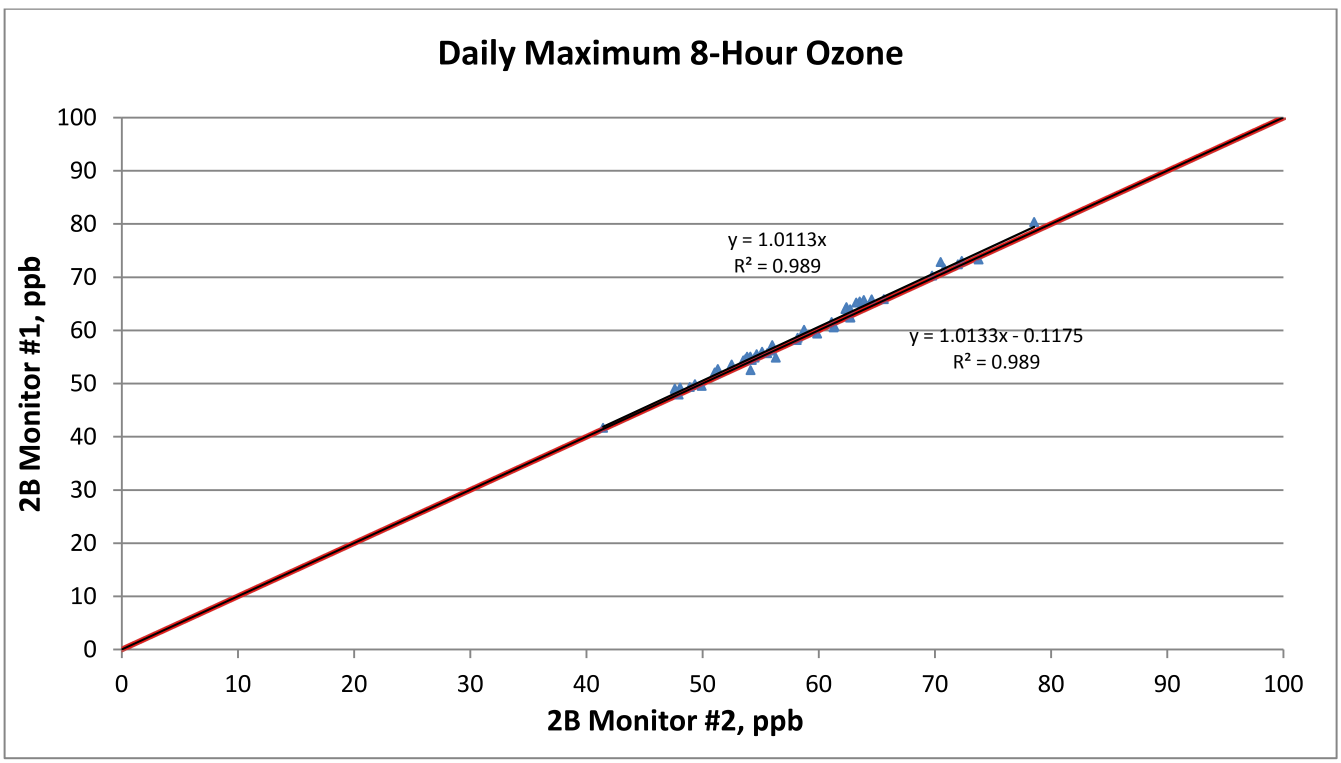


Figure 5.18 2B Monitor #1 and #2 Daily Maximum 8-hour Ozone Linear Regression Model

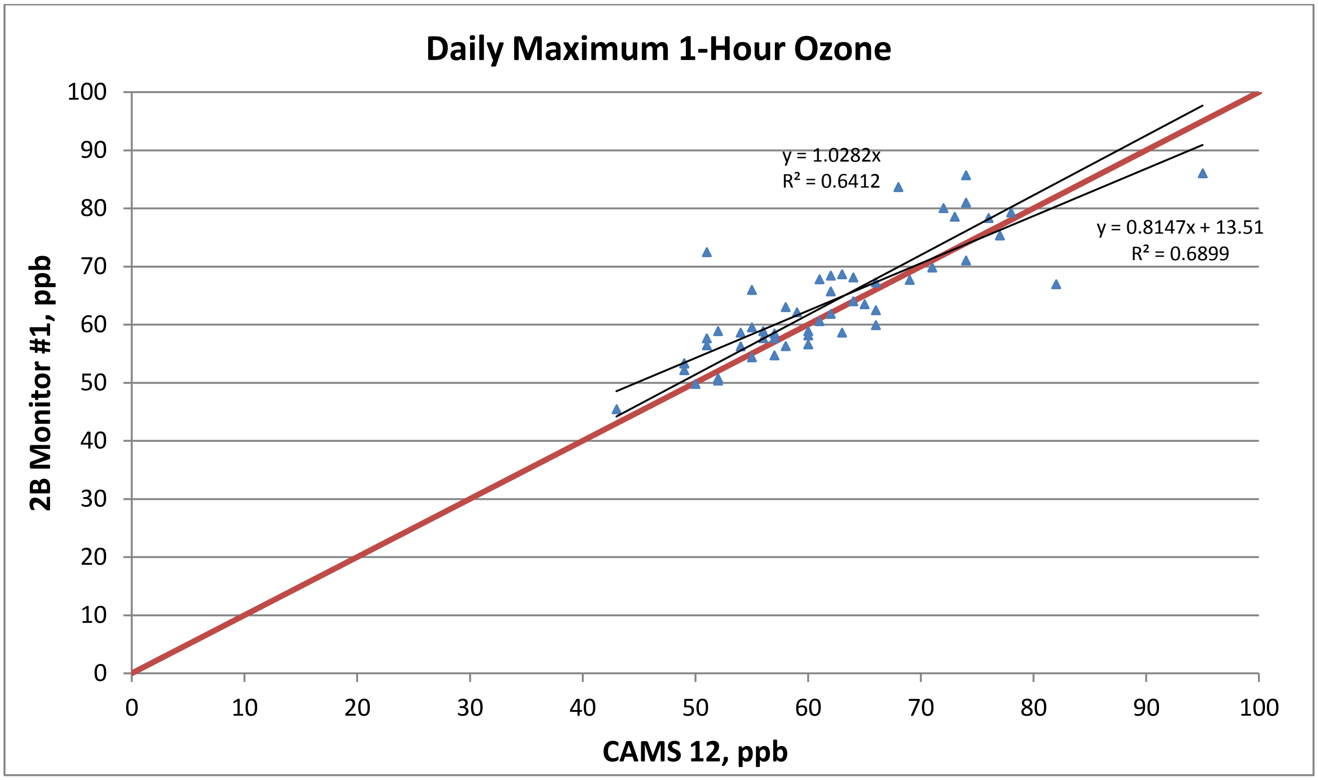


Figure 5.19 2B Monitor #1 and CAMS 12 Daily Maximum 1-hour Ozone Linear Regression Model

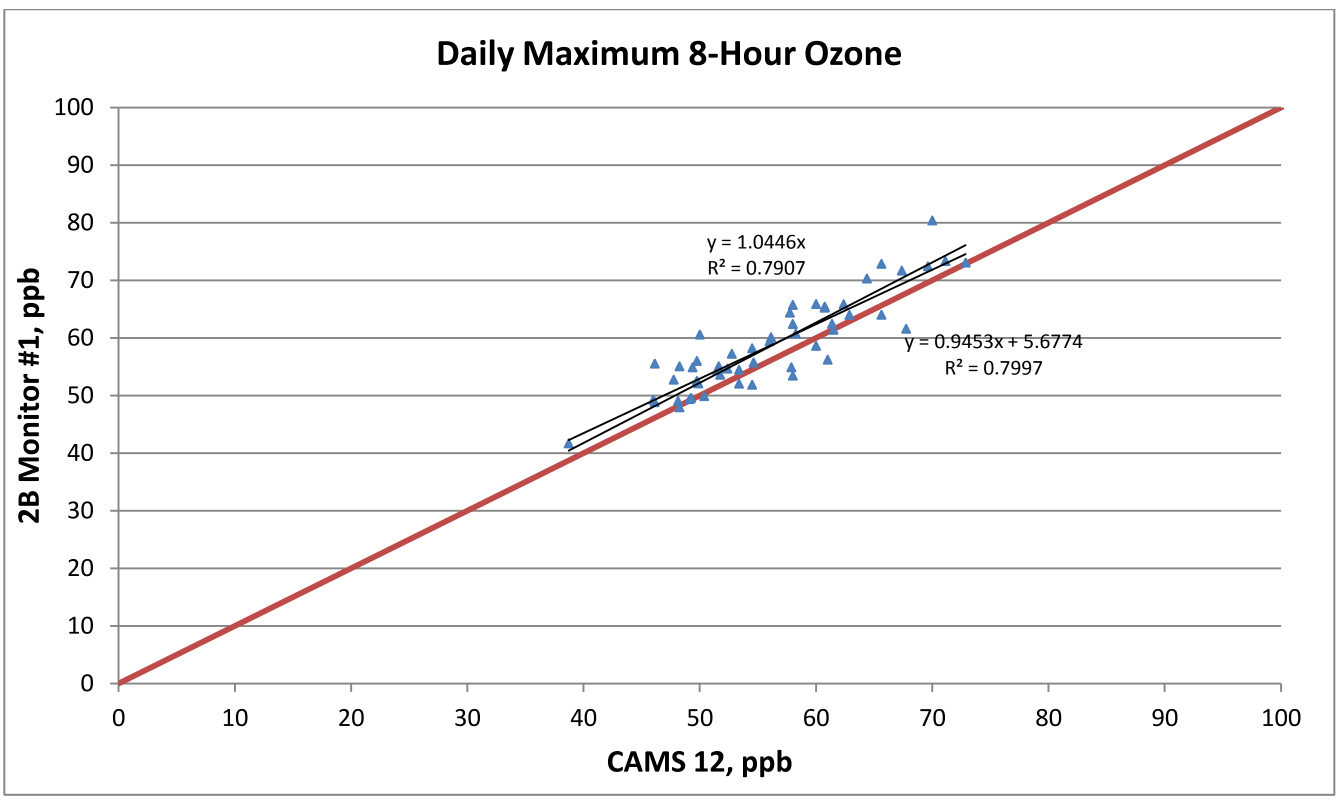


Figure 5.20 2B Monitor #1 and CAMS 12 Daily Maximum 8-hour Ozone Linear Regression Model

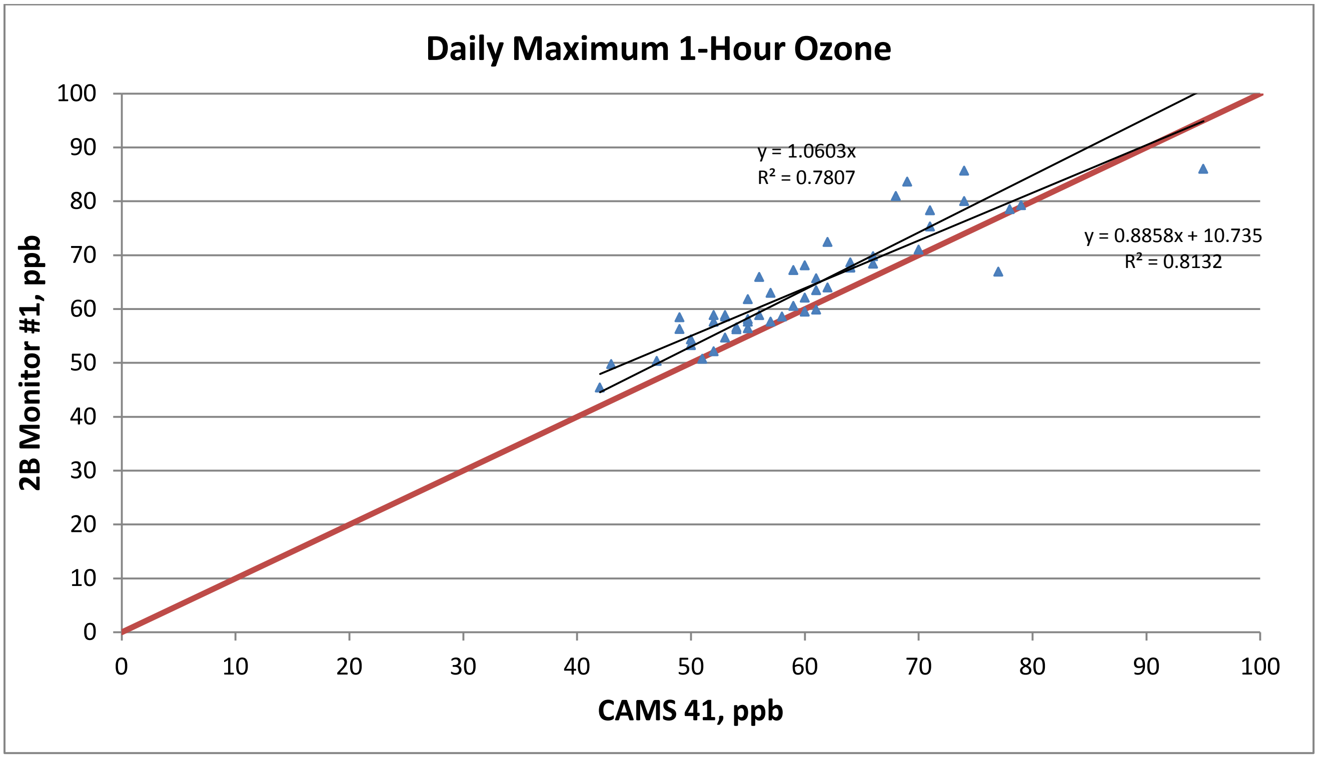


Figure 5.21 2B Monitor #1 and CAMS 41 Daily Maximum 1-hour Ozone Linear Regression Model

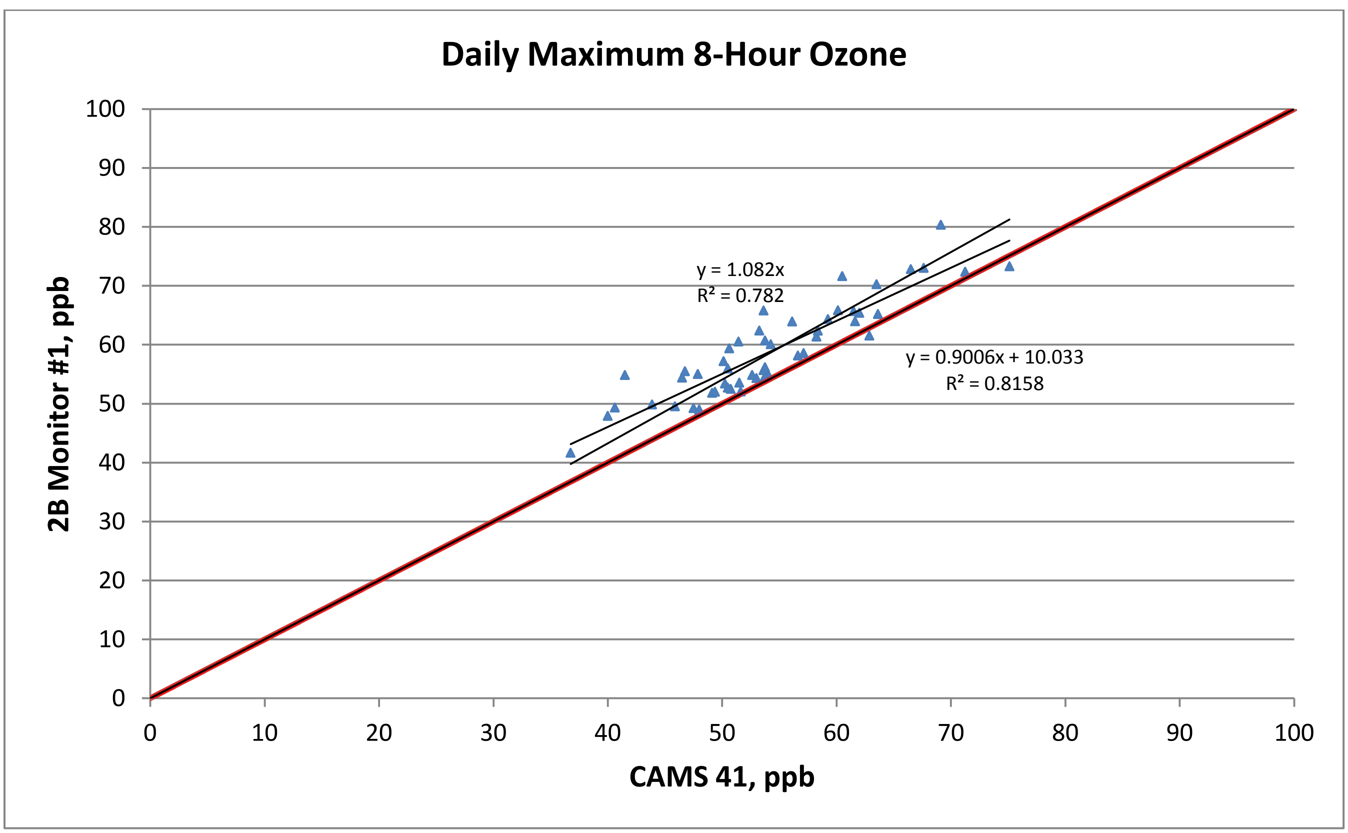


Figure 5.22 2B Monitor #1 and CAMS 41 Daily Maximum 8-hour Ozone Linear Regression Model

5.3 Ozone Measured at Butterfield

The 2B Monitor #2 was deployed at Butterfield Trail Golf Club on July 9th. For all CAM stations and both 2B monitors Figures 5.23 to 5.28 display daily maximum 1 and 8-hour ozone averages from July 9th to November 1st. Figures 5.23 and 5.24 express the daily maximum 1 and 8-hour ozone averages retrieved from Fort Bliss and Butterfield only. Figures 5.25 and 5.26 represent the daily maximum averages for El Paso CAM stations and 5.57 and 5.28 represent Juarez stations. Every vertical gridline for the time series plots were separated every 7th day during this period. Data was flagged for Fort Bliss in both Figures from 8/23/12 to 9/7/12 due to inaccurate display of flow rate values by the monitor. In attempt to download ozone from the monitors, flow rate was displaying zero readings. This indicated various troubleshooting possibilities such as: a contaminated ozone scrubber, contaminated flow path, air pump was not drawing sufficient flow or contaminated solenoid valve was disabling itself from opening and closing properly. In order to fix the problem the monitor was shipped back to the manufacturing company for recalibration before re-deployment at Fort Bliss. Fortunately, Dr. David Dubois from New Mexico State University was willing to let us borrow his 2B Model 202 for the remainder of this study. For this reason we continued to collect data at Fort Bliss for the remainder of the ozone season.

After analyzing these figures you can see Fort Bliss and Butterfield relate well with one another, while CAMS 12 and 41 continue to demonstrate the highest peaks of ozone for El Paso CAM stations. The highest monitored 8-hour rolling average at Fort Bliss was 73.5 ppb. The monitor at Fort Bliss did not experience an exceedance, however the monitor at Butterfield did, with a value of 78.2 ppb. CAMS 12 was the only El Paso station that experienced an exceedance with a value of 77.9 ppb. CAMS 41 peak value was 69.6 ppb and 72 was 69.3 ppb.

A linear regression was also created to further inspect which location measured higher concentration levels of ozone during this period. In addition to CAMS 12 and 41 the station 72 at Skyline was compared with Fort Bliss and Butterfield to understand which site is collecting higher levels of ozone concentration. Because only one 8-hour value exceeded 63 ppb with a value of 70.13 ppb Juarez CAMS will not be used in linear regression Figures. The linear regression expressed in

Figure 5.29 establishes a great linear relationship for Fort Bliss and Butterfield. The equation for this linear relationship is y = 1.0004x with an R^2 = 0.69. Only Fort Bliss Figures were used to compare to CAMS 12 and 41 since Fort Bliss and Butterfield ozone data correlated well. Butterfield linear regression models with CAM stations can be found in Appendix C. During this period CAMS 12 monitored higher levels of ozone concentrations than both 2B monitors and all CAM stations in El Paso and Juarez. The equation for the linear regression model for daily maximum 1 and 8-hour average concentrations at Fort Bliss and CAMS 12 shown in Figure 5.31 was y = 0.9694x and 5.32 was y = 0.9767x making Fort Bliss less than 4% for 1-hour daily maximum averages and less than 3% for 8-hour daily maximum rolling averages of CAMS 12 recorded ozone concentration. Fort Bliss continued to collect higher values of ozone than CAMS 41 during this period. Figures 5.33 and 5.34 equations for are expressed as y = 1.05x and y = 1.072x demonstrating a 5% difference for daily maximum 1-hour averages and 7.2% for daily maximum 8-hour averages.

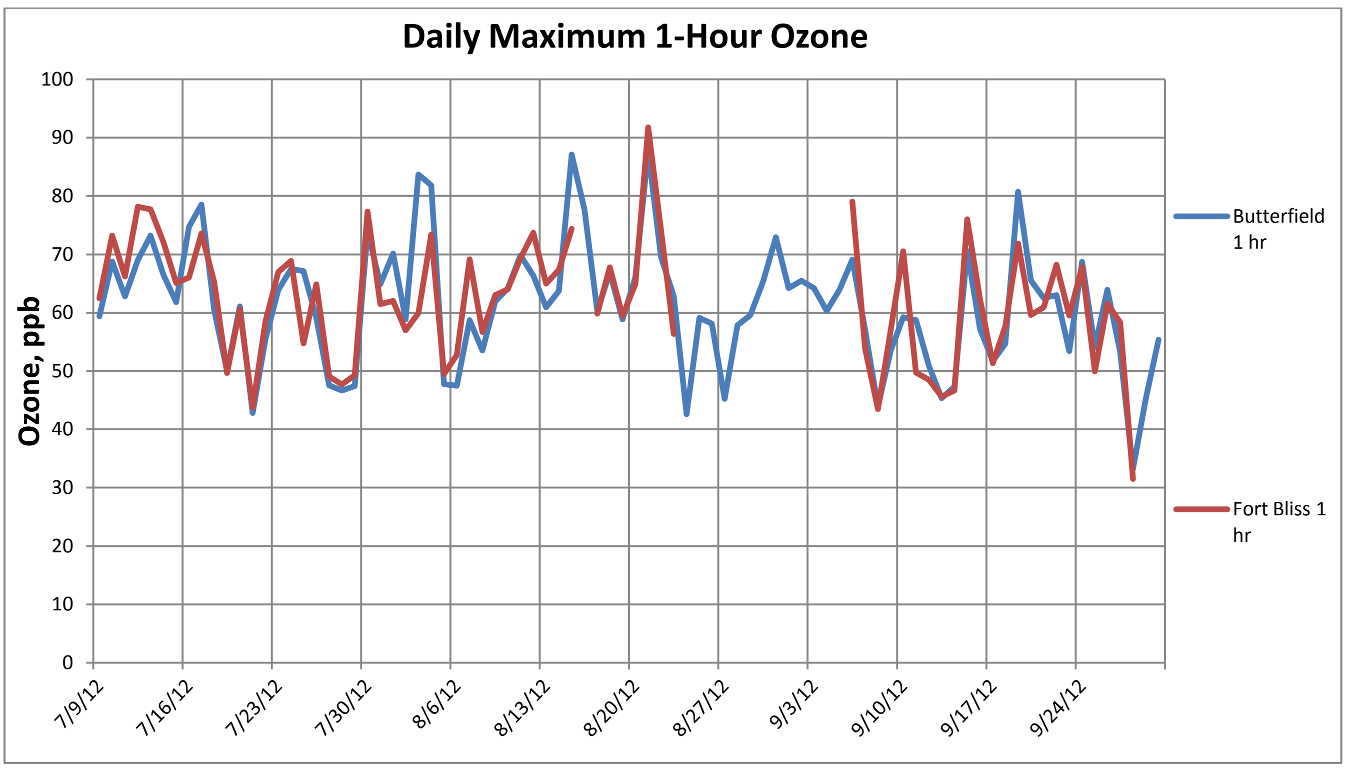


Figure 5.23 Daily Maximum 1-Hour Ozone Recorded from Fort Bliss and Butterfield (July-September)

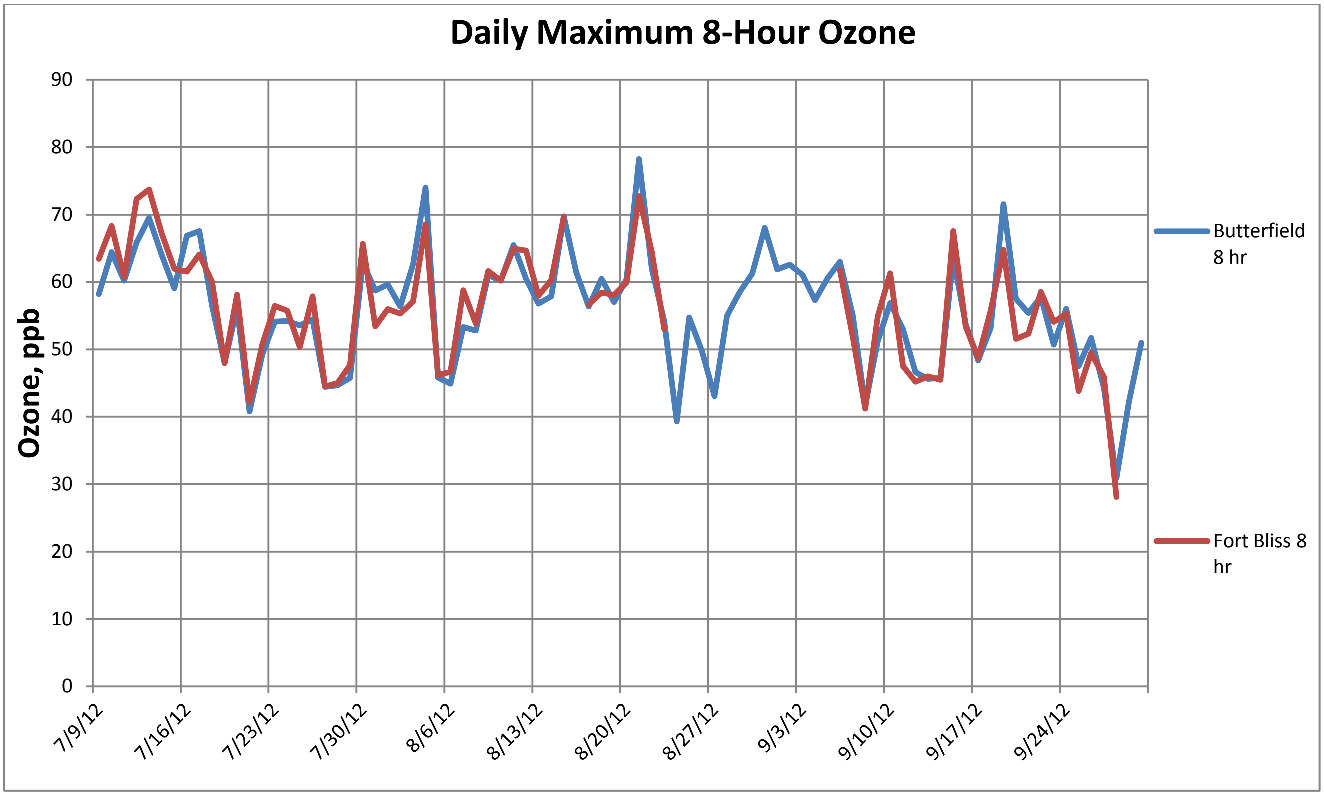


Figure 5.24 Daily Maximum 8-Hour Ozone Recorded from Fort Bliss and Butterfield (July-September)

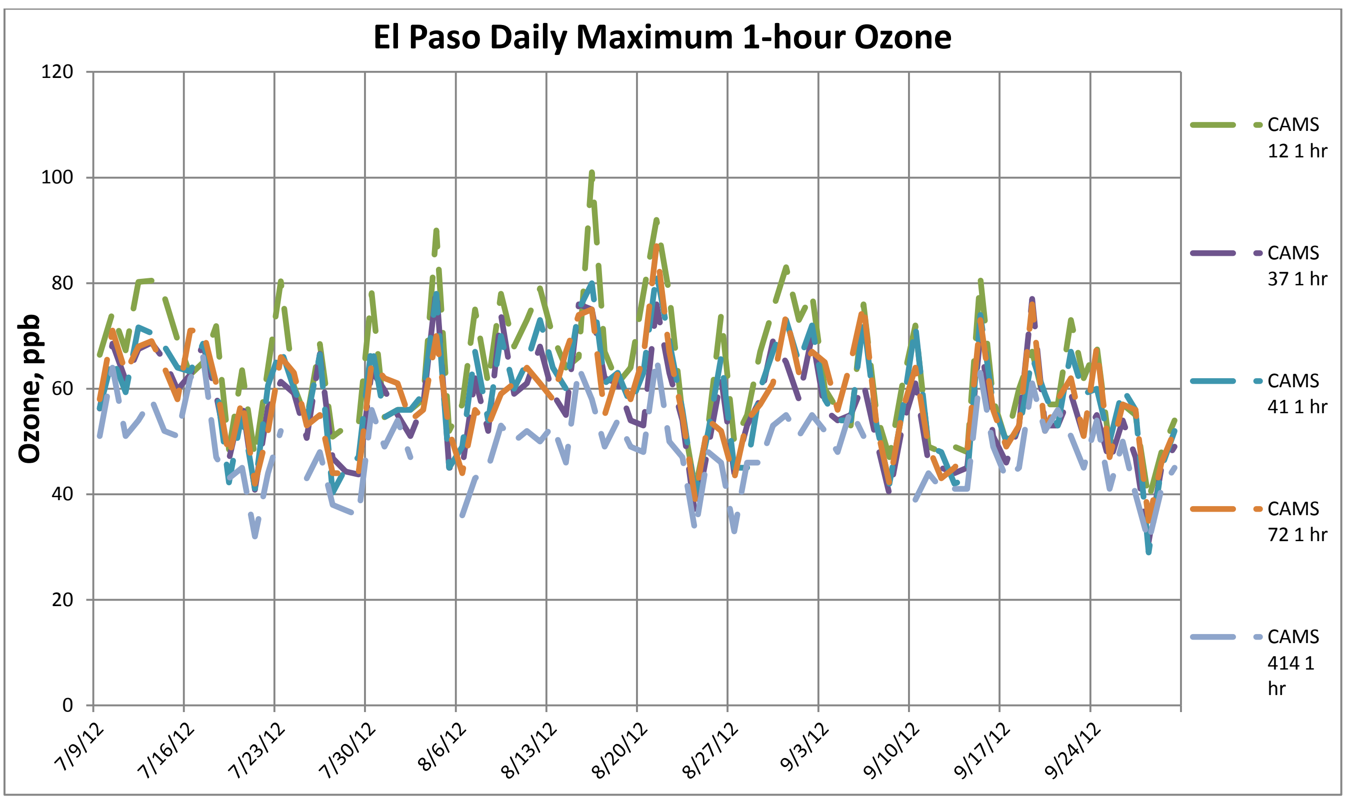


Figure 5.25 Daily Maximum 1-Hour Ozone Recorded from CAM Stations in El Paso (July-September)

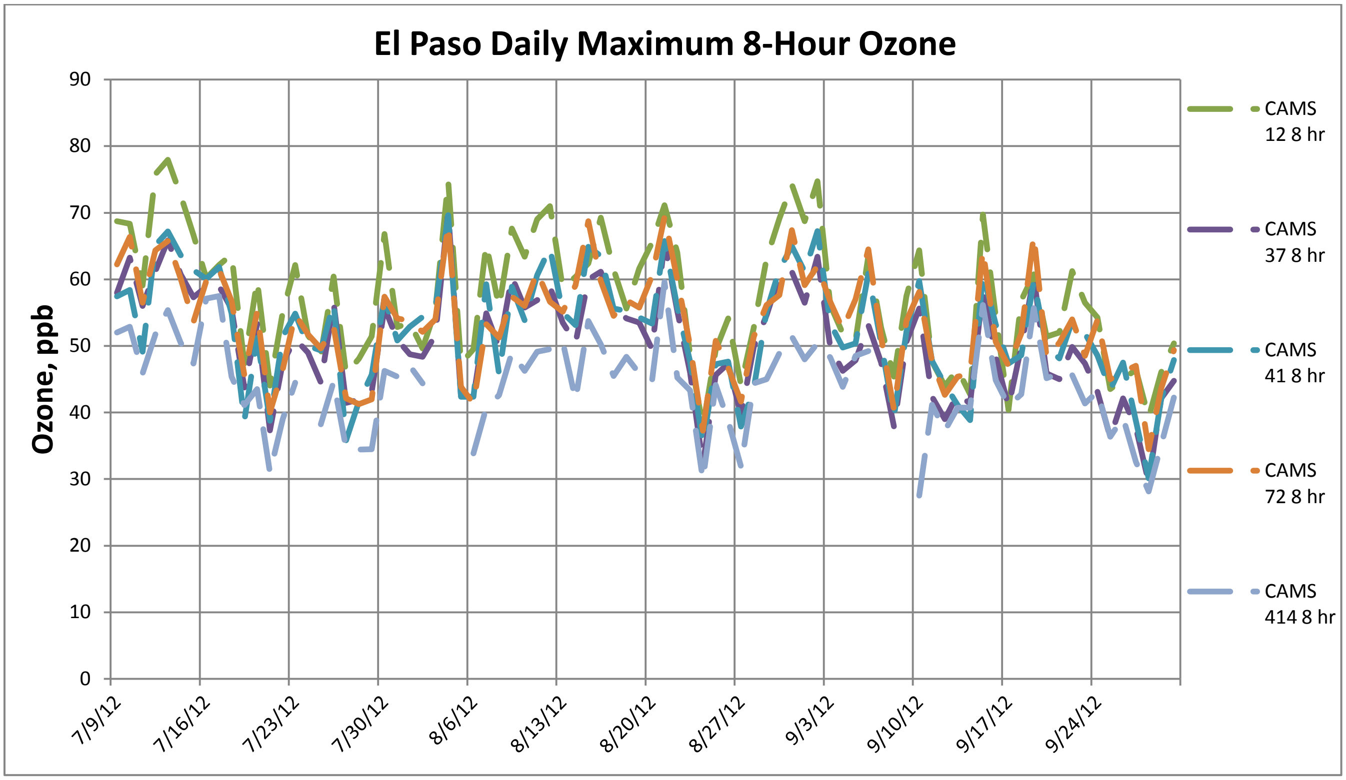


Figure 5.26 Daily Maximum 8-Hour Ozone Recorded from CAM Stations in El Paso (July-September)

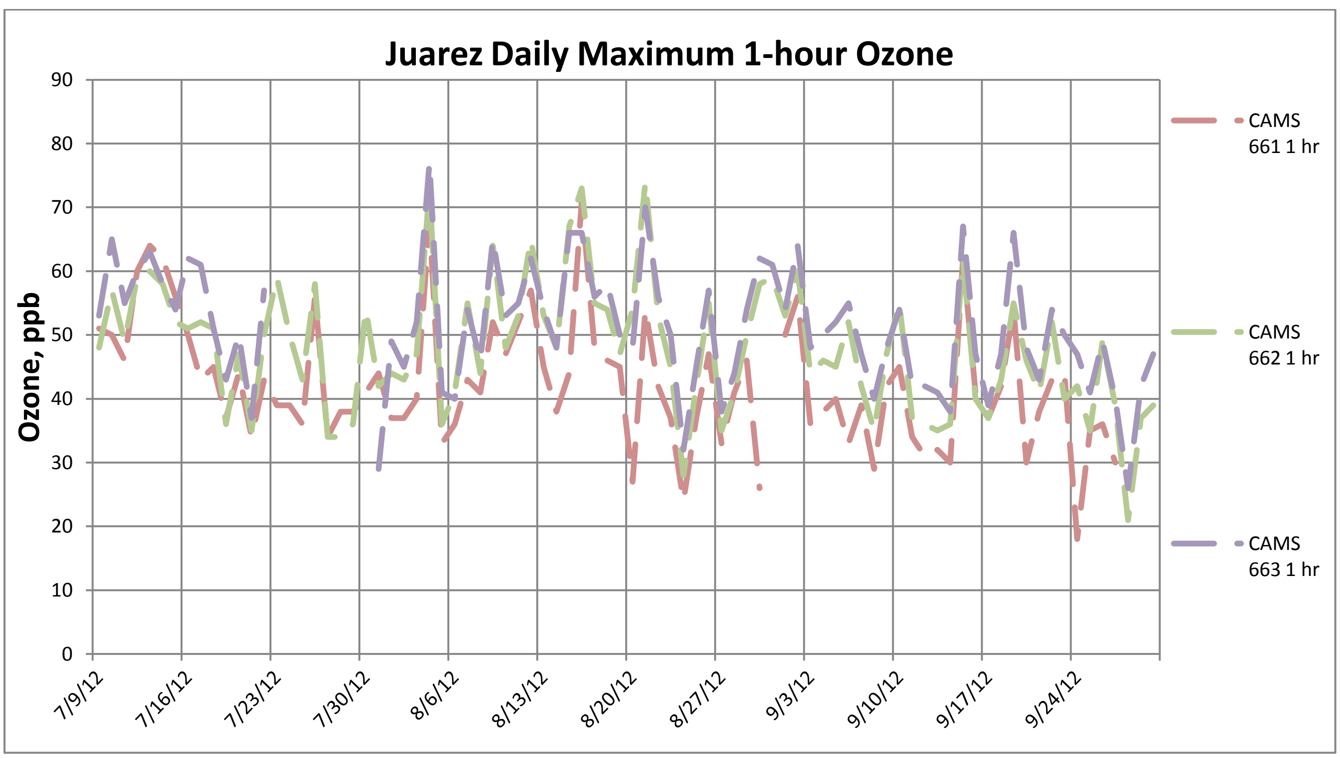


Figure 5.27 Daily Maximum 1-Hour Ozone recorded from CAM Stations in Juarez (July-September)

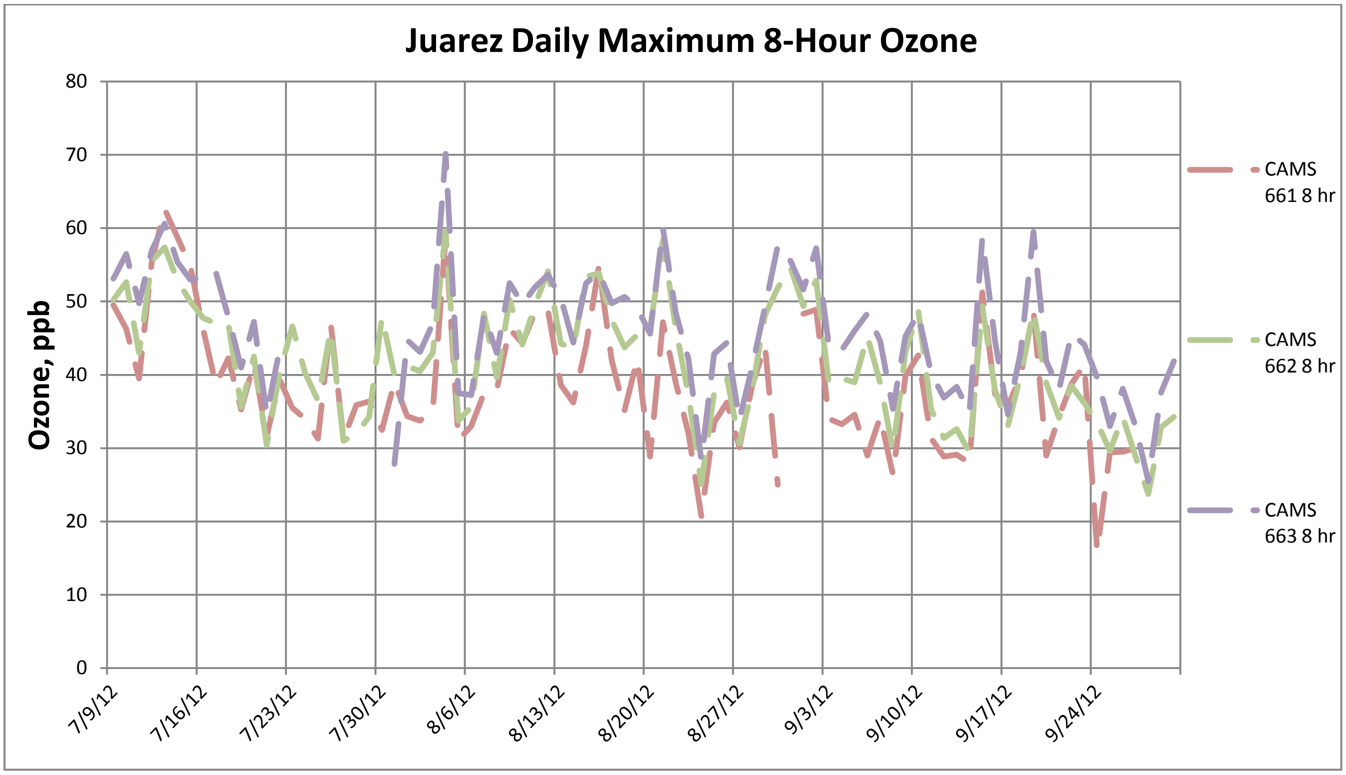


Figure 5.28 Daily Maximum 8-Hour Ozone recorded from CAM Stations in Juarez (July-September)

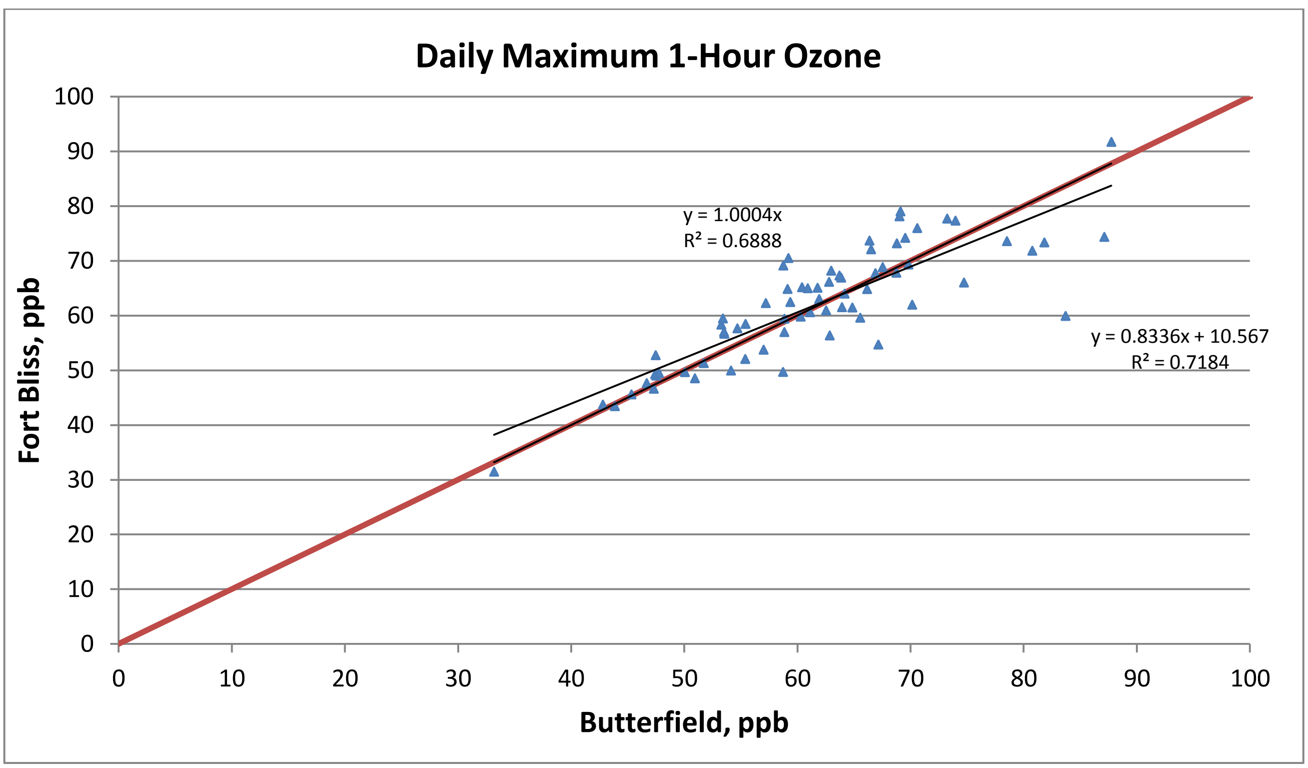


Figure 5.29 Fort Bliss and Butterfield Daily Maximum 1-hour Ozone Linear Regression Model

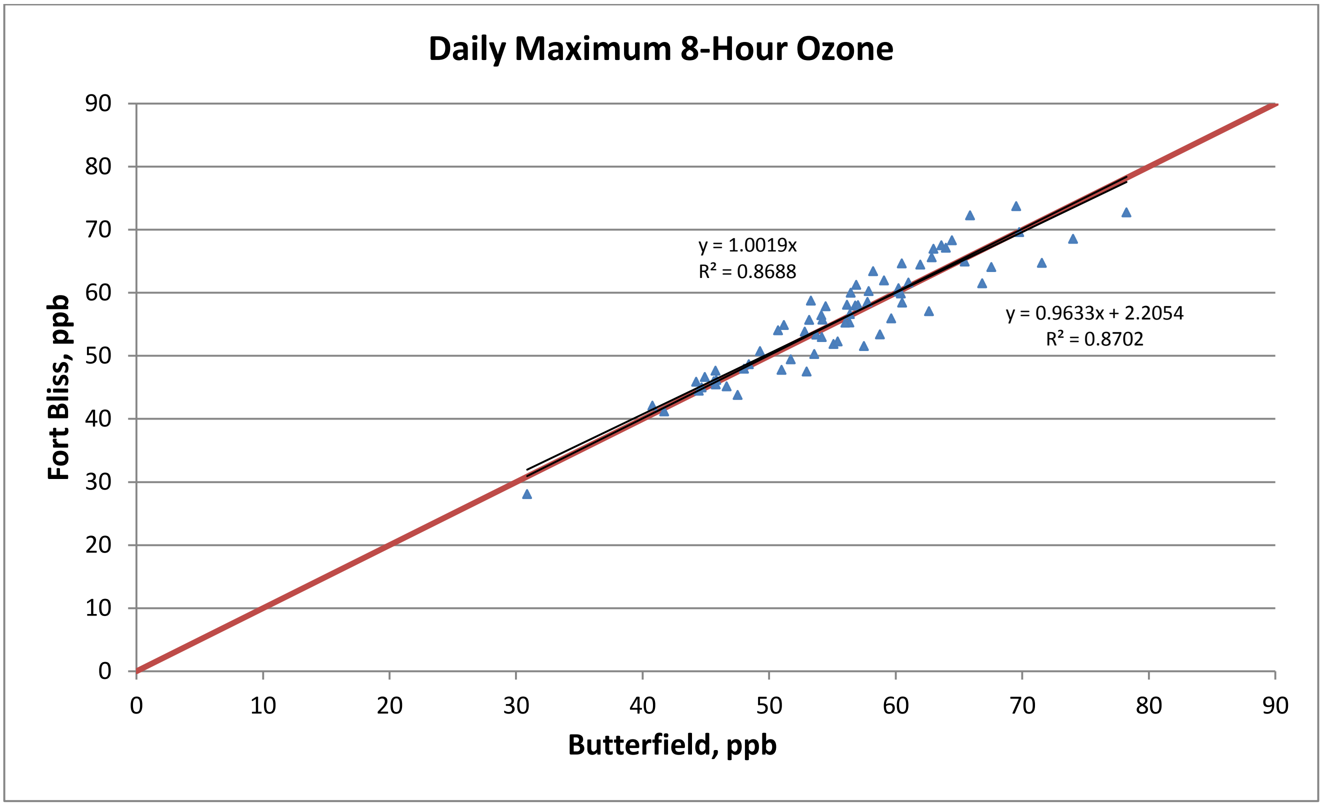


Figure 5.30 Fort Bliss and Butterfield Daily Maximum 8-hour Ozone Linear Regression Model

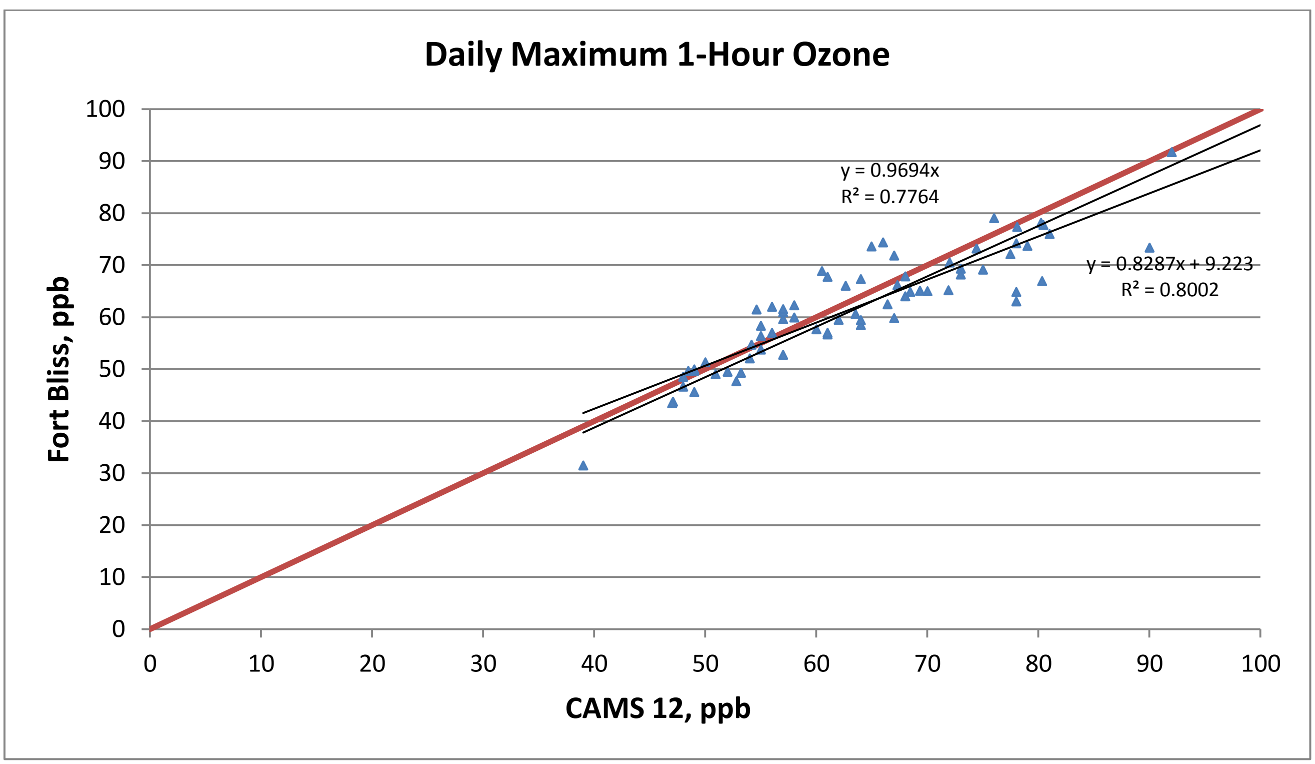


Figure 5.31 Fort Bliss and CAMS 12 Daily Maximum 1-hour Ozone Linear Regression Model

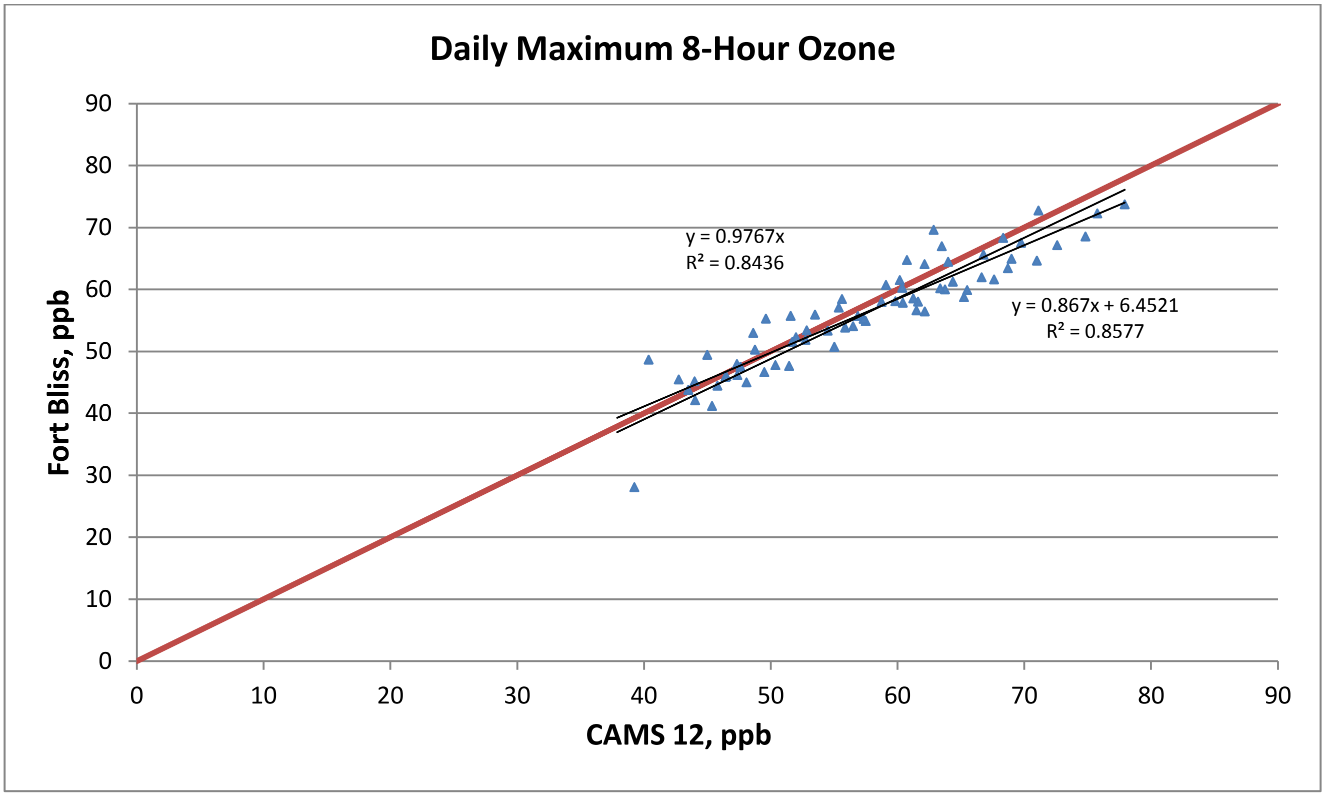


Figure 5.32 Fort Bliss and CAMS 12 Daily Maximum 8-hour Ozone Linear Regression Model

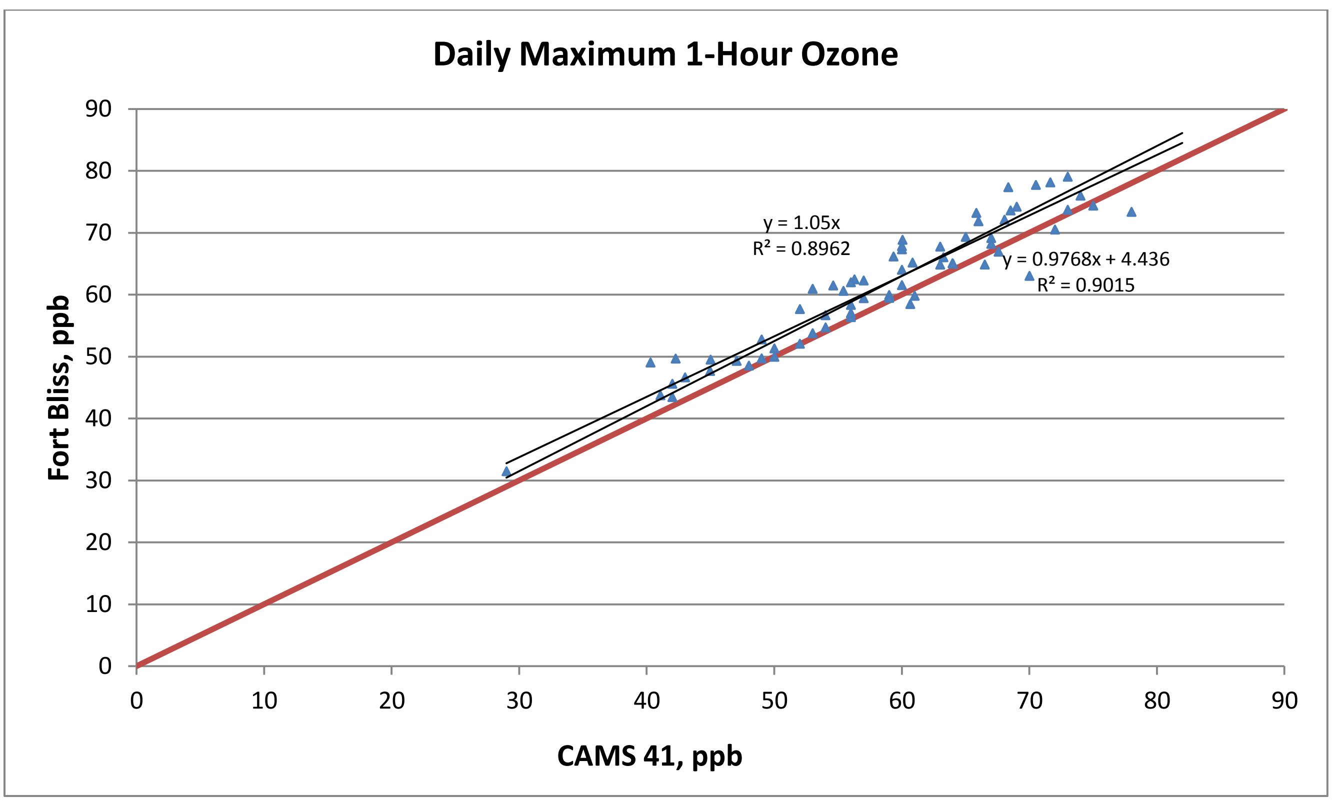


Figure 5.33 Fort Bliss and CAMS 41 Daily Maximum 1-hour Ozone Linear Regression Model

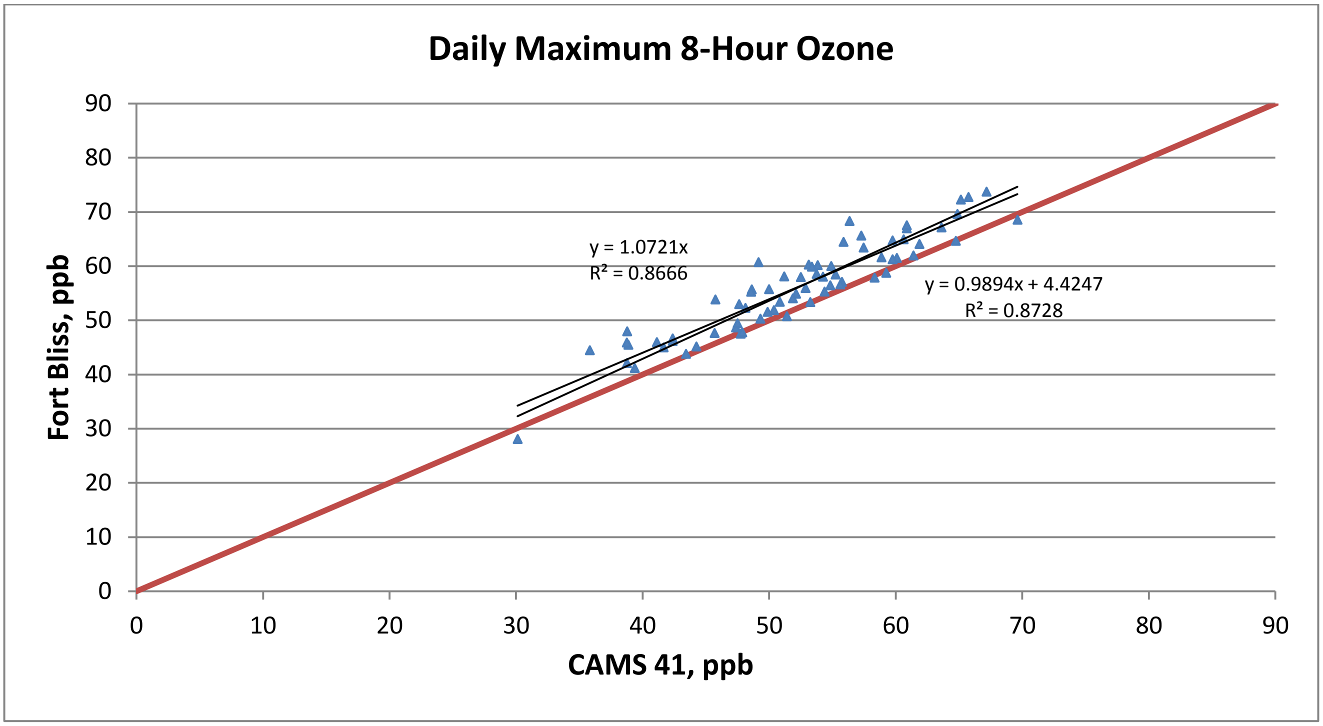


Figure 5.34 Fort Bliss and CAMS 41 Daily Maximum 8-hour Ozone Linear Regression Model

A final time series plot of recorded ozone at Fort Bliss is displayed in Figure 5.35 and 5.36. Only daily maximum 1 and 8-hour values were used for these figures. Also, a final linear regression model was created and compared with CAMS 12 for the duration of this entire study in order to officially state which location recorded higher levels of ozone concentration. Figure 5.37 includes all data collected from May 18, 2012 – November 1, 2012 at Fort Bliss and CAMS 12. After setting the y-intercept to zero Figure 5.37 contains an equation y = 0.9945x with R^2 = 0.69 for daily maximum 1-hour average and Figure 5.38 equation is expressed y = 1.0046x with R^2 = 0.77 for daily maximum 8-hour average. Appendix D contains linear regression of Fort Bliss and Butterfield every 1 and 8-hour average obtained this entire study. These figures conclude that both monitors throughout the ozone season collected similar but not identical values to all CAM stations. They reached the highest peaks of ozone in comparison to both El Paso and Juarez. Because CAMS 12 is known to be one of the biggest hot spot locations in the Paso del Norte region, it is advisable that TCEQ consider Fort Bliss as a potential location for a new CAM station.

The mean, standard deviation, maximum and minimum value were calculated for each month for all El Paso/Cd. Juarez CAMS and supplemental sites. Each of these parameters were calculated for every 1 and 8-hour average processed. The standard deviation is labeled STDEV for these tables. Tables 5.3 contain all these calculated values for the months of May through July and 5.4 contain August through September. Table 5.3 Fort Bliss Monitor #2 stopped monitoring ozone concentration on July 9th because the monitor was then deployed at Butterfield. This is the reason there is no values displayed in May and June for Butterfield.

Table 5.3 Mean, Standard Deviation, Maximum and Minimum Values for all sites (May-July)

Station ID	Hourly Average	May				June				July			
		Mean	STDEV	Max	Min	Mean	STDEV	Max	Min	Mean	STDEV	Max	Min
Fort Bliss Monitor #1	1- hour	49.9	15.5	78.3	3.1	45.3	16.3	86.0	3.6	44.6	14.4	78.1	1.9
	8-hour	49.9	12.2	70.3	8.7	45.3	13.1	80.4	14.3	44.6	12.0	73.7	8.0
Fort Bliss Monitor #2	1- hour	48.9	14.9	76.7	3.3	44.2	15.9	85.3	3.3	43.2	9.7	70.4	12.9
	8-hour	48.8	12.3	69.8	7.2	44.2	13.3	78.6	12.5	43.3	8.0	59.9	26.9
Butterfield Monitor #2	1- hour									43.9	14.8	78.5	6.3
	8-hour									43.8	12.6	69.5	13.2
CAMS 12	1- hour	43.8	14.0	76.0	5.0	40.5	16.4	95.0	2.0	44.6	15.1	80.4	2.4
	8-hour	43.7	10.5	64.4	9.0	40.5	12.8	72.9	13.0	44.6	12.4	77.9	11.9
CAMS 37	1- hour	37.4	15.3	63.0	0.6	32.9	17.3	88.0	0.0	37.9	14.8	68.7	0.3
	8-hour	37.4	11.8	58.9	1.0	33.0	13.6	73.3	1.4	37.8	12.0	65.9	6.3
CAMS 41	1- hour	42.7	15.7	71.0	0.0	37.1	18.2	95.0	0.0	38.9	14.4	71.6	0.0
	8-hour	42.6	12.0	63.6	2.4	37.1	14.0	75.1	7.9	38.8	11.4	67.2	6.1
CAMS 72	1- hour	46.8	12.1	69.0	2.0	40.7	13.9	74.0	2.0	42.5	13.1	71.0	1.0
	8-hour	46.6	9.5	63.9	13.1	40.8	11.3	68.1	4.1	42.4	11.1	66.4	4.1
CAMS 441	1- hour	37.4	13.0	61.0	0.0	34.4	13.3	68.0	0.0	35.9	11.4	66.0	4.0
	8-hour	37.4	10.2	56.0	7.0	34.5	10.7	59.8	1.9	35.8	9.8	57.5	9.6
CAMS 661	1- hour	33.8	11.6	59.0	0.0	27.7	12.6	65.0	0.0	30.5	12.9	64.0	0.0
	8-hour	33.6	8.7	50.1	9.1	28.2	9.9	53.8	5.1	30.4	10.8	62.7	3.4
CAMS 662	1- hour	33.3	13.2	55.0	1.0	29.3	15.4	83.0	0.0	31.5	12.6	61.0	0.0
	8-hour	33.1	9.9	50.9	1.9	29.3	11.4	66.1	3.8	31.4	9.9	57.4	2.1
CAMS 663	1- hour	34.4	14.2	60.0	0.0	31.2	15.7	77.0	0.0	36.9	12.8	65.0	0.0
	8-hour	34.4	10.5	52.1	0.6	31.2	12.2	64.1	0.5	36.9	10.5	60.6	8.1

Table 5.4 Mean, Standard Deviation, Maximum and Minimum Values for all sites (August-September)

Station ID	Hourly Average	August				September				Total			
		Mean	STDEV	Max	Min	Mean	STDEV	Max	Min	Mean	STDEV	Max	Min
Fort Bliss Monitor #1	1- hour	46.1	14.2	91.7	9.1	36.6	16.6	79.1	0.4	44.1	15.9	91.7	0.4
	8-hour	46.1	11.1	72.8	19.5	36.7	13.1	67.5	5.7	44.1	13.0	80.4	5.7
Fort Bliss Monitor #2	1- hour									45.3	15.2	85.3	3.3
	8-hour									45.2	12.8	78.6	7.2
Butterfield Monitor #2	1- hour	44.3	14.3	87.8	11.6	38.4	14.9	80.8	2.1	42.1	14.9	87.8	2.1
	8-hour	44.3	11.3	78.2	18.9	38.4	11.7	71.5	12.1	42.1	12.1	78.2	11.3
CAMS 12	1- hour	43.8	16.3	101	2	36.7	17.4	81	1	42.2	16.1	101	1
	8-hour	43.8	12.4	74.8	18.4	36.8	13.6	74.8	5.3	42.1	12.8	77.9	5.3
CAMS 37	1- hour	37.2	16.4	79	0	29.3	17	77	0	35.2	16.44	88	0
	8-hour	36.9	12.9	70.1	5.6	29.5	12.9	63.4	0.3	35.2	13.1	73.3	0.3
CAMS 41	1- hour	37.9	16.2	82	0	31.8	18	74	0	37.7	16.7	95	0
	8-hour	37.9	12.2	69.6	8	31.8	13.9	67.3	1.4	37.7	13.1	75.1	1.4
CAMS 72	1- hour	43.1	13.1	87	8	37.5	15	76	1	42.5	13.7	87	1
	8-hour	43.1	10.4	69.4	15.6	37.5	12	66.6	5	42.5	11.2	69.4	4.1
CAMS 441	1- hour	36.1	10.6	66	5	30.7	12.6	63	0	34.9	12.3	68	0
	8-hour	36.1	8.3	59.6	18.5	30.7	9.5	56.1	9.9	34.9	9.9	59.8	1.9
CAMS 661	1- hour	27.3	12.3	71	0	22.2	13.6	62	0	28.9	13.3	71	0
	8-hour	27.4	9.5	59	8.2	22	10.7	51.3	0.3	28.7	11.0	62.7	0.3
CAMS 662	1- hour	31.1	14.2	74	0	22.7	15	62	0	29.8	14.6	83	0
	8-hour	30.9	10.4	59.6	4.8	22.8	11.4	52.9	0.1	29.8	11.3	66.1	0.1
CAMS 663	1- hour	34.5	14.1	77	2	27.5	15.3	67	0	33.2	14.8	77	0
	8-hour	34.4	10.9	70.1	8.4	27.5	11.5	59.5	1.4	33.2	11.6	70.1	0.5

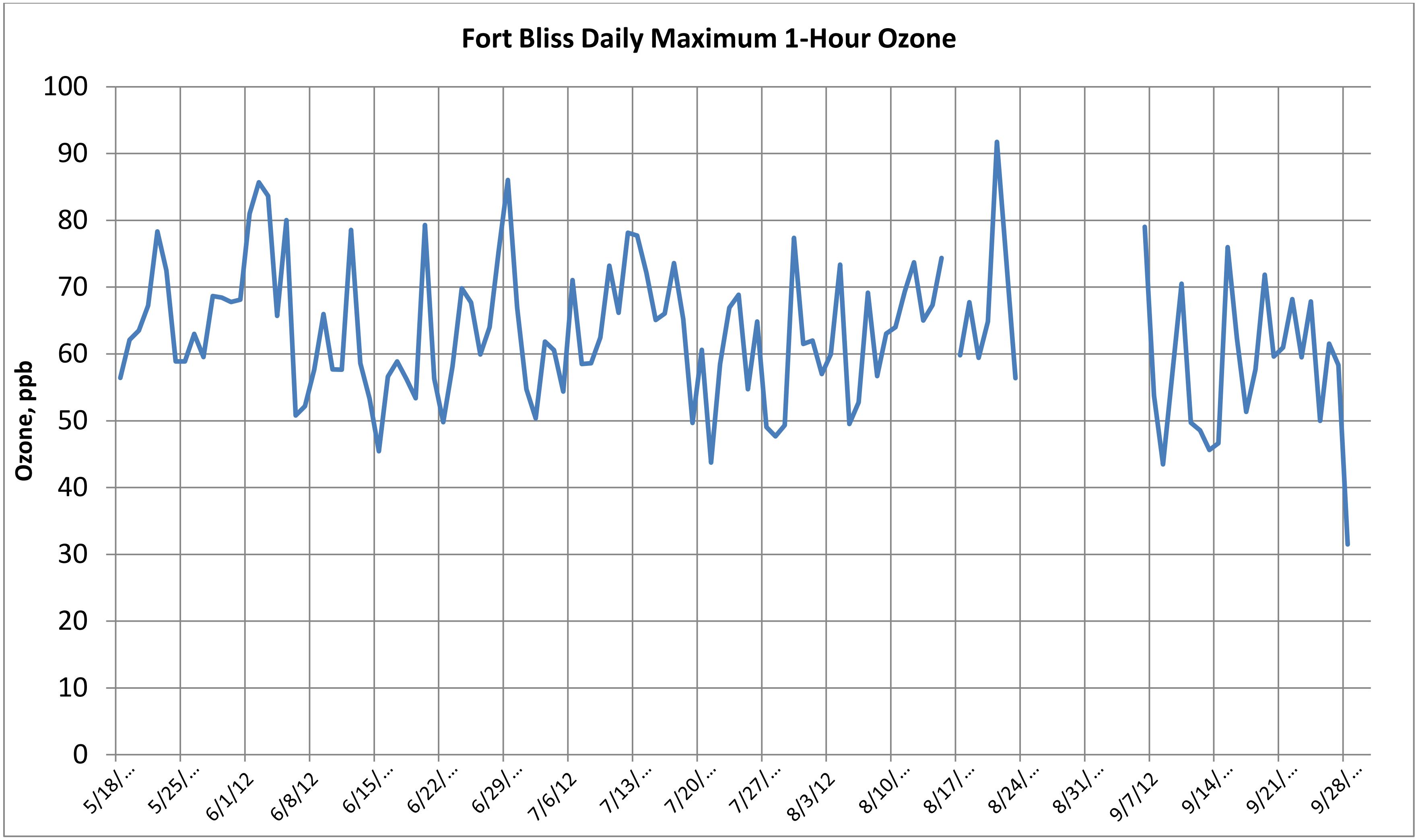


Figure 5.35 Daily Maximum 1-Hour Ozone Recorded at Fort Bliss (May-November)

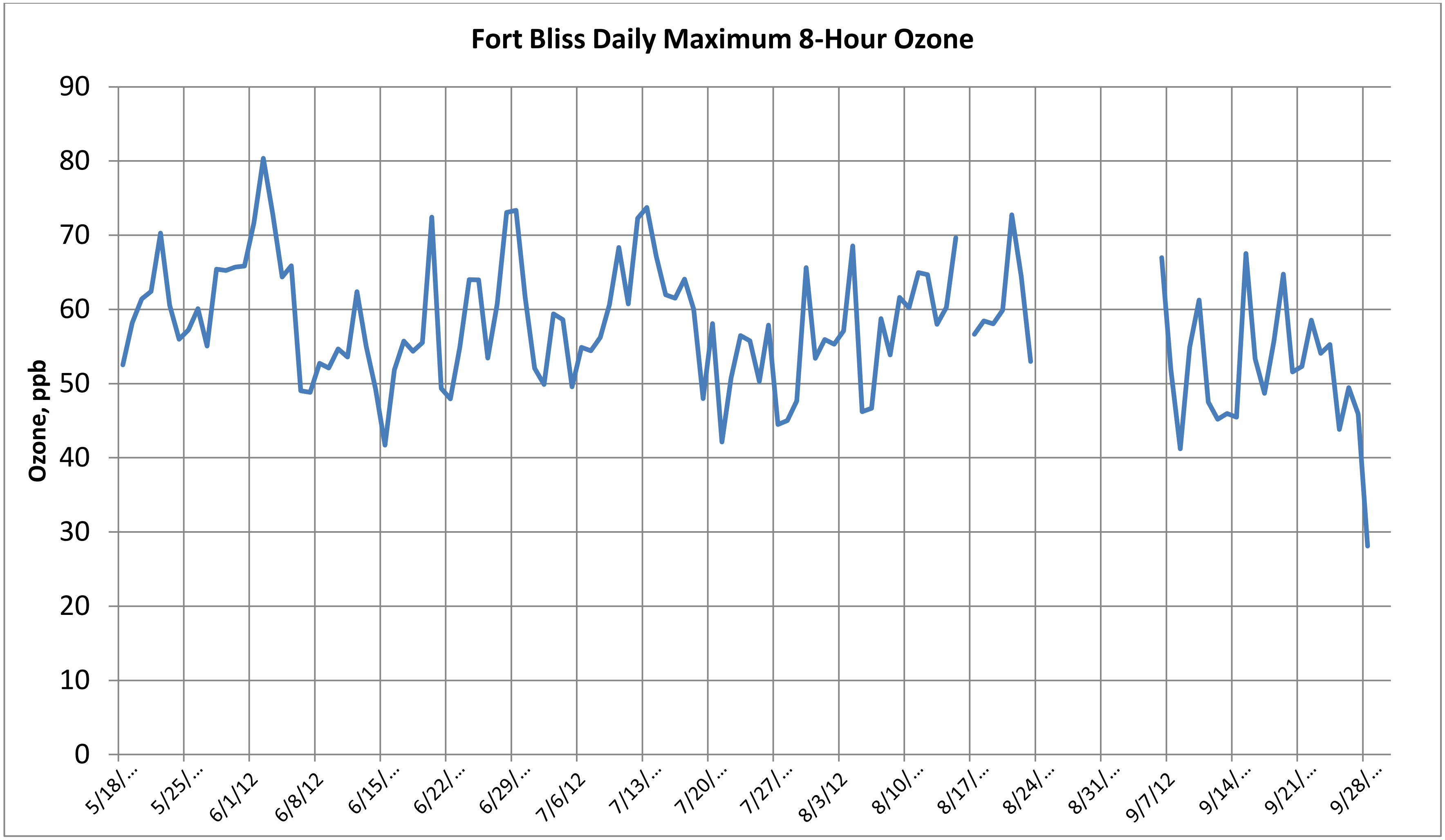


Figure 5.36 Daily Maximum 8-Hour Ozone Recorded at Fort Bliss (May-September)

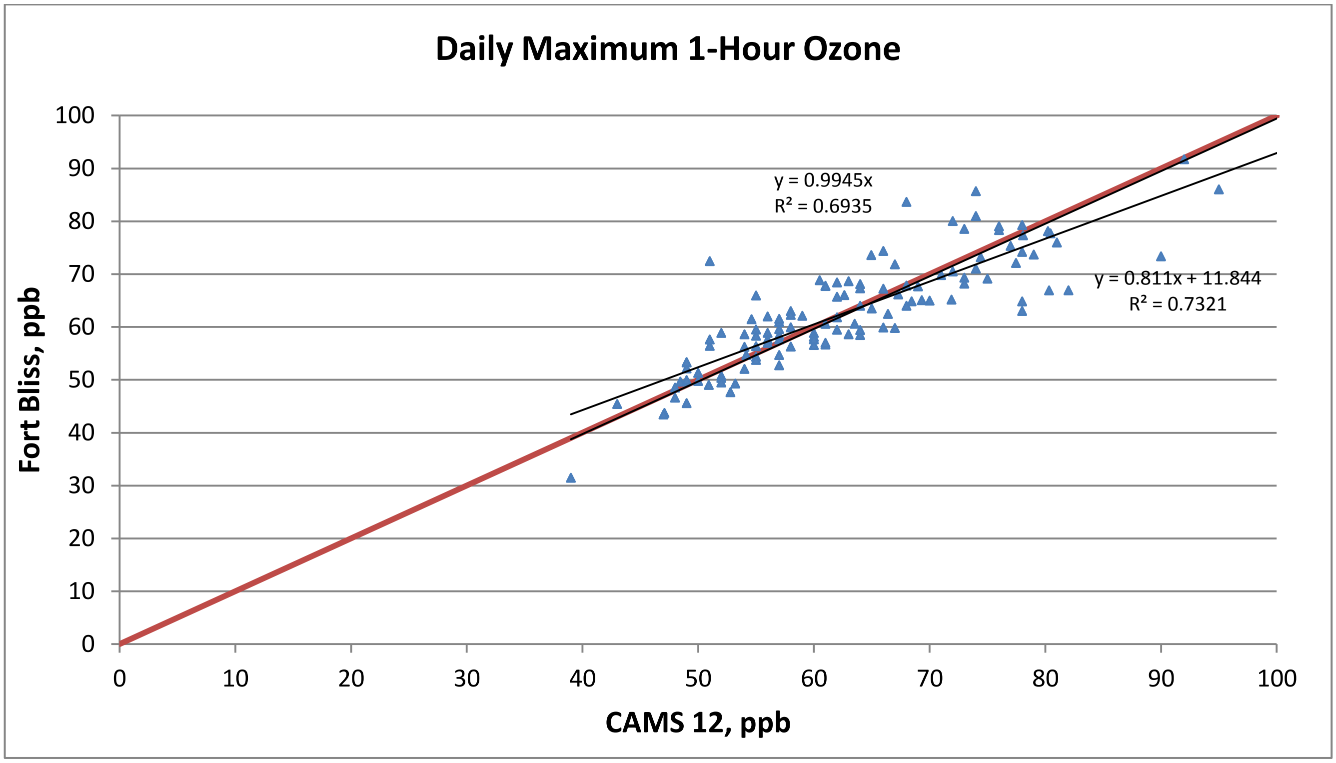


Figure 5.37 Fort Bliss and CAMS 12 Final Daily Maximum 1-hour Ozone Linear Regression Model

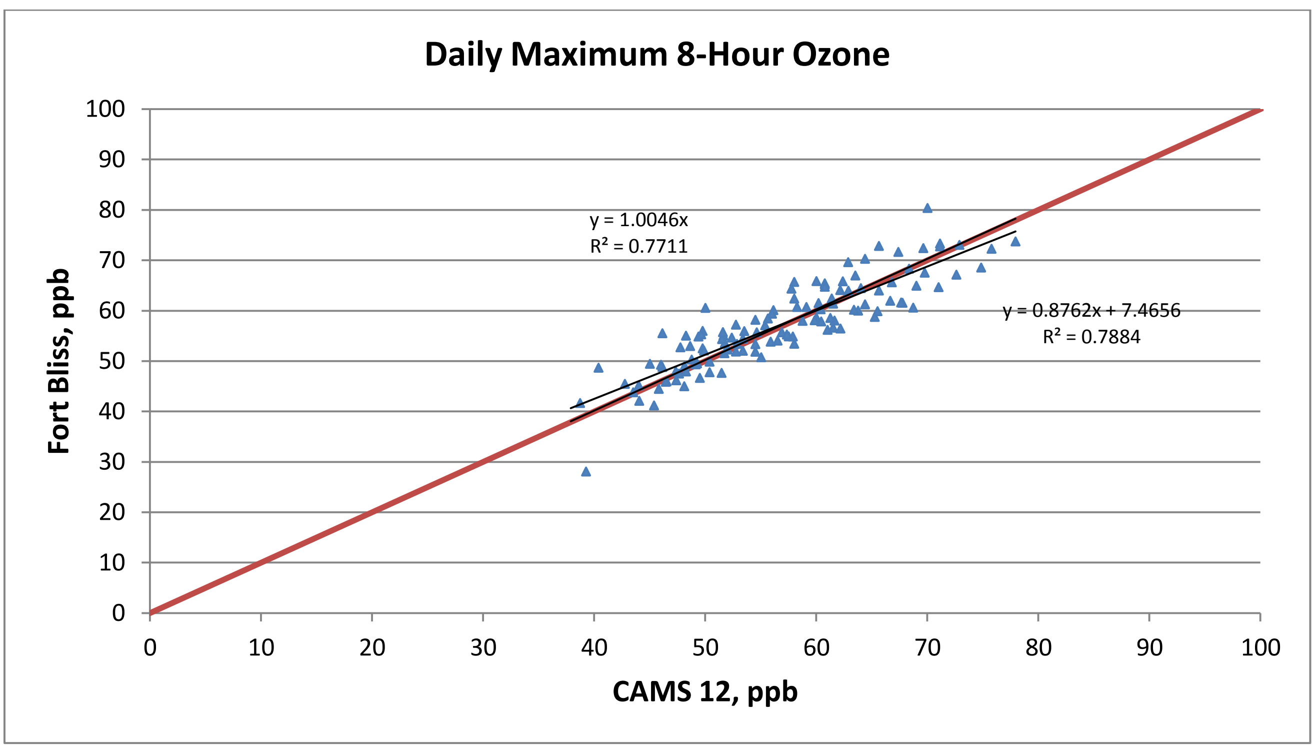


Figure 5.38 Fort Bliss and CAMS 12 Final Daily Maximum 8-hour Ozone Linear Regression Model

In addition to the regression models a t-test was conducted in order to evaluate the comparison of ozone collected at Fort Bliss and CAMS 12. These were the only two sites chosen since they collected the highest values the duration of this study. A t-test is used for comparing the means of the two samples, even if they have different numbers. It compares the actual difference between two means in relation to the variation in the data (expressed as the standard deviation of the difference between the means). After setting the hypothesized mean difference to 0 with an alpha of 0.05 or 5% the results found a P(T<=t) value to be 1.313E-08. This value shows an extremely low probability meaning the means are significantly different. Refer to Table 5.4 for results.

Table 5.4 t-Test: Two-Sample Assuming Unequal Variances

	Variable 1	Variable 2
Mean	44.06719274	41.6958716
Variance	257.9859479	267.4954873
Observations	2854	3217
Hypothesized Mean Difference	0	
df	6007	
t Stat	5.692252696	
P(T<=t) one-tail	6.56507E-09	
t Critical one-tail	1.645107332	
P(T<=t) two-tail	1.31301E-08	
t Critical two-tail	1.960358926	

5.4 Surface Wind Analysis

In order to understand the fate and transport of atmospheric pollutants, it is very important to consider wind direction and wind speed. Wind rose production is a common method used to express both these parameters. These wind roses were created using WRPLOT View provided by Lakes Environmental. The wind rose is a graphical presentation of the frequency of occurrence of wind direction and wind speed categories at a monitoring station. Though meteorological data varies from hour to hour, it remains unchanged when looking at long-term statistics. Two days of high ozone concentration were chosen to express wind direction and wind speed in the PdN region. One day was

chosen during the first period of this study when both monitors were deployed at Fort Bliss and the other day was chosen when the 2B monitors were separated. Figure 5.39 displays a map including all wind roses at El Paso and Juarez CAM stations that collected meteorological data on 6/29/12. The daily maximum 1 and 8-hour ozone concentrations for this day can be found in Figures 5.11 to 5.16. There was no exceedances recorded on this day but Fort Bliss, CAMS 12, 37 and 41 recorded ozone concentrations greater than 70 ppb. Figure 5.40 displays a map including all wind roses at El Paso and Juarez CAM stations that collected meteorological data on 8/21/12. The daily maximum 1 and 8-hour ozone concentrations for this day can be found in Figures 5.23 to 5.28. There was one 8-hour exceedance recorded at Butterfield with a value of 78.2 ppb. No CAM stations except 12 exceeded 70 ppb on this day. Figure 5.41 displays a map of the PdN region including the locations of both 2B monitors and wind rose for each of the CAM stations using meteorological data recorded the entire period of this study. Each tail represents the percent frequency of wind blowing from this angle at each CAM station. Each color represents the wind speed in meters/second (m/s).

CAMS 12, 37 and 41 for all wind roses display dominate south-easterly/north-westerly winds along the border of Juarez, Chihuahua and El Paso, Texas. The Juarez CAM station wind roses also follow along border. CAMS 324 at Fort Bliss, located away from the valley, is well distributed having the greatest westerly wind speed blowing downwind from the Franklin Mountains. CAMS 72 located even further north of the border is influenced by north-south winds along the Franklin Mountains and downslope wind gusts from the eastern slopes of the mountains. Figure 5.42 contains a detailed wind rose of each CAM station for this entire study.

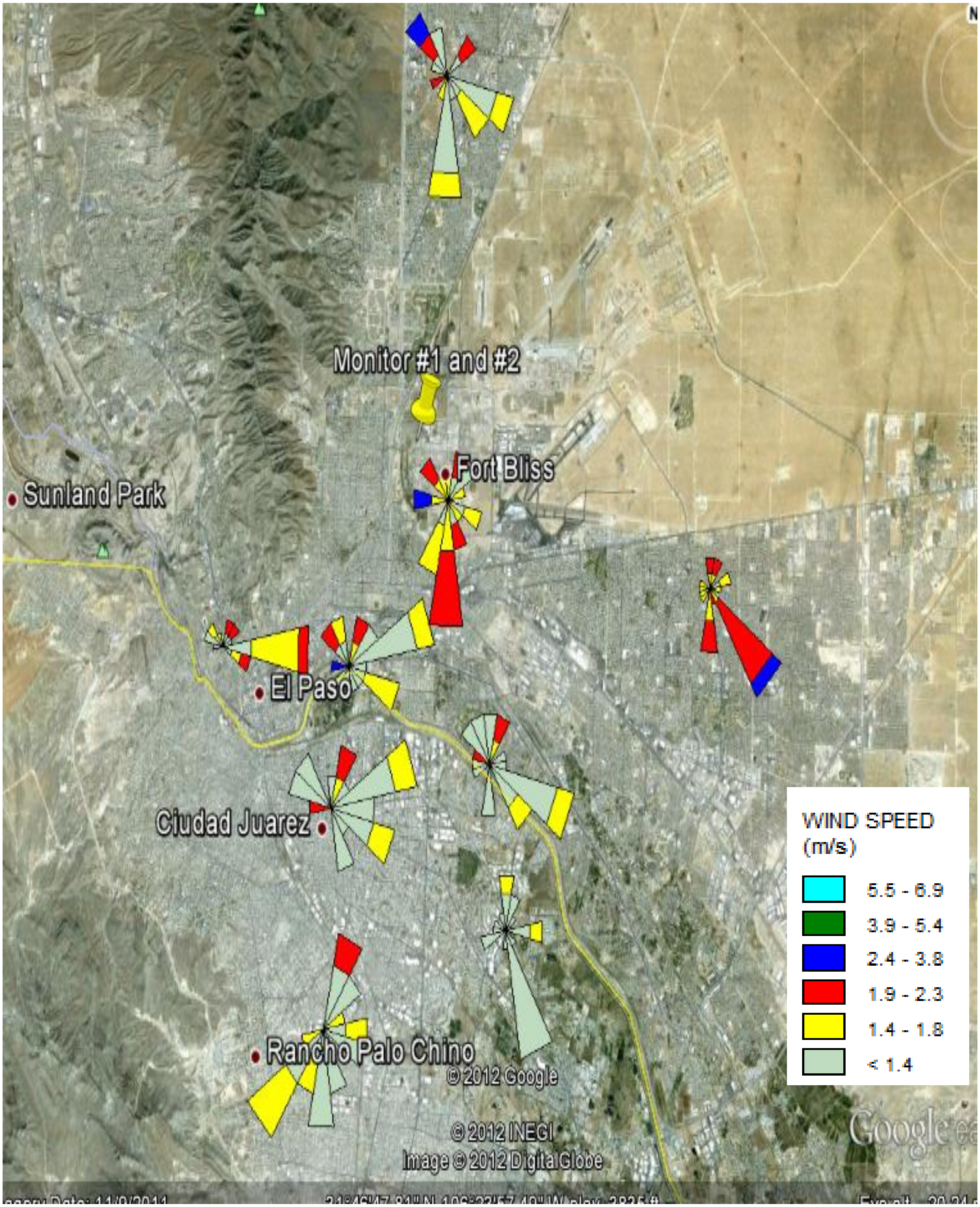


Figure 5.39 Map of all Wind Roses in El Paso and Juarez CAMS on 6/29/12

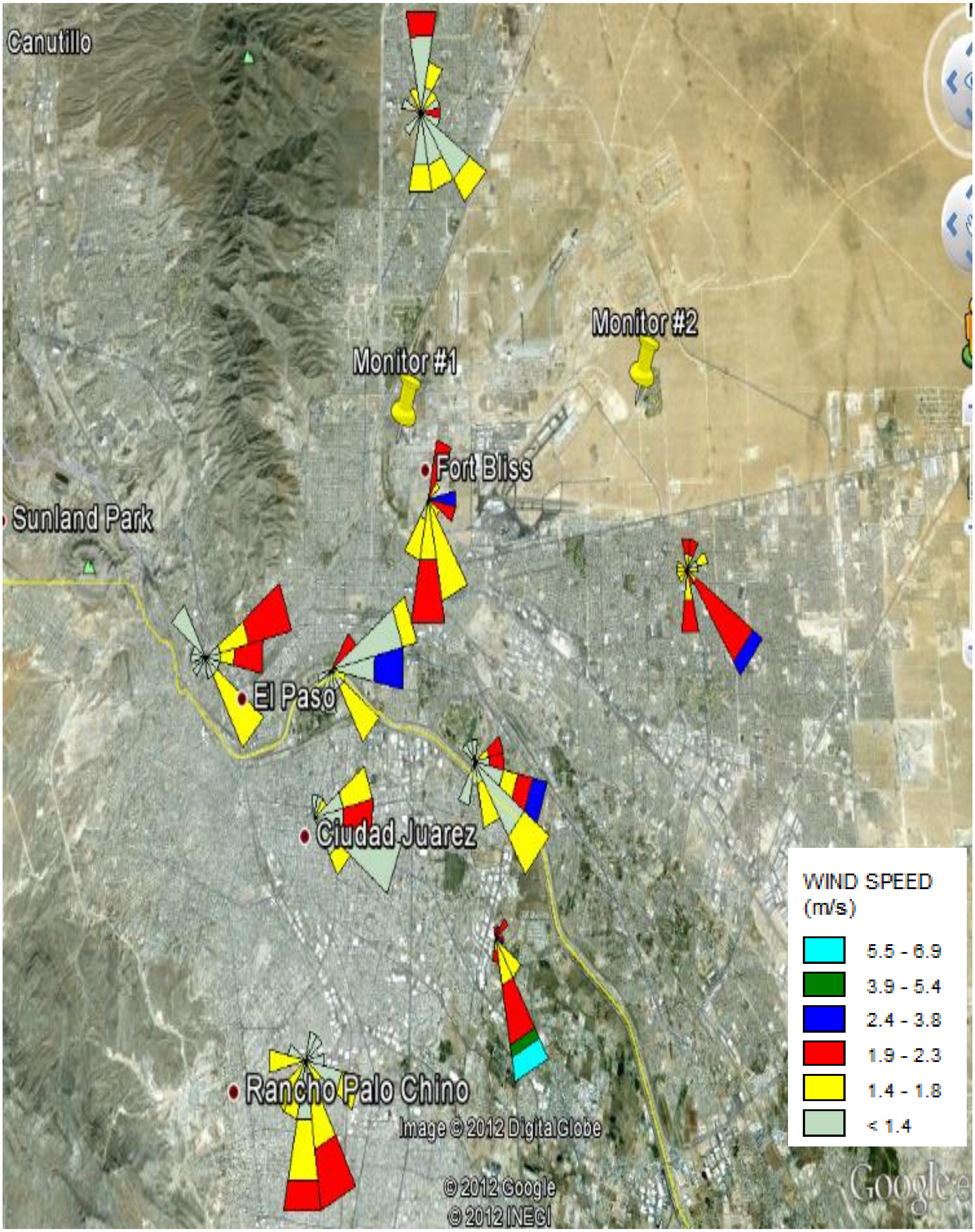


Figure 5.40 Map of all Wind Roses in El Paso and Juarez CAMS on 8/21/12

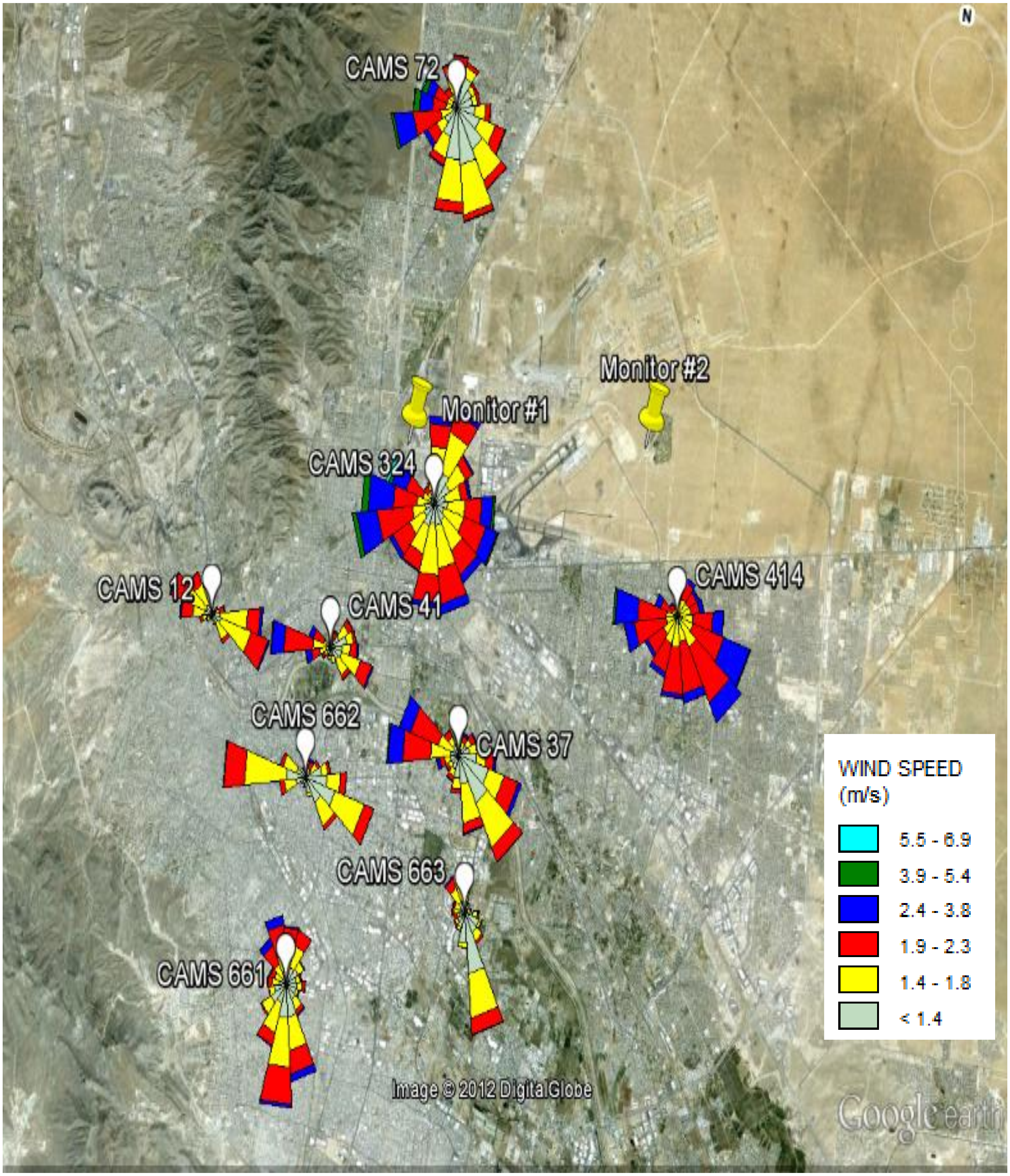
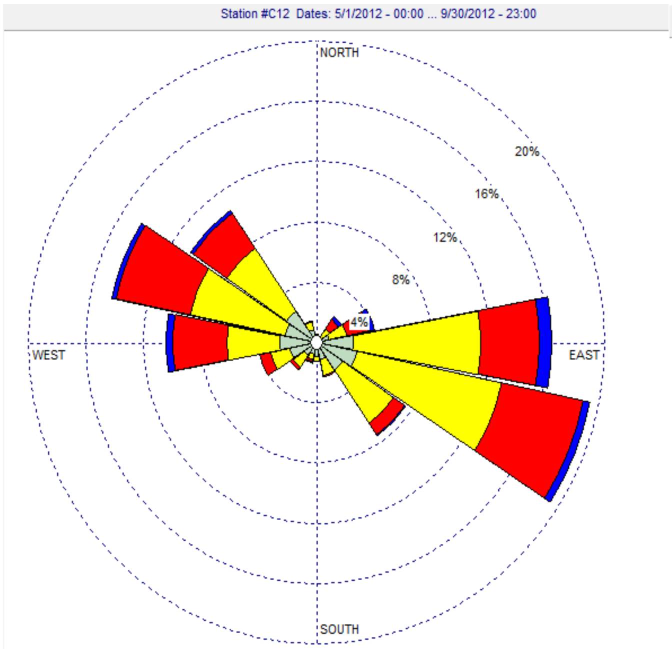
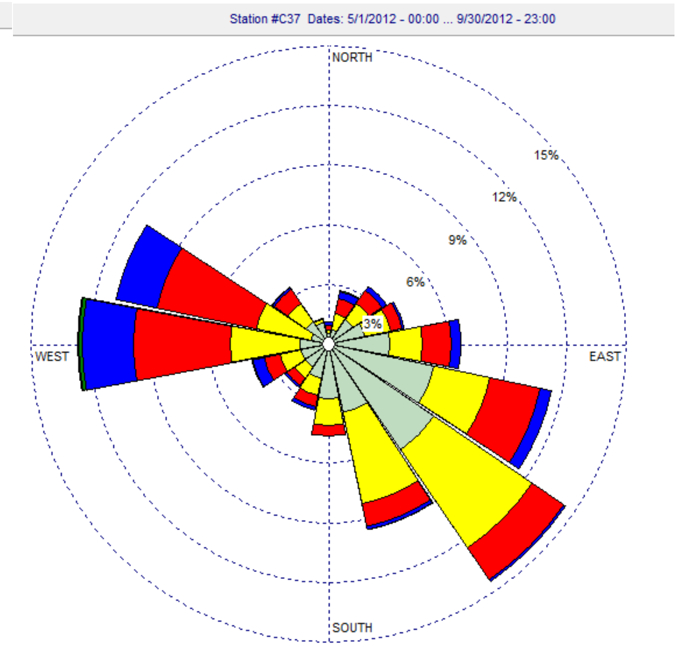
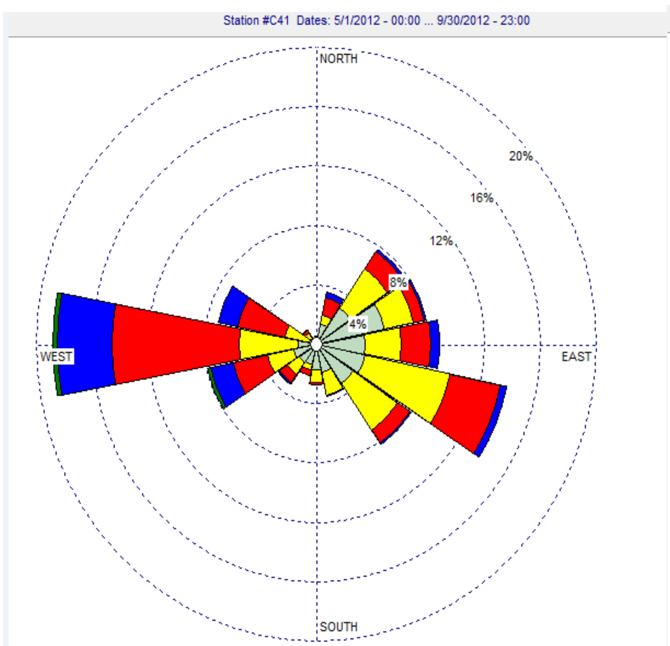
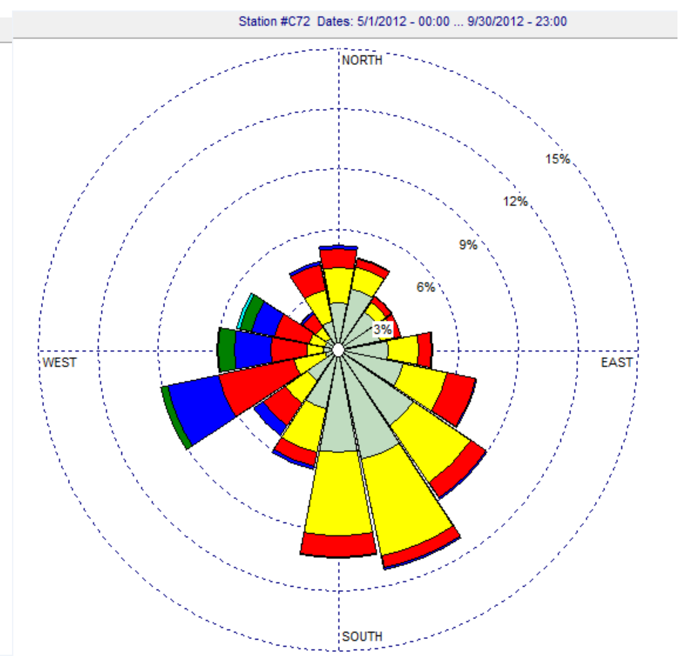


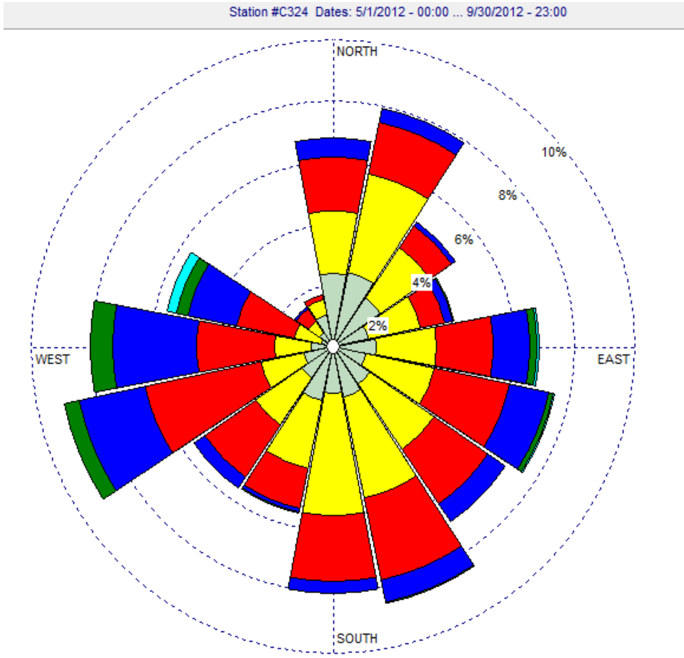
Figure 5.41 Map of all the CAMS and Wind Roses in El Paso and Juarez from May-September

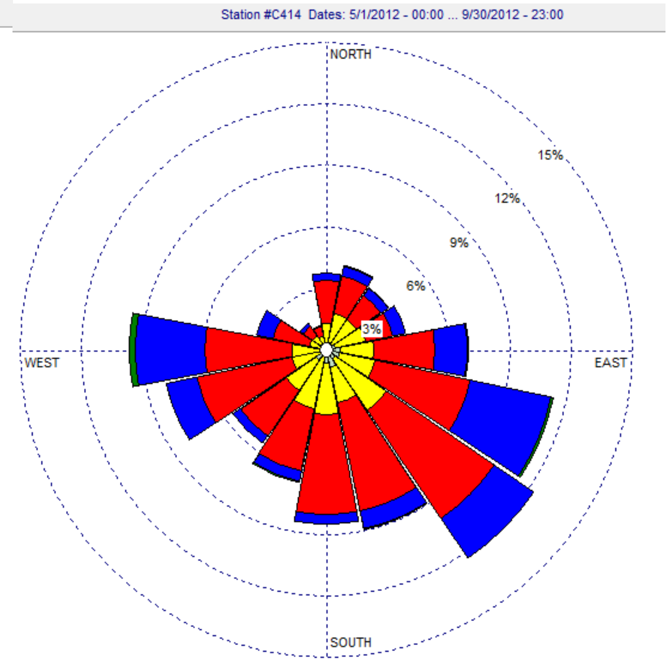

Station #C12 Dates: 5/1/2012 - 00:00 ... 9/30/2012 - 23:00
NORTH
20%
16%
12%
8%
4%
WEST
EAST
SOUTH

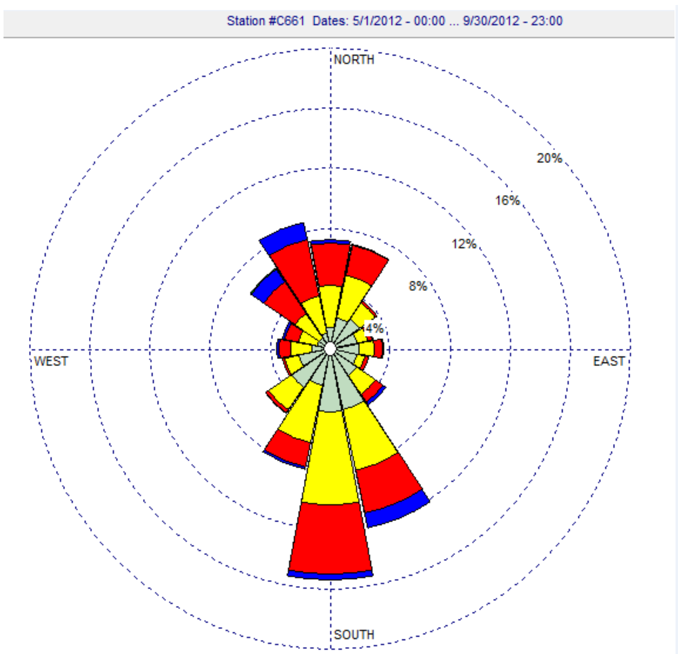

Station #C37 Dates: 5/1/2012 - 00:00 ... 9/30/2012 - 23:00
NORTH
15%
12%
9%
6%
3%
WEST
EAST
SOUTH

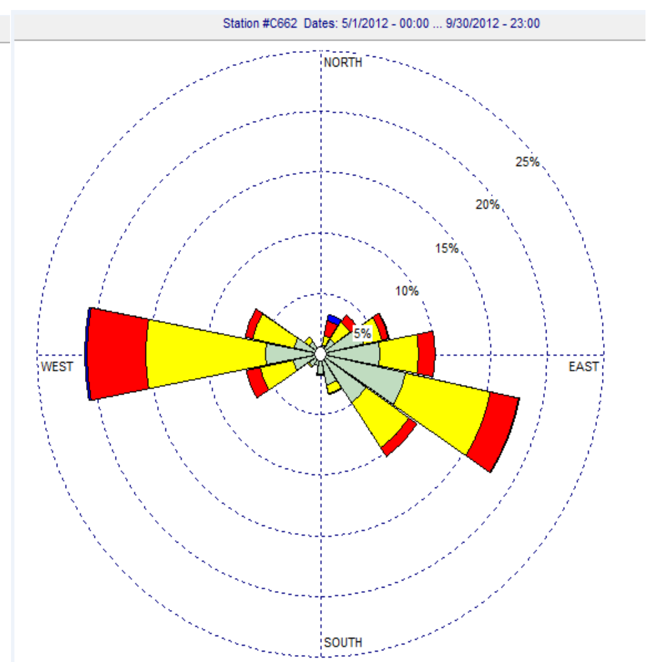

Station #C41 Dates: 5/1/2012 - 00:00 ... 9/30/2012 - 23:00
NORTH
20%
16%
12%
8%
4%
WEST
EAST
SOUTH


Station #C72 Dates: 5/1/2012 - 00:00 ... 9/30/2012 - 23:00
NORTH
15%
12%
9%
6%
3%
WEST
EAST
SOUTH


Station #C324 Dates: 5/1/2012 - 00:00 ... 9/30/2012 - 23:00
NORTH
WEST
EAST
SOUTH
2%
4%
6%
8%
10%


Station #C414 Dates: 5/1/2012 - 00:00 ... 9/30/2012 - 23:00
NORTH
WEST
EAST
SOUTH
3%
6%
9%
12%
15%


Station #C661 Dates: 5/1/2012 - 00:00 ... 9/30/2012 - 23:00
NORTH
WEST
EAST
SOUTH
4%
8%
12%
16%
20%


Station #C662 Dates: 5/1/2012 - 00:00 ... 9/30/2012 - 23:00
NORTH
WEST
EAST
SOUTH
5%
10%
15%
20%
25%

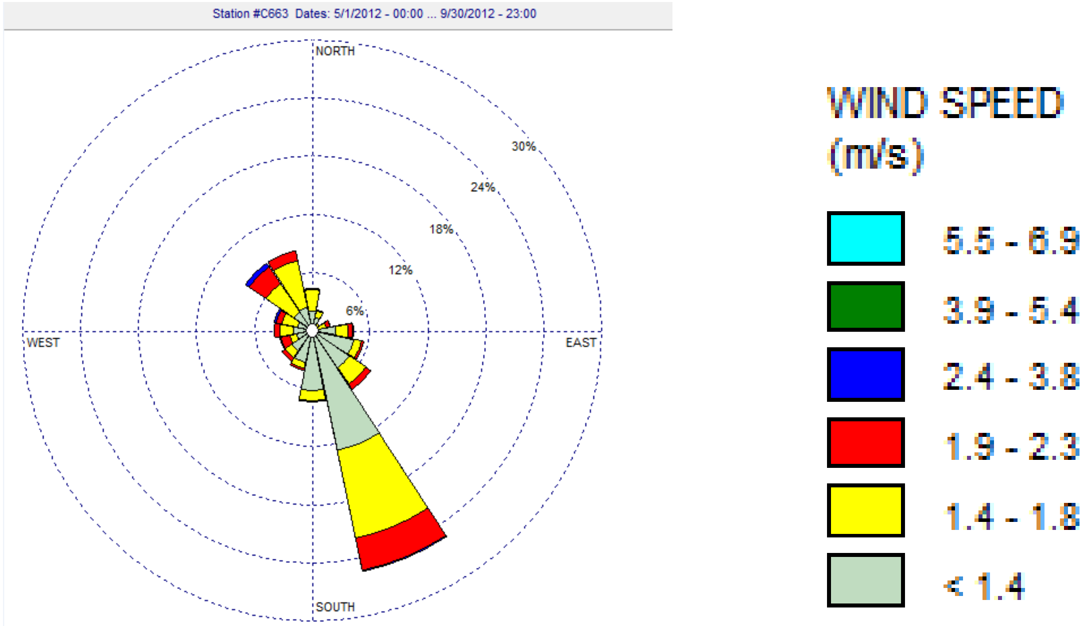


Figure 5.42 Individual Wind Roses for each CAM Stations

5.4 Isopleth Maps

In addition to wind roses isopleth maps were created using SigmaPlot 11 to visualize the hot spots in the region. Though this study only included ozone data from El Paso and Juarez CAM stations the isopleths created included six additional stations in New Mexico (NM) to produce a better distribution. These stations reside in Anthony, La Union, Chaparral, Santa Teresa and two in Sunland Park, NM (Figure 2.1 and Table 2.1 include all these stations in the PdN region). Four isopleths were created to examine different variations of ozone distribution. One isopleth displayed in Figure 5.43 represents the daily maximum 8-hour ozone recorded at each station (El Paso, Juarez and New Mexico) and both 2B monitors at Fort Bliss on 6/29/12. The isopleths are given in latitude (y-axis) and longitude (x-axis) coordinates with a z value that represents the ozone concentration. Details for each station are described in Table 2.1. Labels FB and BF in all isopleths represent the 2B monitor locations at Fort Bliss and Butterfield. In addition to inputting CAMS concentrations two ozone concentrations of 30 ppb were used to represent both the Franklin Mountains and the Juarez Mountains (labeled FM and JM).

Figure 5.44 display the daily maximum 8-hour ozone recorded at each existing station (El Paso, Juarez and New Mexico) and both supplemental sites for 8/21/12. Figure 5.43 and 5.44 demonstrate similar variations compared to the isopleth created in the conceptual model (Figure 4.5 and 4.6). Figure 5.44 is more distributed in the northeast side of the map due to inputting the additional point where Butterfield is located. Butterfield is not included in Figure 5.43. The legend below each isopleth represents the concentrations of ozone. Ozone concentrations did not reach the high levels that are indicated in the legend. These occurrences potentially result from extrapolation that this program underwent. Extrapolation in these isopleths estimates other area ozone concentrations using the original observations from all CAM stations and both supplemental sites. Extrapolation is very similar to interpolation (produces estimates between known observations) but extrapolation is subject to greater uncertainty and gives a higher risk of producing meaningless results (Wikipedia, 2012).

Figure 5.45 and 5.46 represent the highest 1 and 8-hour ozone recorded at each station the duration of this study. The hot spot in the center of each isopleth is the geographical area where NM Stations (all stations but Chaparral) meet El Paso stations. Figure 5.45 and 5.46 contain extremely high ozone values due to one station located at Sunland Park, NM (6ZG station). This station recorded a daily maximum 1-hour concentration of 205 ppb and a daily maximum 8-hour concentration of 105.3 ppb. As previously mentioned extrapolation could ultimately be the main factor for this hot spot.

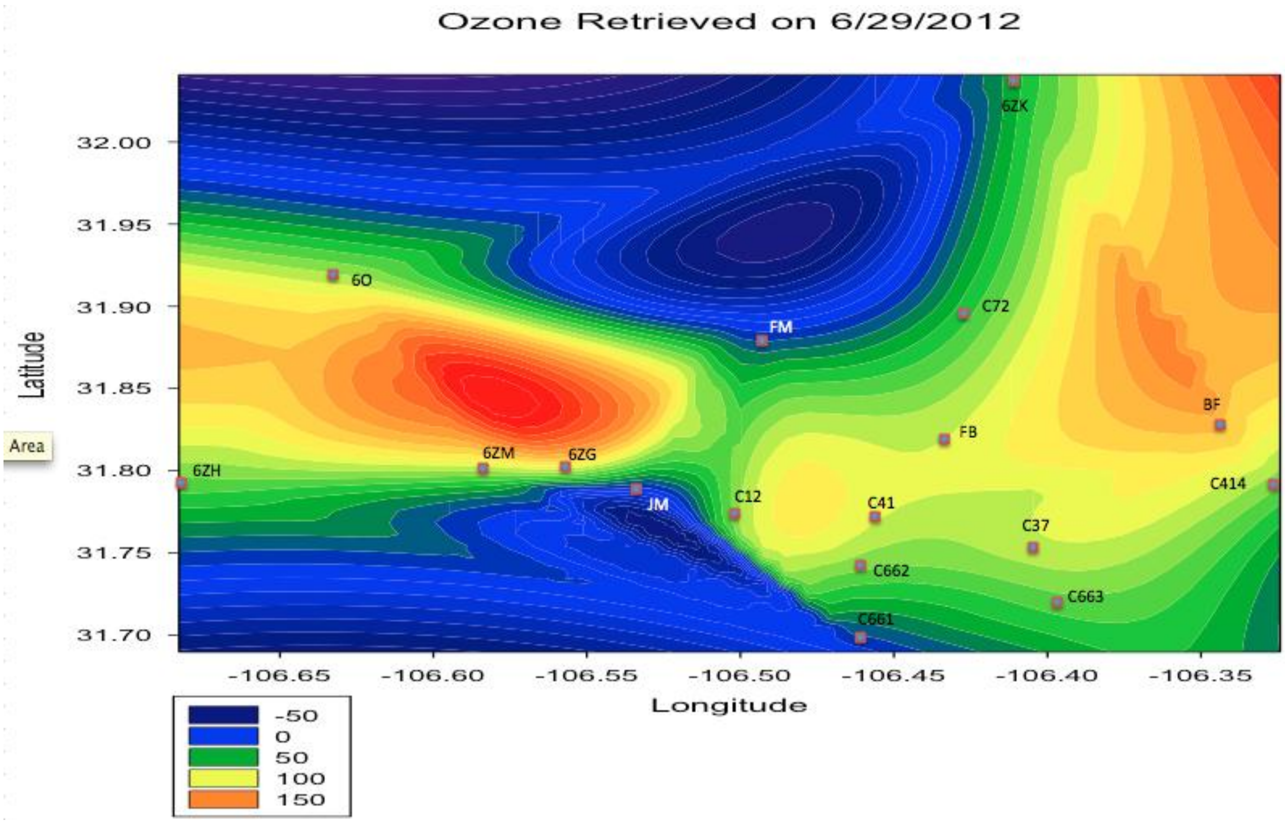


Figure 5.43 Isopleth Representing Ozone Collected at all PdN Ozone Monitoring Stations on 6/29/12

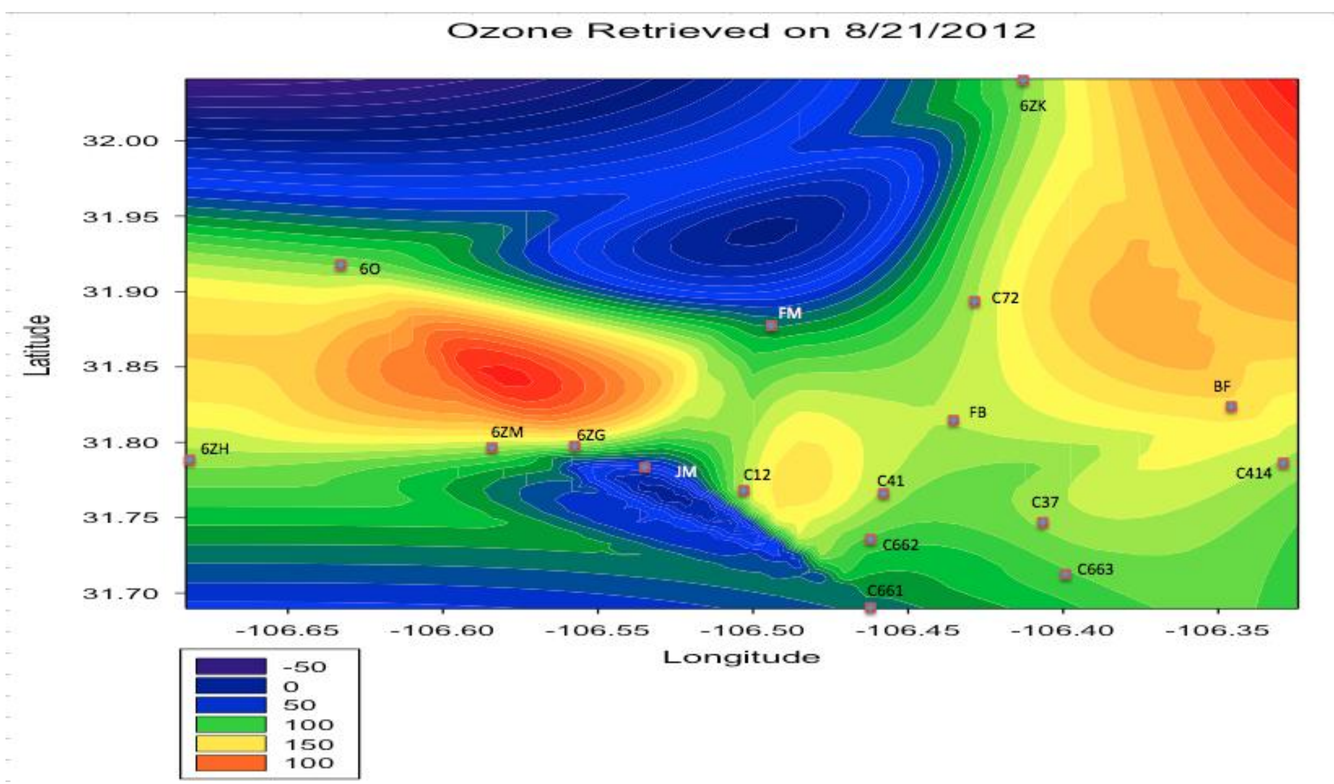


Figure 5.44 Isopleth Representing Ozone Collected at all PdN Ozone Monitoring Stations on 8/21/12

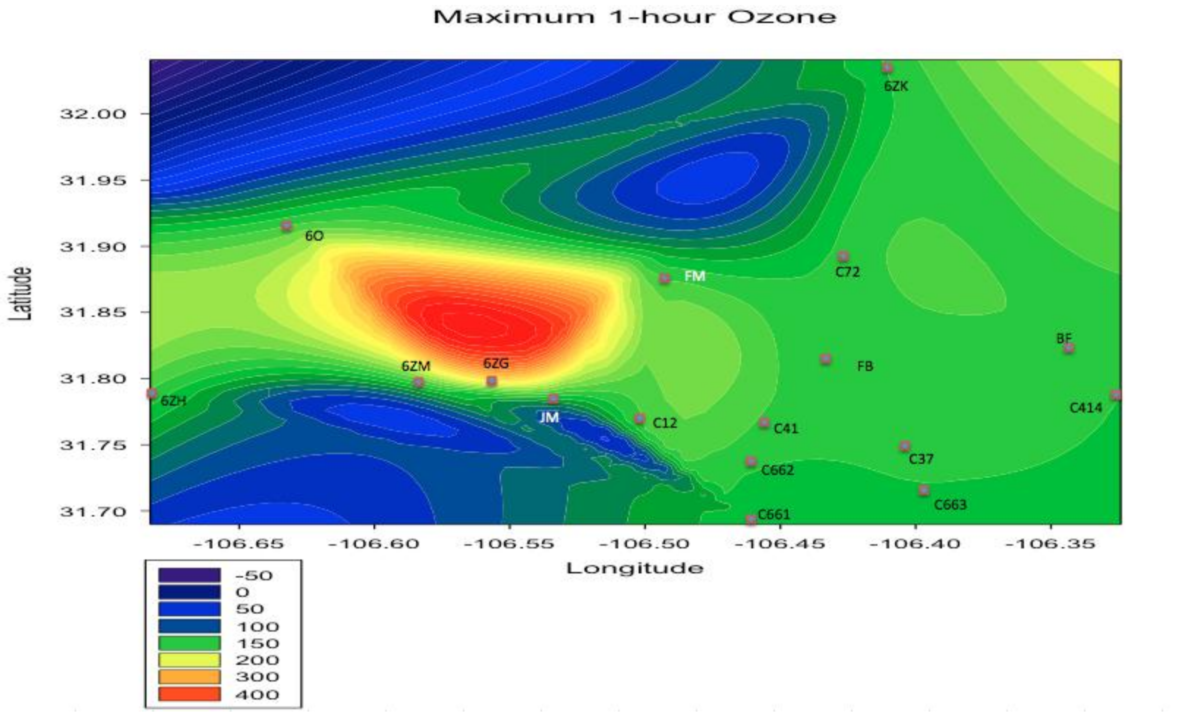


Figure 5.45 Isopleth Representing Maximum 1-Hour Ozone Collected at all PdN Ozone Monitoring Stations the Duration of this Study

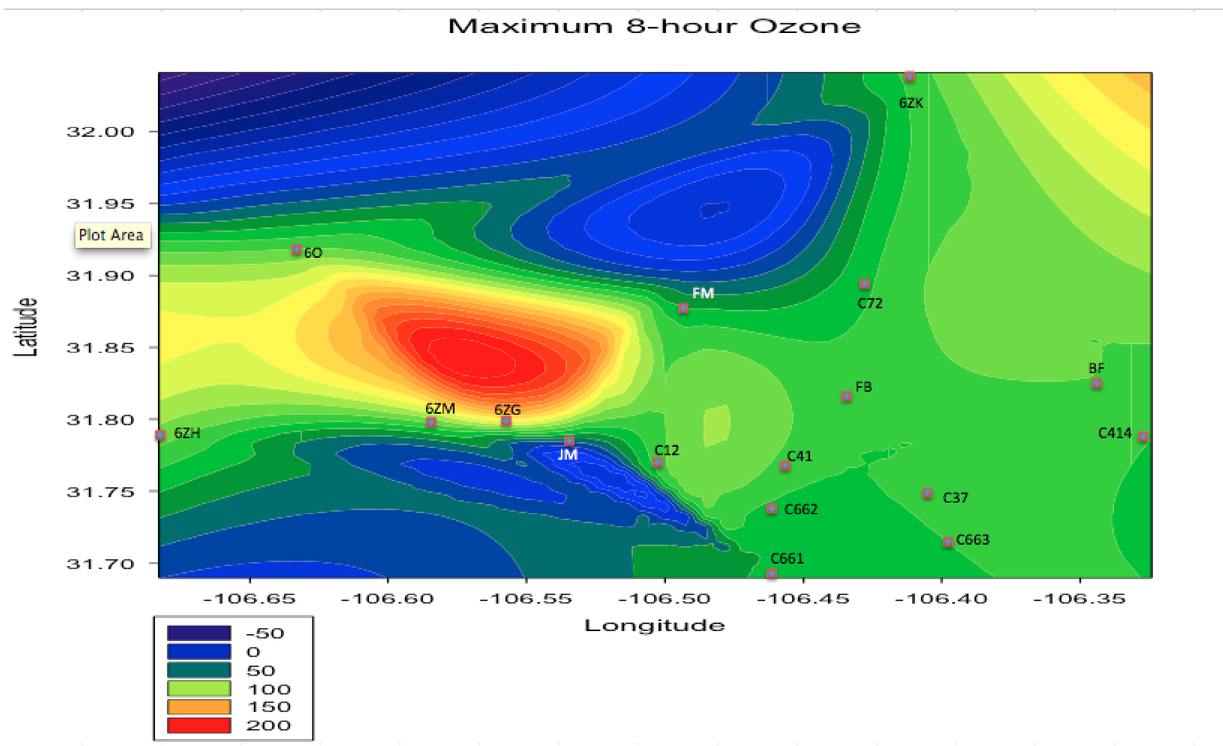


Figure 5.46 Isopleth Representing Maximum 8-Hour Ozone Collected at all PdN Ozone Monitoring Stations the Duration of this Study

CHAPTER 6 DISCUSSIONS

6.1 Number of 8-hour Ozone Exceedance Days

As mentioned in Chapter 5, there were three recorded exceedances throughout the duration of ozone season: one from CAMS 12, Butterfield and Fort Bliss. These exceedances were related to the current NAAQS (75 ppb). In order to further examine if El Paso would still be designated attainment bar charts were conducted to demonstrate the amount of exceedances for 60 ppb, 65 ppb and 70 ppb. Figure 6.1 through 6.3 demonstrates the amount of exceedances using the 60, 65 and 70 ppb standard. All stations from El Paso (CAMS and supplemental sites) and Juarez are shown in the x-axis and the number of exceedances is on the y-axis. The #2 next to Fort Bliss #1 on the x-axis represents the 2B Monitor #2 when it was deployed at Fort Bliss prior to Butterfield.

After analyzing the daily maximum 8-hour averages there was a total of 12 or greater exceedances at all stations in El Paso alone using the 60 ppb standard. There were only one or two days that exceeded this standard in Juarez. By increasing this standard to 65 ppb there were seven or more exceedances at all monitoring stations in El Paso except CAMS 37 (only exceeded this standard twice). If the current standard lowered to 70 ppb, Fort Bliss, Butterfield and CAMS 12 will be considered potential locations to designate El Paso as nonattainment status for ozone. Nine days during this period, both Fort Bliss and CAMS 12 exceeded 70 ppb. Though Butterfield only exceeded the 70 ppb standard three times there is a possibility there could have been more exceedances during the first time period of the ozone season, when both monitors were located at Fort Bliss (May – July). This study will have to continue monitoring ozone at Fort Bliss and Butterfield for the next three years in order to determine whether El Paso will be officially considered in nonattainment for 60, 65 or 70 ppb.

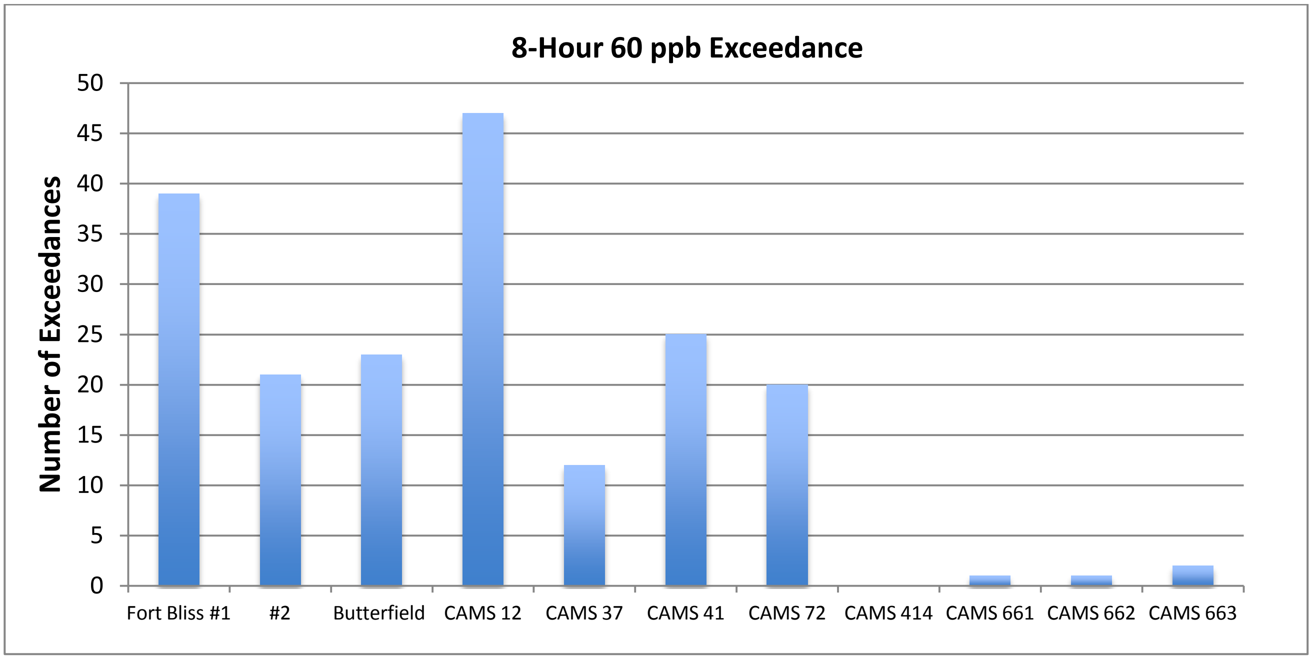


Figure 6.1 Number of 8-hour Ozone Exceedance Days for El Paso and Juarez Using a 60 ppb Standard

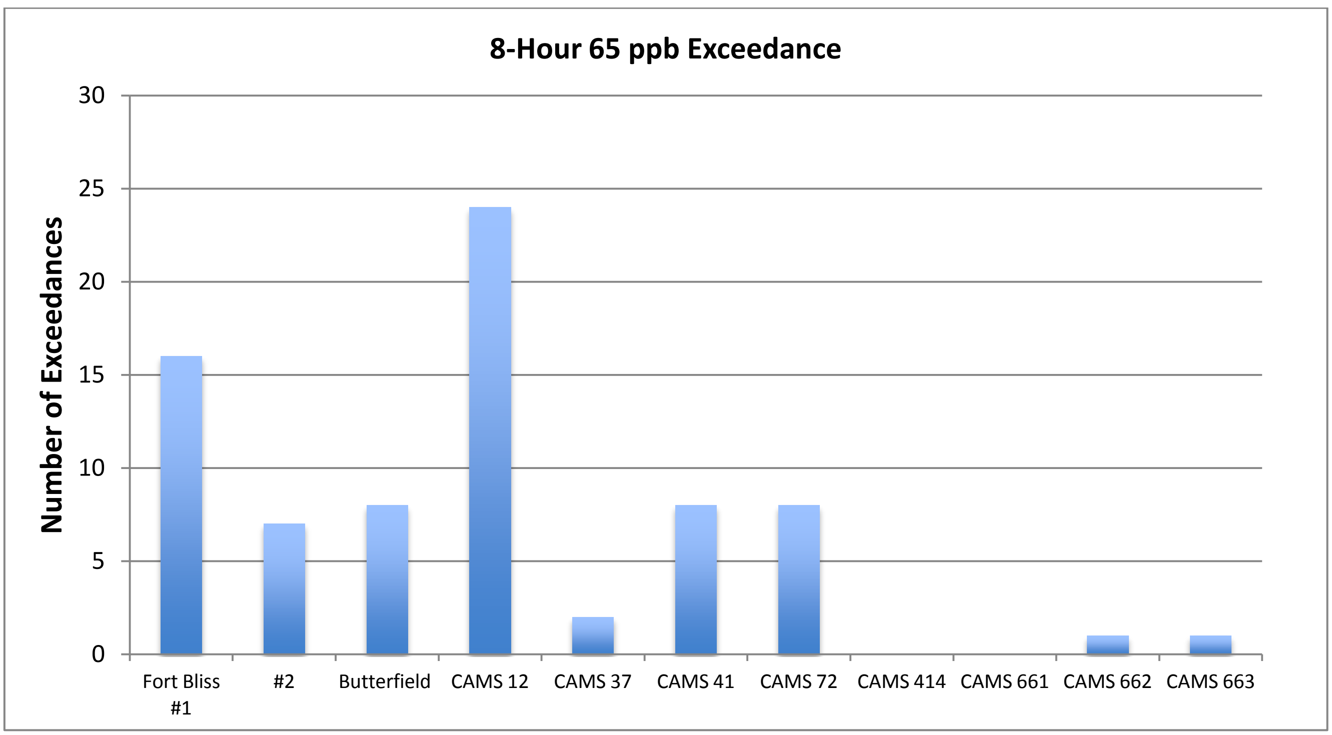


Figure 6.2 Number of 8-hour Ozone Exceedance Days for El Paso and Juarez Using a 65 ppb Standard

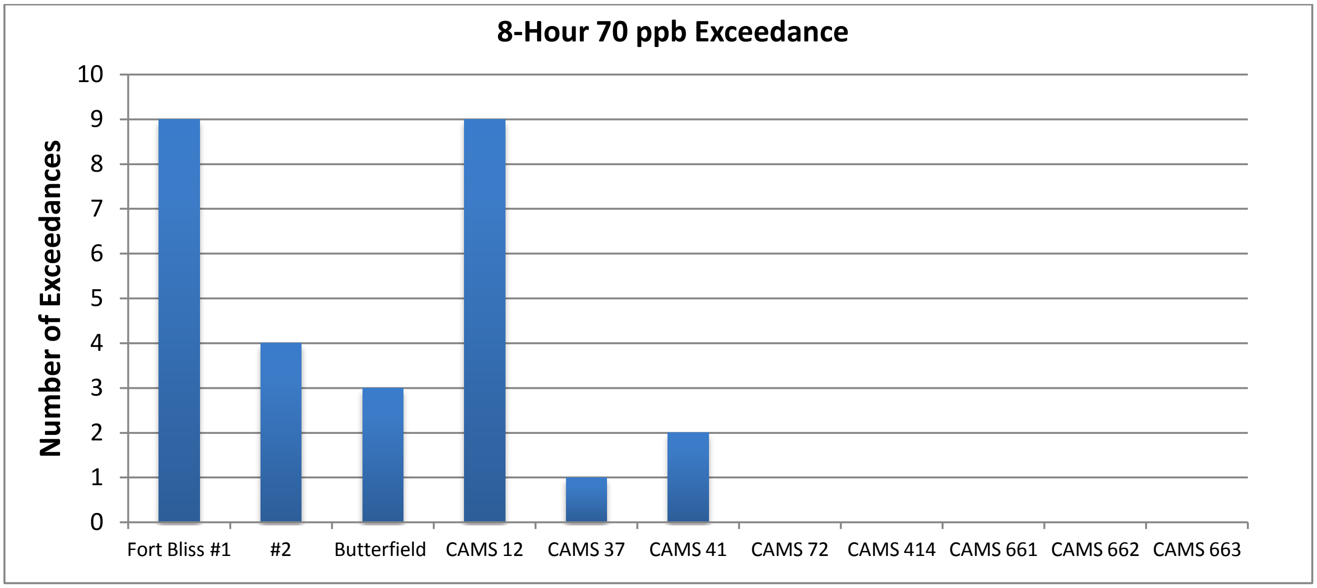
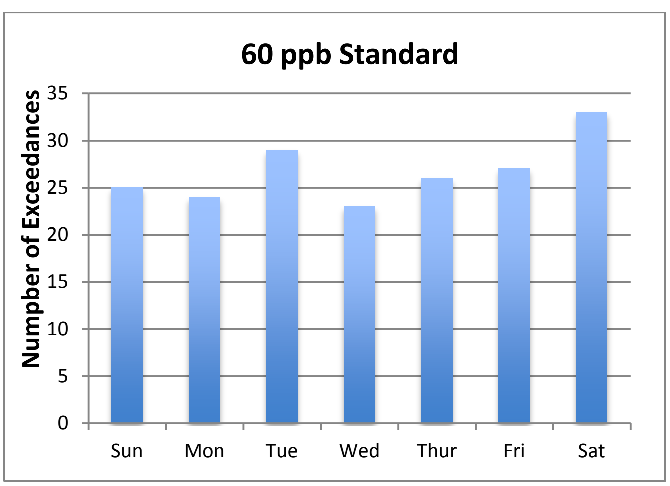
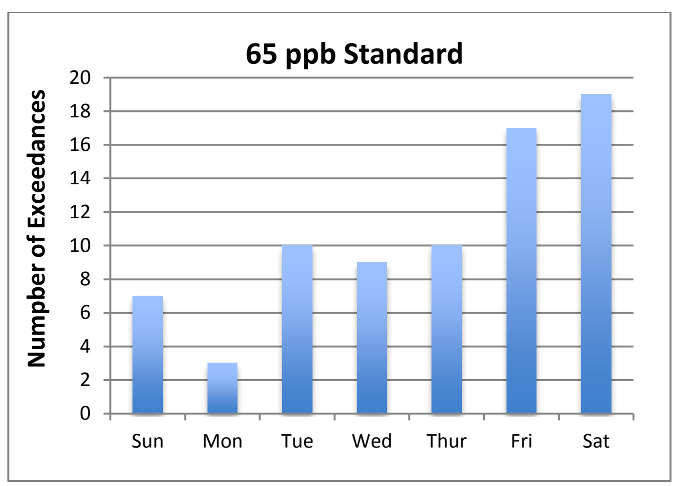


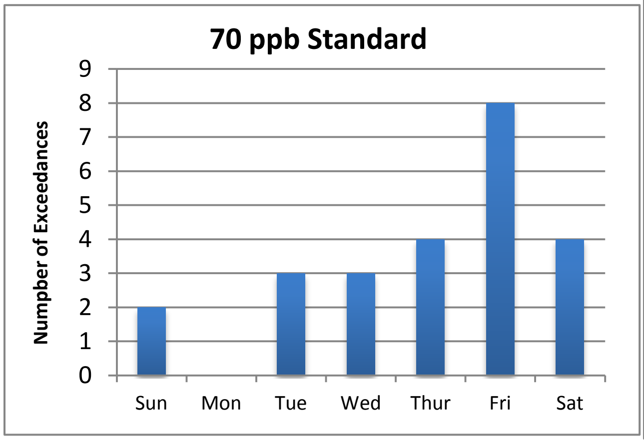
Figure 6.3 Number of 8-hour Ozone Exceedance Days for El Paso and Juarez Using a 70 ppb Standard

6.2 Trends of Ozone Distribution

The number of daily 8-hour ozone exceedances from 2001 to 2010 in El Paso, Dona Ana County and Cd. Juarez, regardless of the standards, revealed majority occurred on weekends; particularly on Saturdays, when compared to weekdays. In this study most ozone exceedances (both 75 ppb and 70 ppb) occurred during the week, particularly Fridays. When lowering the standard to 65 and 60 ppb Saturday experienced the most exceedances. Figure 6.3 shows exceedances day numbers by the week for both 75 ppb and 70 ppb standards.







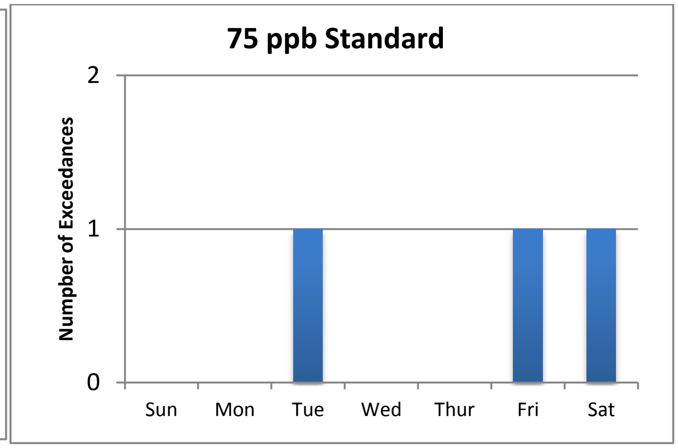
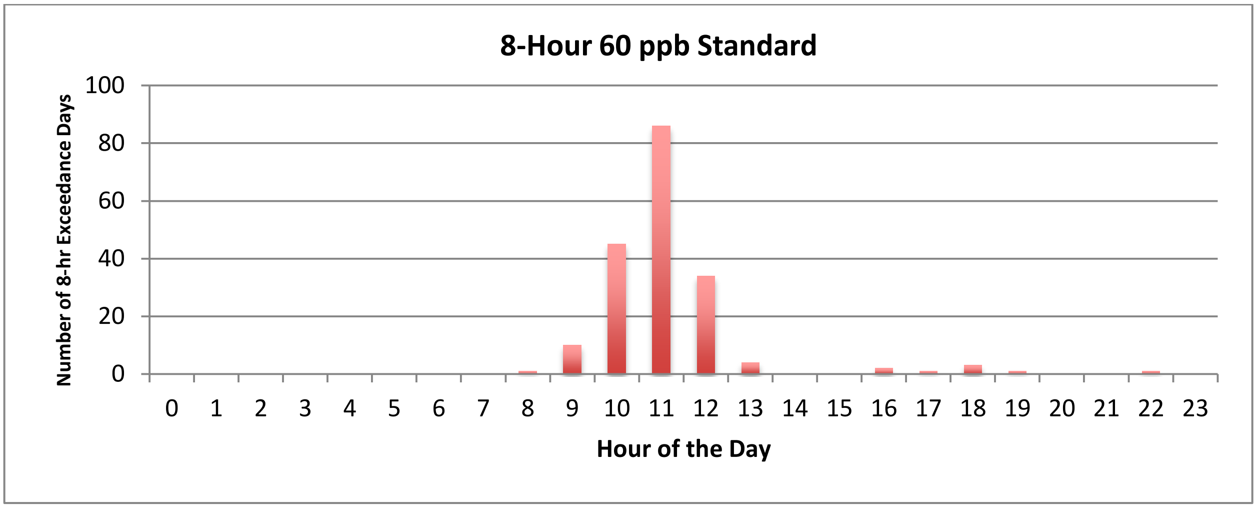
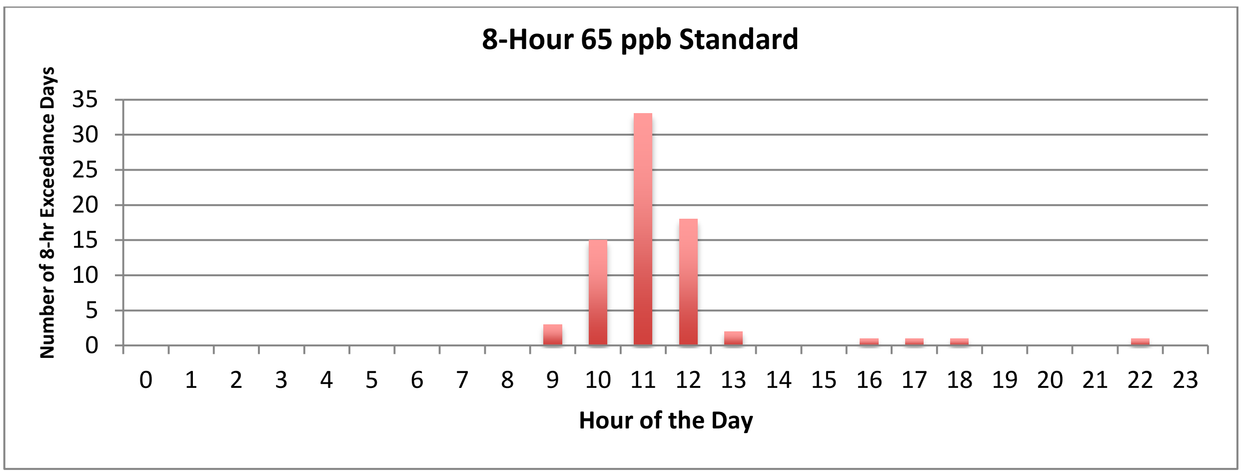


Figure 6.4 Number of 8-hour Ozone Exceedance days by day of the week using 60, 65, 70 and 75 ppb Standard

The hour of highest 8-hour averages were examined in addition to day-by-day trends. The conceptual model found that El Paso experienced most 8-hour exceedances beginning from 10 a.m. to 6 p.m. TCEQ reports air quality data by the beginning of each hour in local standard time. Daylight savings was adjusted to collect real time values for this study. Since there were only three exceedances for the current standard, hourly trends were examined using 70, 65 and 60 ppb. Days were sorted by the starting hour of the day when the given ozone standard was exceeded. Figures 6.5 contain all 8-hour ozone exceedances by starting hour of the day using the 70, 65 and 60 ppb standard. The most frequent beginning hour for the each standard is 11 a.m. but time was adjusted as mentioned. Due to this adjustment it is concluded just as the conceptual model revealed, the beginning hour containing the most frequent 8-hour exceedances was 10 a.m. if local standard time had been used in place of real time.





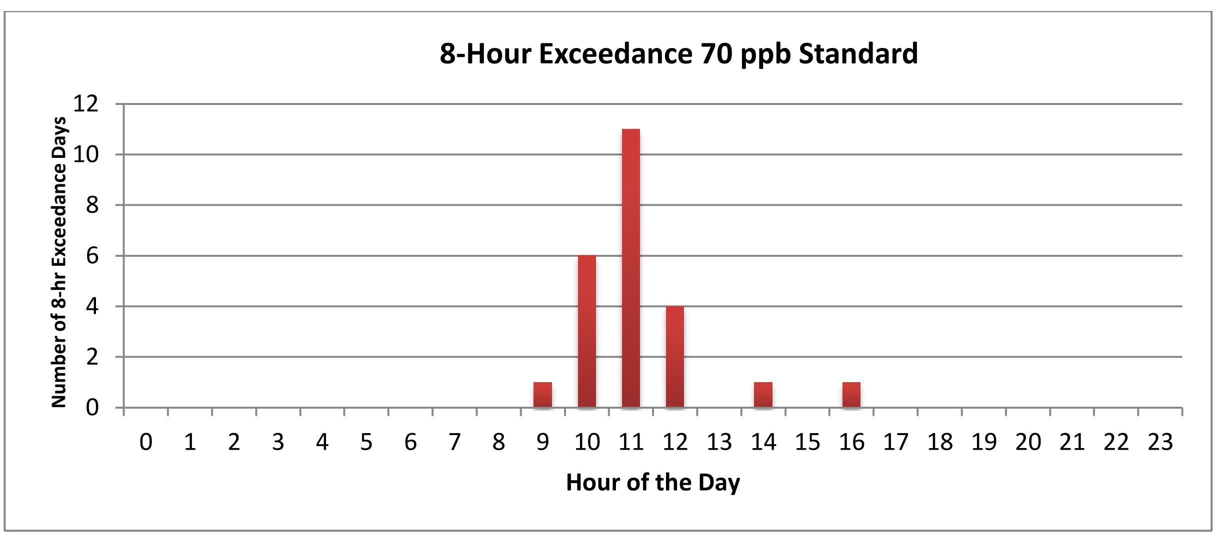


Figure 6.5 Number of 8-hour Ozone Exceedance Days by Hour of the Day Using 70, 65 and 60 ppb Standard

CHAPTER 7 CONCLUSION

The pre-calibration assessed by 2B Technologies, Inc., side-by-side analysis with CAMS 12 and performance evaluations using the Tanabyte 724 ensured the quality and reliability of data retrieved this entire period. It is additionally worth noting that during the side-by-side analysis both monitors recorded 4-10% lower ozone than CAMS 12 giving Fort Bliss and Butterfield a possibility of experiencing more exceedances during the ozone season.

Being that Fort Bliss is the most populated military installation in the world (Regional Stakeholders Committee, 2009) this site is highly recommended to continue monitoring ozone in order to ensure this is a safe environment for current and future soldiers, their families and civilians transporting in and out of this installation. Since both sites, Fort Bliss and Butterfield Trail Golf Club, collected higher ozone concentrations than Juarez stations and nearly all CAM stations in El Paso it would also be recommended to continue monitoring ozone at both these sites or other sites nearby to officially clarify if these are hot spots that can designate El Paso as nonattainment.

Meteorological parameters and isopleth maps demonstrated consistent variations throughout the entire period of the ozone season. Though the wind roses and isopleths demonstrated an indication of where ozone precursors potentially begin, additional analysis should be further examined in order to officially justify the fate and transport of ozone around the PdN region. Analysis including the relationship between solar radiation, VOC/NO_x ratios, humidity, and outdoor temperature and its affects on increased ozone.

Though the Paso del Norte region might be of great concern for future ozone, El Paso is still designated in attainment of the current NAAQ standard. President Obamas decision to withdraw the updated standard is not promising being that the EPA could request this provision again. If the EPA does lower the standard to 60–70 ppb for the health of the public El Paso would most likely be designated nonattainment for the ozone NAAQS.

REFERENCES

2B Technology, Inc. Model 202 Ozone Monitor. Retrieved from http://www.twobtech.com/brochures/model_202.pdf

2B Technology, Inc. (2001 – 2005). Operation Manual: Model 202. Retrieved from http://www.twobtech.com/manuals/model_202_revF.pdf

Clinuvel. (2012). UV Damage and Carcinogenesis. Clinuvel Pharmaceuticals Ltd. Retrieved from http://www.clinuvel.com/en/skin-science/skin-sun/skin-cancer/uv-damage-and-carcinogenesis

Coe, D.L., Ryan, P.A., Chinkin, L.R. Weekday/Weekend Activity Patterns for Residential and Small Commercial Area Sources in Los Angeles. Retrieved from http://www.epa.gov/ttnchie1/conference/ei11/stationarysource/coe.pdf

Harbour, R.L. (1972). Geology of the Northern Franklin Mountains, Texas and New Mexico. USGS Bulletin 1298. Washington, D.C.: U.S. Government Printing Office

Joint Advisory Committee (JAC) For the Improvement Air Quality Paso del Norte. (2010, July 10). Retrieved from http://www.jac-ccc.org/Monitoring.htm#intro

Ketter, R. G. (1998, March). Paso del Norte (PdN) Air Quality Task Force: A Case Study.

Li, W.W., Fitzgerald, R., Yang, H., Yang, H., Olvera, H., Cheu, K.R.L. (2011, October). Conceptual Model for Ozone Reduction in El Paso, Texas. Dept. of Civil Engineering, Physics Dept., Dept. of Mathematical Sciences, University of Texas at El Paso, El Paso, TX.

Regional Stakeholders Committee. (2009). "The Paso del Norte Region, US-Mexico: Self-Evaluation Report", OECD Reviews of Higher Education in Regional and City Development, IMHE. Retrieved from http://www.oecd.org/edu/imhe/regionaldevelopment

Sillman, S. (2003). Treatise on Geochemistry: Tropospheric Ozone and Photochemical Smog (Volume 9; pp 402 – 431). Elsevier Ltd.

Tanabyte Products. (2002 – 2008). Model 72x Series Model Selection. Retrieved from http://www.tanabyte.com/Ozone%20Module.html

Tanabyte Products. (2002 – 2008). Model 723 Transfer Standard with Cal/Sample Values. Retrieved from http://www.tanabyte.com/T723%20Module.html

Texas Commission on Environmental Quality (TCEQ). (1994, September). El Paso Ozone History: One-Hour Ozone Standard. Retrieved from http://www.tceq.state.tx.us/cgi-bin/compliance/monops/daily_info.pl?cams

Texas Commission on Environmental Quality (TCEQ). (2001 – 2012). What is CAMS? Retrieved from http://www.tceq.state.tx.us/cgi-bin/compliance/monops/daily_info.pl?cams

The Royal Society. (2008, October). Ground-level Ozone in the 21st Century: future trends, impacts and policy implications. Salisbury, United Kingdom: Techset Composition Limited.

U.S. Environmental Protection Agency. (1999, July). Smog – Who Does it Hurt? What You Need to Know About Ozone and Your Health. Washington, DC: Air and Radiation.

U.S. Environmental Protection Agency. (2006, February). Air Quality Criteria for Ozone and Related Photochemical Oxidants (EPA-600/R-05/004aF Volume I and III). Research Triangle Park, NC: Office of Research and Development.

U.S. Environmental Protection Agency. (2007, January). Review of the National Ambient Air Quality Standards for Ozone: Policy Assessment of Scientific and Technical Information (EPA-452/R-07-003). Research Triangle Park, NC: Office of Air Quality Planning and Standards.

U.S. Environmental Protection Agency. (2010, April). Office of Research and Development; Ambient Air Monitoring Reference and Equivalent Methods: Designation of One New Equivalent Method. Washington, DC: National Exposure Research Laboratory.

U.S. Environmental Protection Agency. (2011, July). Ozone – Good Up High Bad Nearby. Washington, DC: Air and Radiation.

U.S. Environmental Protection Agency. (2012, March). What Are the Six Common Air Pollutants?: State Implementation Plan Overview. Washington, DC: Air and Radiation.

APPENDIX A: 2B BIRTH AND CALIBRATION CERTIFICATES

2B Technologies Model 202 Ozone Monitor™

Birth Certificate

Serial Number: 1131

Calibration Date	15-Nov-11
Slope (S)	1.02
Offset (Z), ppbv	0
Flow Rate Cal Factor	0.99
Precision, ppbv	1.41
Precision at 1 atm, ppbv	1.15
Photodiode Voltage	1.60
Flow Rate, cc/min volumetric	990
Solenoid Valve	Pneutronics (NPB)
Air Pump	Sensidyne AA (x2)
Ozone Scrubber	Headline
PCB Version	DB/NOx Version G
Software Version	O3 202 Ver. 5.3C
Current, Amp	0.41
Power at 12 V, Watt	4.92

Model 202 #1131 & #1133 11_15_11

Figure A.1 Birth Certificate for 2B Monitor #1

2B *Technologies* Model 202 Ozone Monitor™

CALIBRATION CERTIFICATE

Based on the following calibration provided by the U.S. National Institute of Standards and Technology (NIST), 2B Technologies designates the calibration of all Ozone Monitors™ to be NIST traceable:

Calibration Description:	NIST Traceable Calibration of Ozone Monitors
Transfer Standard Calibration Date:	October 21, 2009
Working Standard Calibration Date:	August 26, 2011

The calibration of all 2B Technologies ozone monitors is traceable to NIST through an unbroken chain of comparisons. The transfer standard is used to calibrate the working standard, which in turn is used to calibrate the customer's instrument. Each step in the chain is fully documented.

Transfer standard. Our transfer standard is a Thermo Electron O3 Calibration Primary Standard, model 49i-PS, serial number 0726724741. The transfer standard was calibrated by NIST against their Standard Reference Photometer, serial number 2, in Gaithersburg, MD on October 21, 2009. Measurements were collected of ten concentrations (25 to 1000 ppbv) and two zero concentrations. A linear regression was fit to the data and calibration factors were determined for the transfer standard.

Working standard. Our working standard is a 2B Technologies Model 205 Ozone Monitor, serial number 773DB. The working standard was calibrated by 2B Technologies by comparison to our transfer standard. Measurements were collected of six concentrations (50 to 300 ppbv) and one zero concentration. A linear regression was fit to the data and calibration factors were determined for the working standard.

Customer's instrument. The instrument was calibrated against the working standard. Ozone was generated by photolysis of oxygen followed by dilution in a flow of ozone-free air. The gas mixture was sampled by both instruments through a sampling tee. Ten measurements were collected from each instrument at six different concentrations (50 to 300 ppbv) and one zero concentration. A linear regression was fit to the data, and calibration factors were determined.

Serial Number:	**1131**	**Calibration Parameters:**	
Date of Calibration:	**15-Nov-11**	**Z =**	**0**
Expiration Date:	**13-Nov-12**	**S =**	**1.02**

John Birks

Dr. John Birks
President, 2B Technologies, Inc.

Model 202 #1131 & #1133 11_15_11

Figure A.2 Calibration Certificate for 2B Monitor #1

2B Technologies Model 202 Ozone Monitor™

Birth Certificate

Serial Number: 1147

Calibration Date	29-Feb-12
Slope (S)	1.01
Offset (Z), ppbv	0
Flow Rate Cal Factor	1.12
Precision, ppbv	1.38
Precision at 1 atm, ppbv	1.13
Photodiode Voltage	1.52
Flow Rate, cc/min volumetric	950
Solenoid Valve	Pneutronics (NPB)
Air Pump	Sensidyne AA (x2)
Ozone Scrubber	Headline
PCB Version	DB/NOx Version G
Software Version	O3 202 Ver. 5.3D
Current, Amp	0.33
Power at 12 V, Watt	3.96

Model 202 #1147 02_29_12

Figure A.3 Birth Certificate for 2B Monitor #2

2B Technologies Model 202 Ozone Monitor™
CALIBRATION CERTIFICATE

Based on the following calibration provided by the U.S. National Institute of Standards and Technology (NIST), 2B Technologies designates the calibration of all Ozone Monitors™ to be NIST traceable:

Calibration Description:	NIST Traceable Calibration of Ozone Monitors
Transfer Standard Calibration Date:	October 12, 2011
Working Standard Calibration Date:	January 9, 2012

The calibration of all 2B Technologies ozone monitors is traceable to NIST through an unbroken chain of comparisons. The transfer standard is used to calibrate the working standard, which in turn is used to calibrate the customer's instrument. Each step in the chain is fully documented.

Transfer standard. Our transfer standard is a Thermo Electron O3 Calibration Primary Standard, model 49i-PS, serial number 0726724741. The transfer standard was calibrated by NIST against their Standard Reference Photometer, serial number 0, in Gaithersburg, MD on October 12, 2011. Measurements were collected of ten concentrations (25 to 1000 ppbv) and two zero concentrations. A linear regression was fit to the data and calibration factors were determined for the transfer standard.

Working standard. Our working standard is a 2B Technologies Model 205 Ozone Monitor, serial number 773DB. The working standard was calibrated by 2B Technologies by comparison to our transfer standard. Measurements were collected of six concentrations (50 to 300 ppbv) and one zero concentration. A linear regression was fit to the data and calibration factors were determined for the working standard.

Customer's instrument. The instrument was calibrated against the working standard. Ozone was generated by photolysis of oxygen followed by dilution in a flow of ozone-free air. The gas mixture was sampled by both instruments through a sampling tee. Ten measurements were collected from each instrument at six different concentrations (50 to 300 ppbv) and one zero concentration. A linear regression was fit to the data, and calibration factors were determined.

Serial Number:	**1147**	**Calibration Parameters:**
Date of Calibration:	**29-Feb-12**	**Z = 0**
Expiration Date:	**27-Feb-13**	**S = 1.01**

Dr. John Birks
President, 2B Technologies, Inc.

Model 202 #1147 02_29_12

Figure A.4 Calibration Certificate for 2B Monitor #2

APPENDIX B: SIDE-BY-SIDE ANALYSIS WITH CAMS 12 AND PERFORMANCE EVALUATIONS

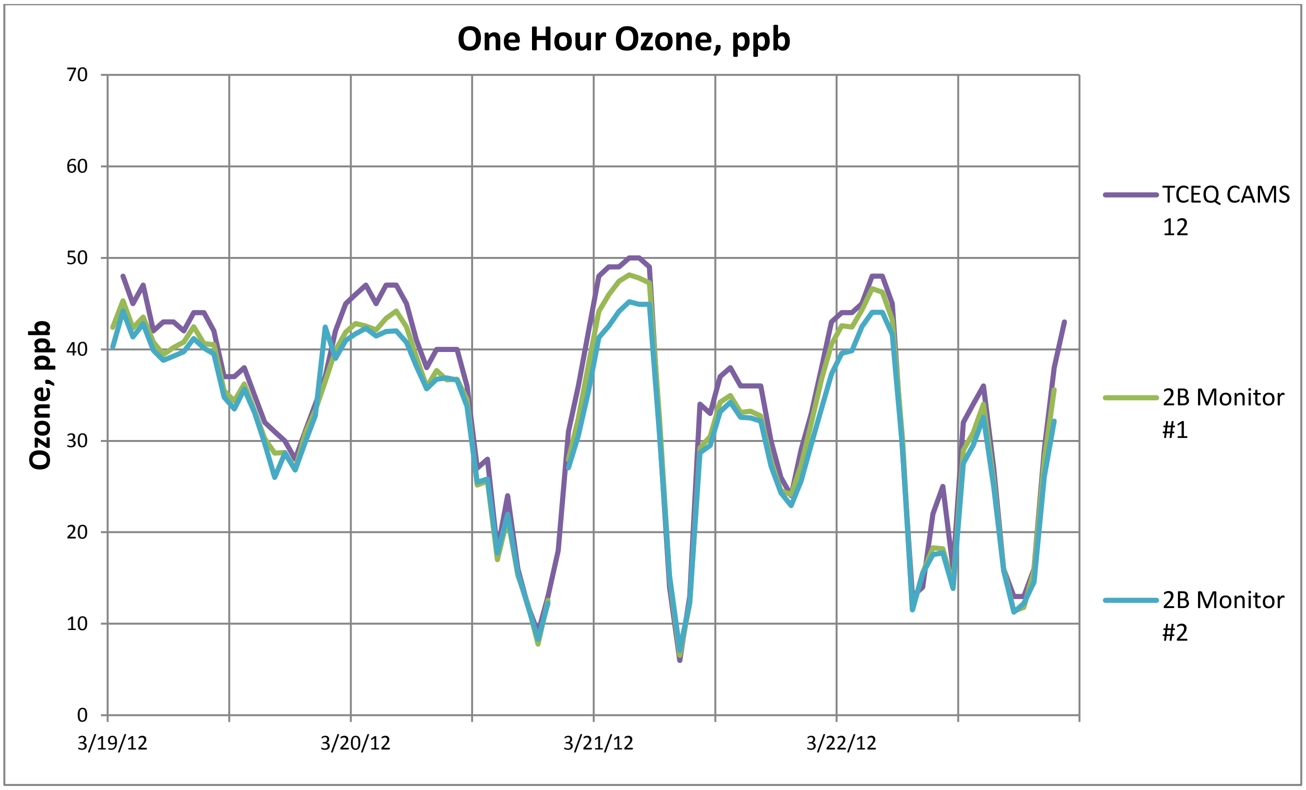


Figure B.1 1-hour average Ozone of both 2B Monitors and CAMS 12

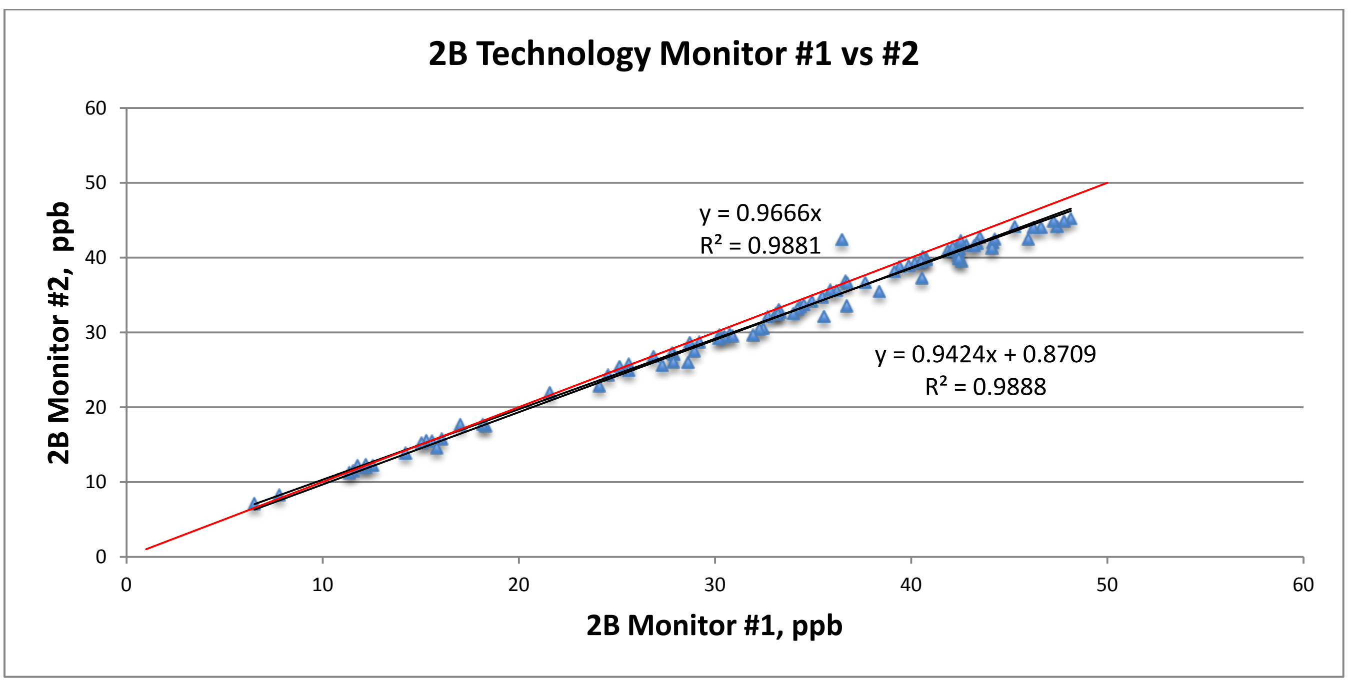


Figure B.2 Correlation between both 2B Monitors

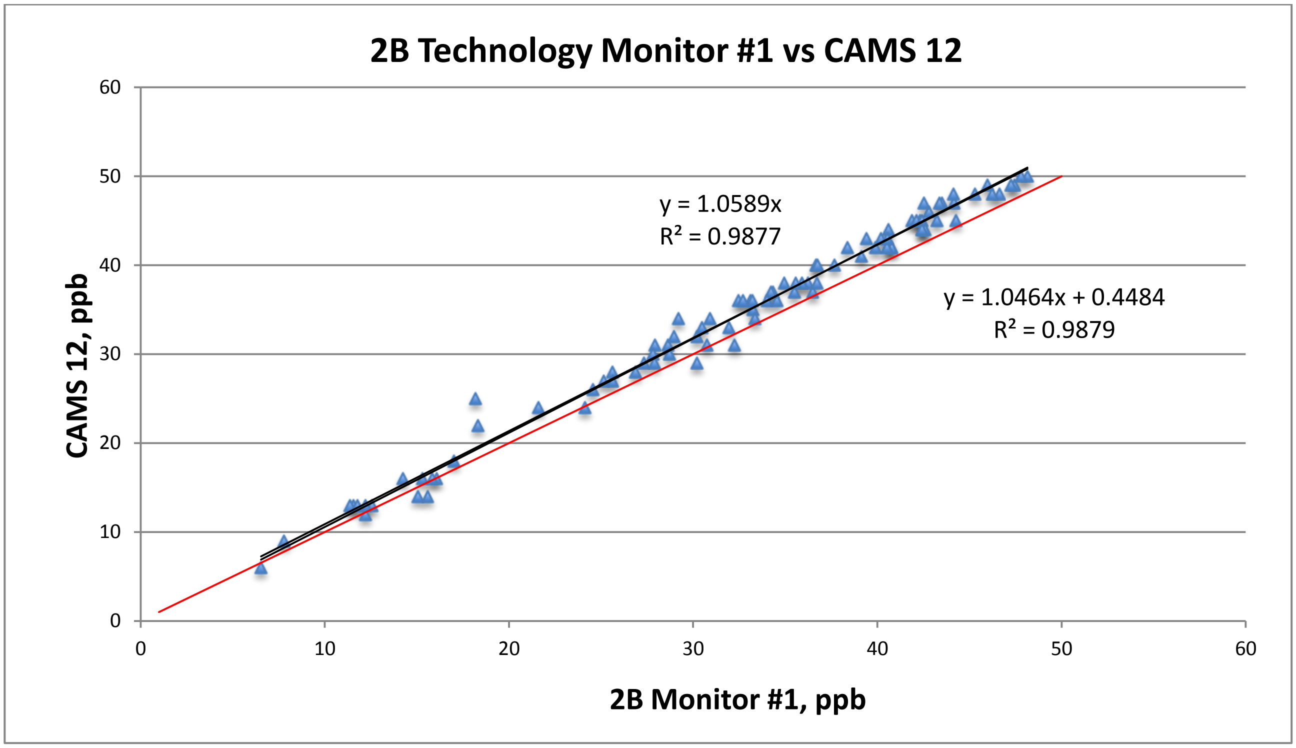


Figure B.3 Correlation between 2B Monitor #1 and CAMS 12

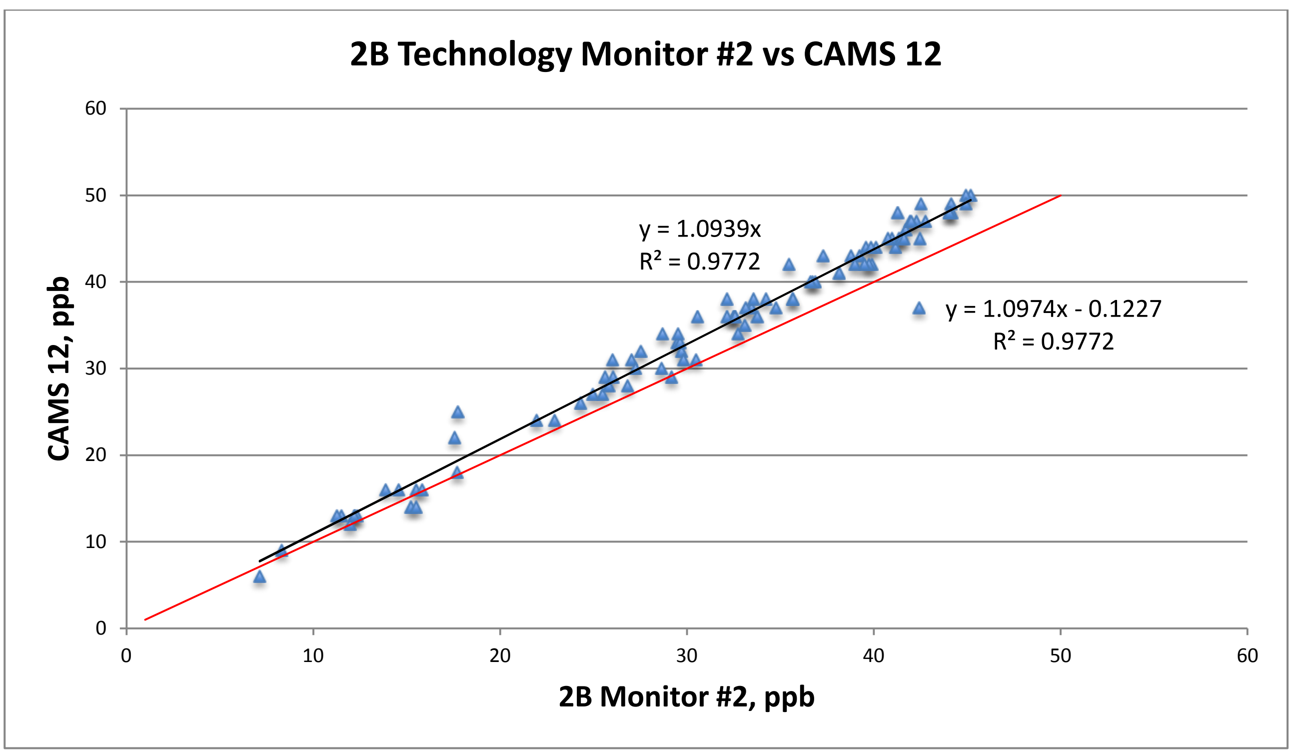


Figure B.4 Correlation between 2B Monitor #2 and CAMS 12

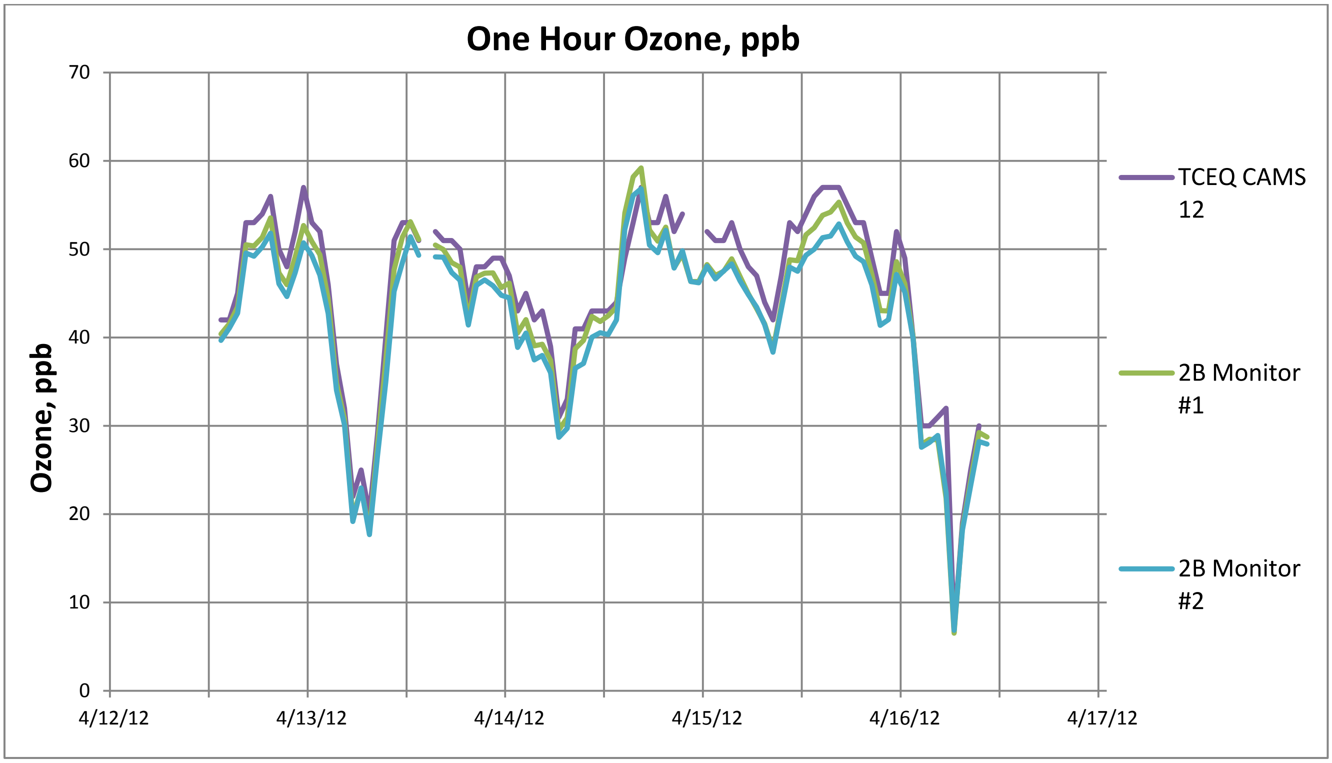


Figure B.4 1-hour average Ozone of both 2B Monitors and CAMS 12

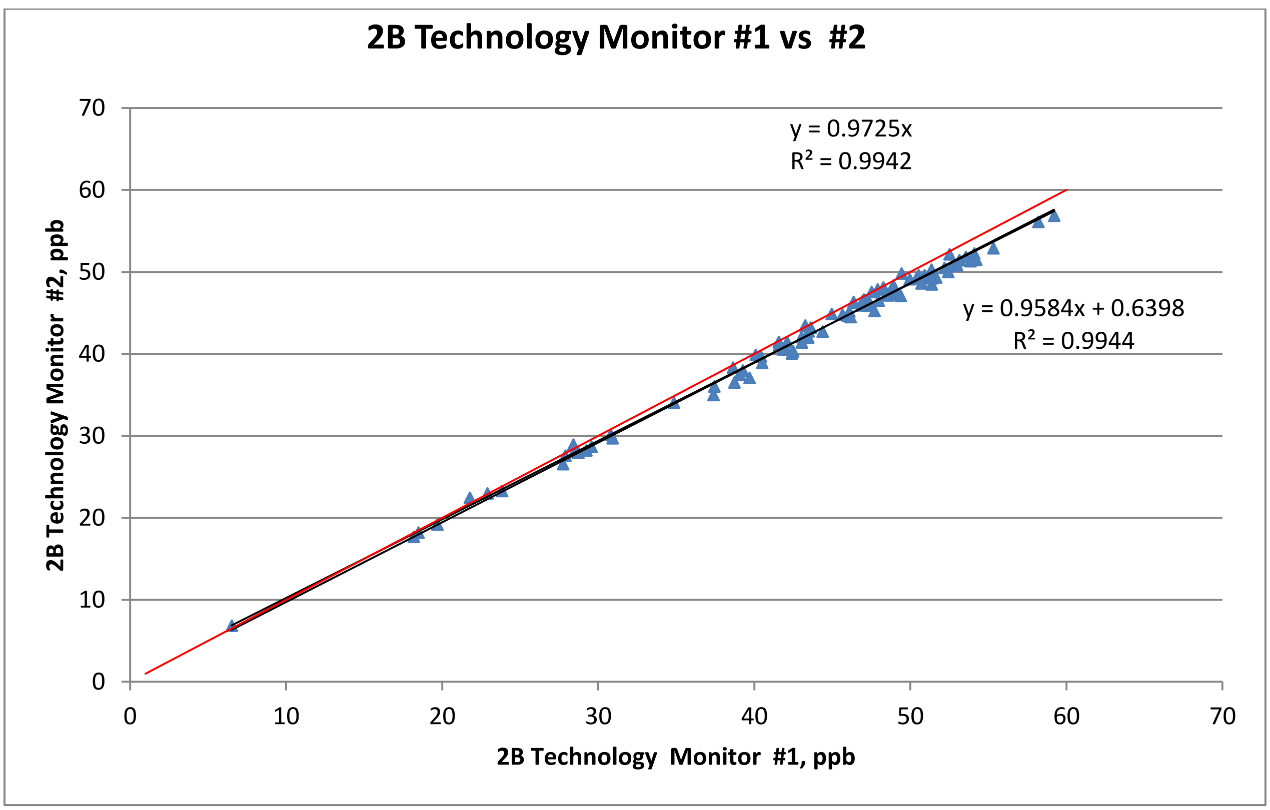


Figure B.5 Correlation between both 2B Monitors

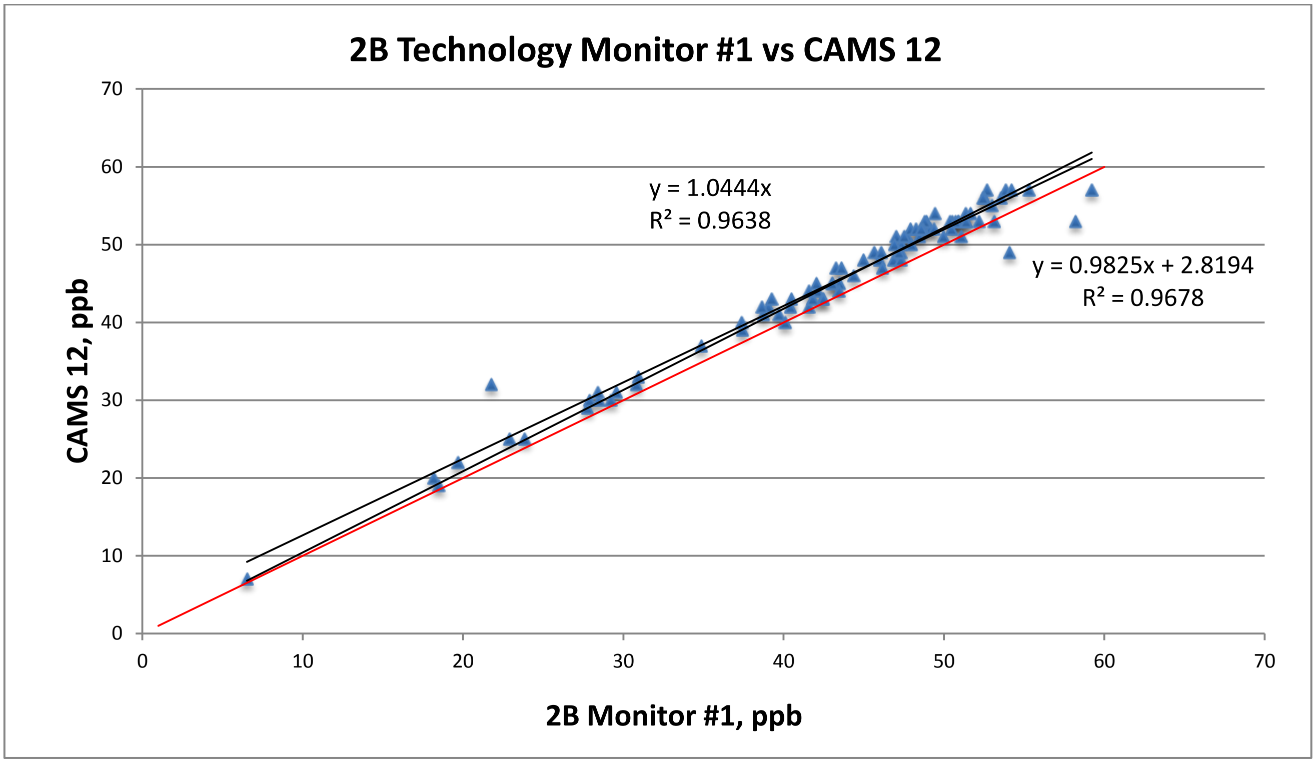


Figure B.6 Correlation between 2B Monitor #1 and CAMS 12

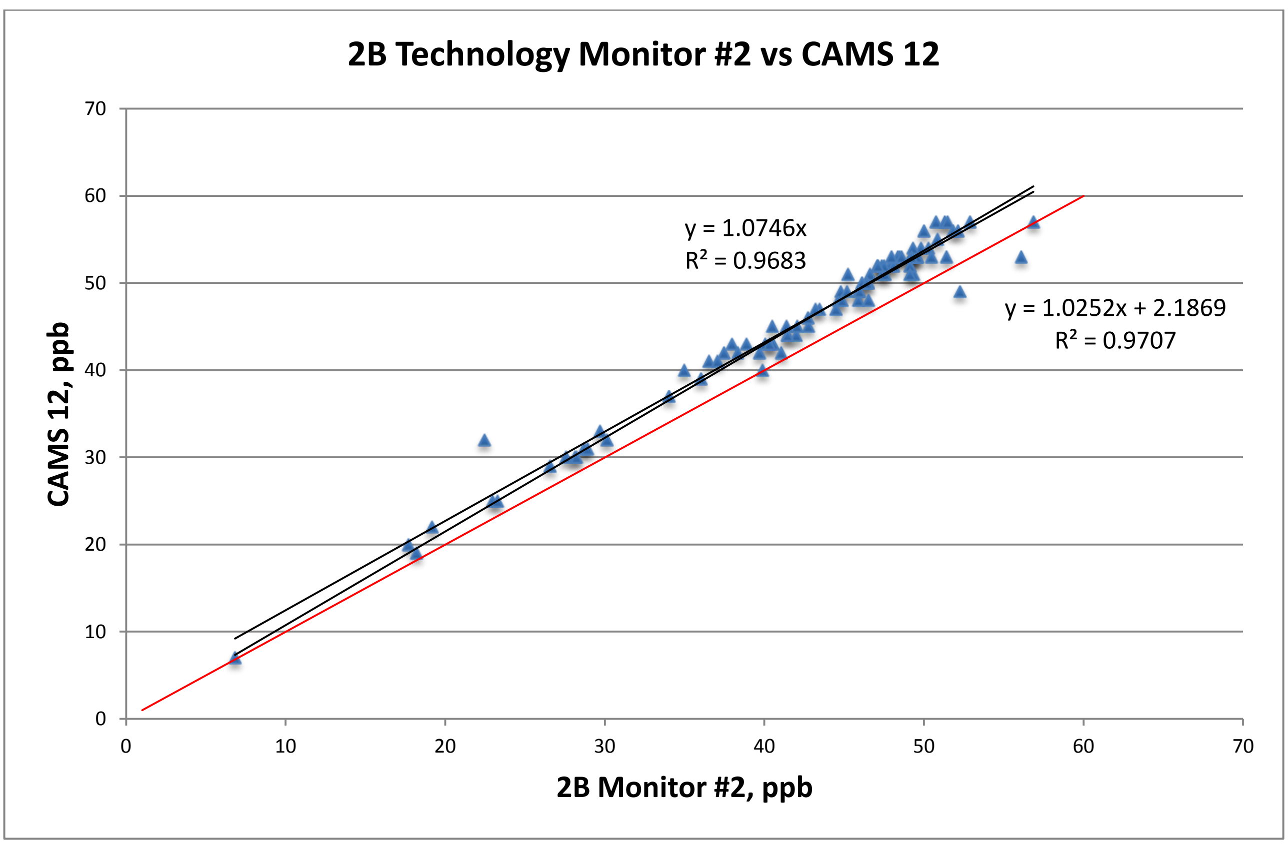


Figure B.7 Correlation between 2B Monitor #1 and CAMS 12

Table B.1 Concentration Values from the Tanabyte Analyzer and 2B Monitor using Standard Concentrations

7/2/12		
Standard Concentration	Tanabyte Analyzer	2B Monitor #2
0	0	1.5
50	52	47.5
100	96	87.7
150	147	138.1
200	198	188

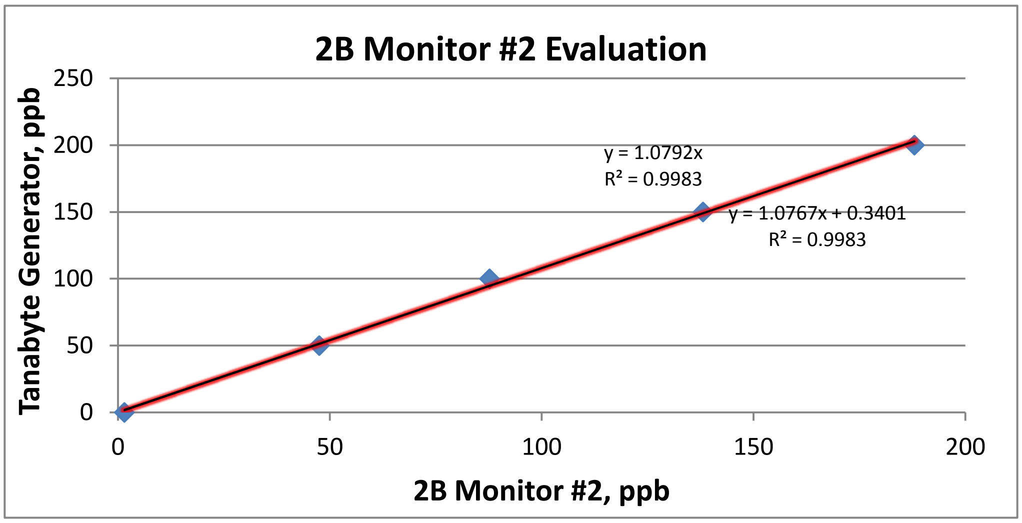


Figure B.8 Tanabyte Generated Ozone vs. 2B Monitor #2

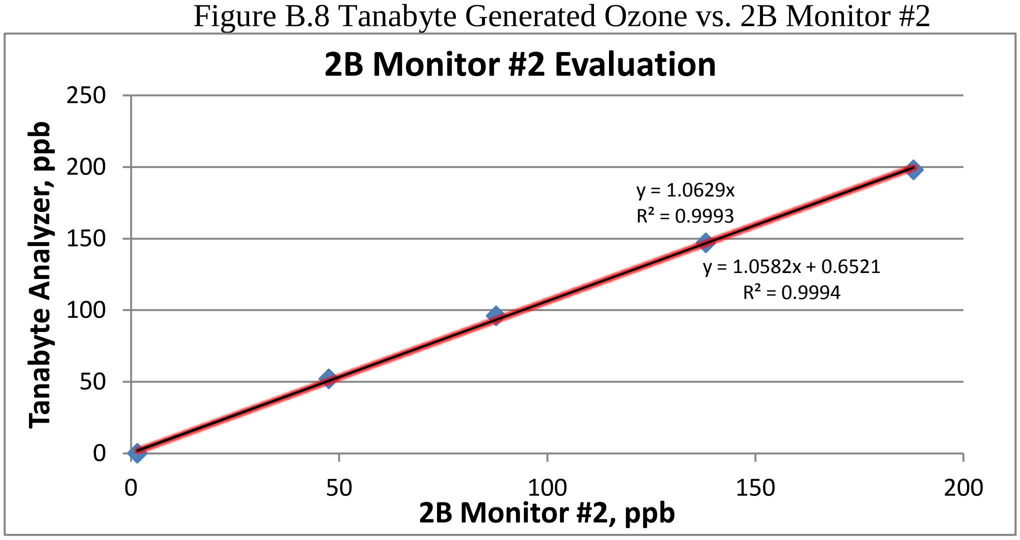


Figure B.9 Tanabyte Internal Analyzer vs. 2B Monitor #2

Table B.2 Concentration Values from the Tanabyte Analyzer and 2B Monitor using Standard Concentrations

7/25/12		
Standard Concentration	Tanabyte Analyzer	2B Monitor #1
0	5.42	0.4
50	49.74	41.6
100	99.69	91.1
150	150.06	138.1
200	200.19	186.9

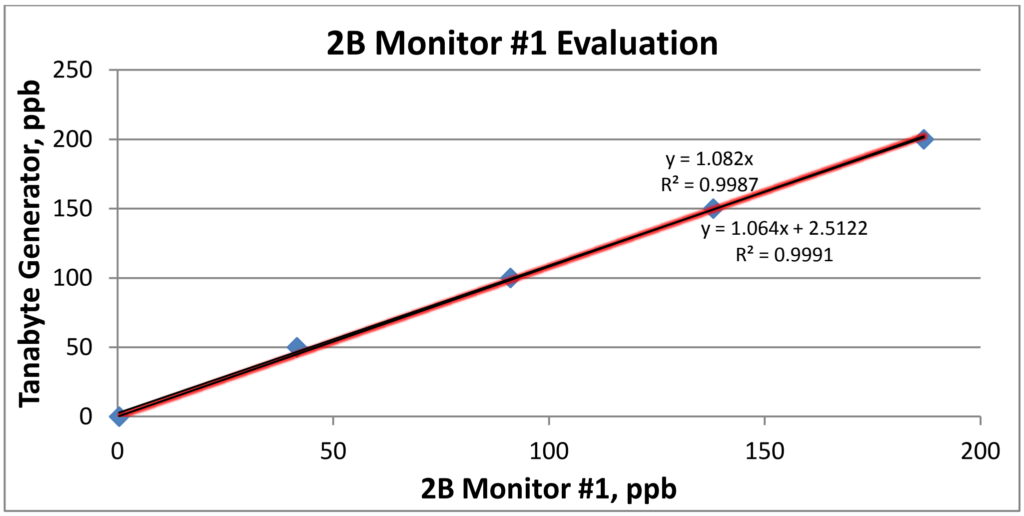


Figure B.10 Tanabyte Generated Ozone vs. 2B Monitor #1

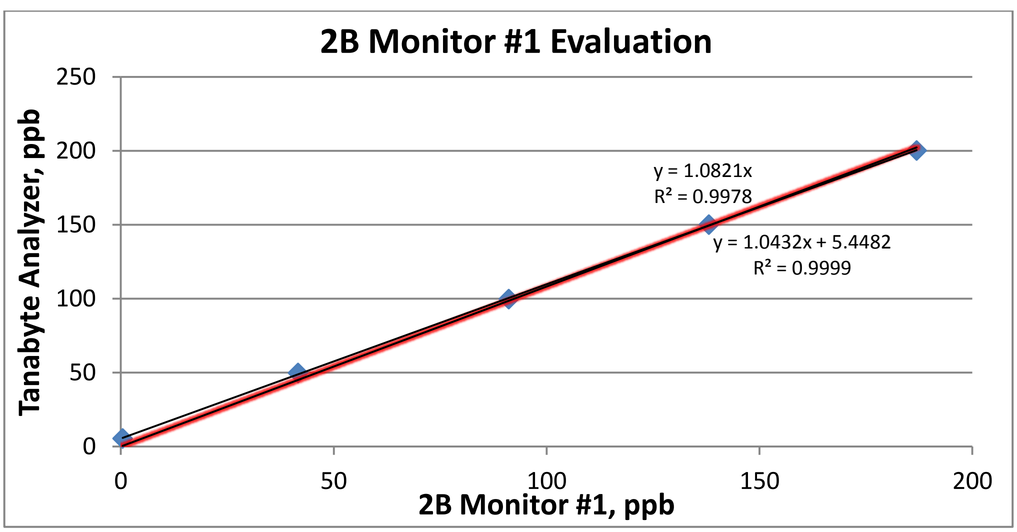


Figure B11 Tanabyte Internal Analyzer vs. 2B Monitor #1

Table B.3 Concentration Values from the Tanabyte Analyzer and 2B Monitor using Standard Concentrations

7/25/12		
Standard Concentration	Tanabyte Analyzer	2B Monitor #2
0	7.68	4.5
50	50.04	43
100	99.20	91.2
150	145.48	137.8
200	199.35	185.5

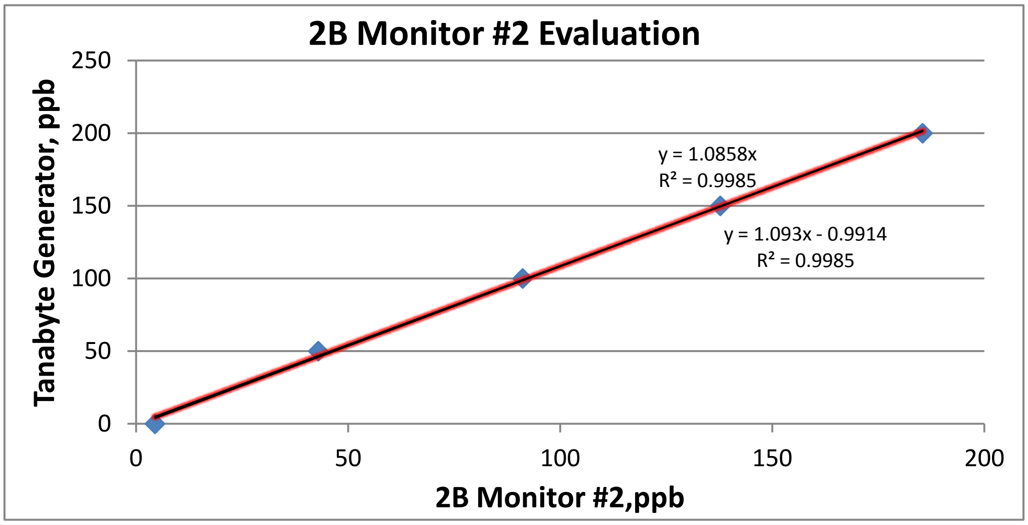


Figure B.12 Tanabyte Generated Ozone vs. 2B Monitor #2

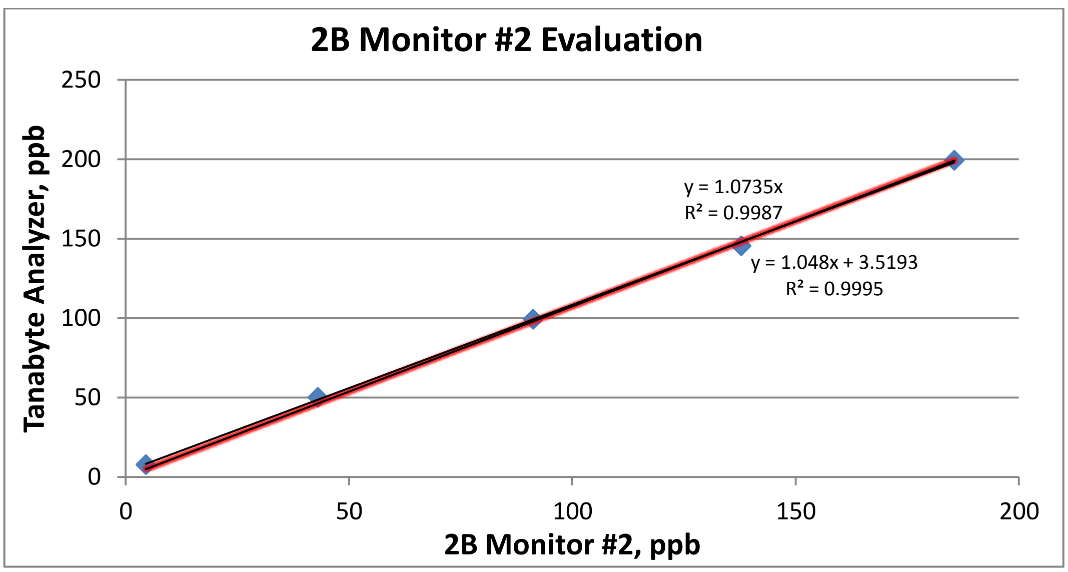


Figure B.13 Tanabyte Internal Analyzer vs. 2B Monitor #2

Table B.4 Concentration Values from the Tanabyte Analyzer and 2B Monitor using Standard Concentrations

8/3/12		
Standard Concentration	Tanabyte Analyzer	2B Monitor #1
0	12.73	8.6
50	48.83	44.2
100	95.41	92.6
150	151.07	142.4
200	200.29	198

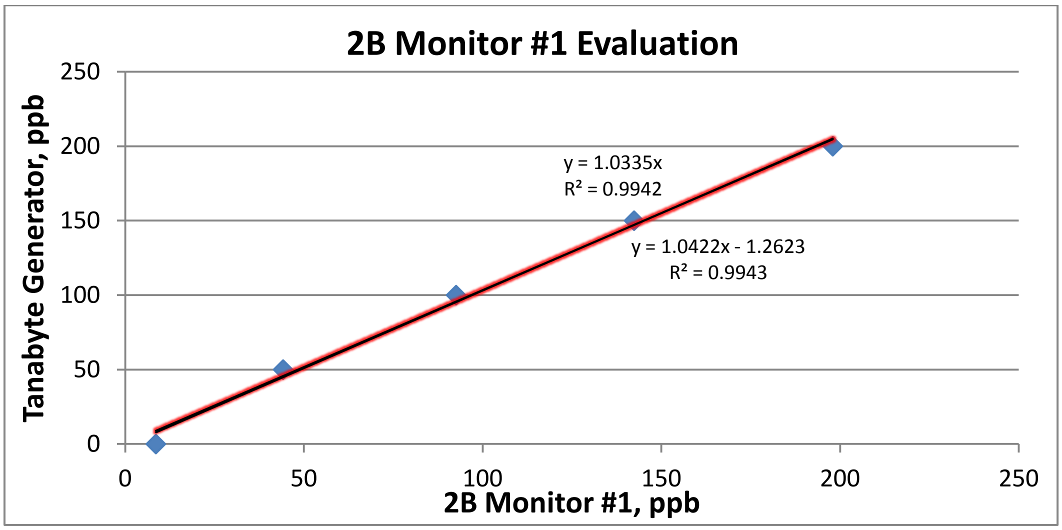


Figure B.14 Tanabyte Generated Ozone vs. 2B Monitor #1

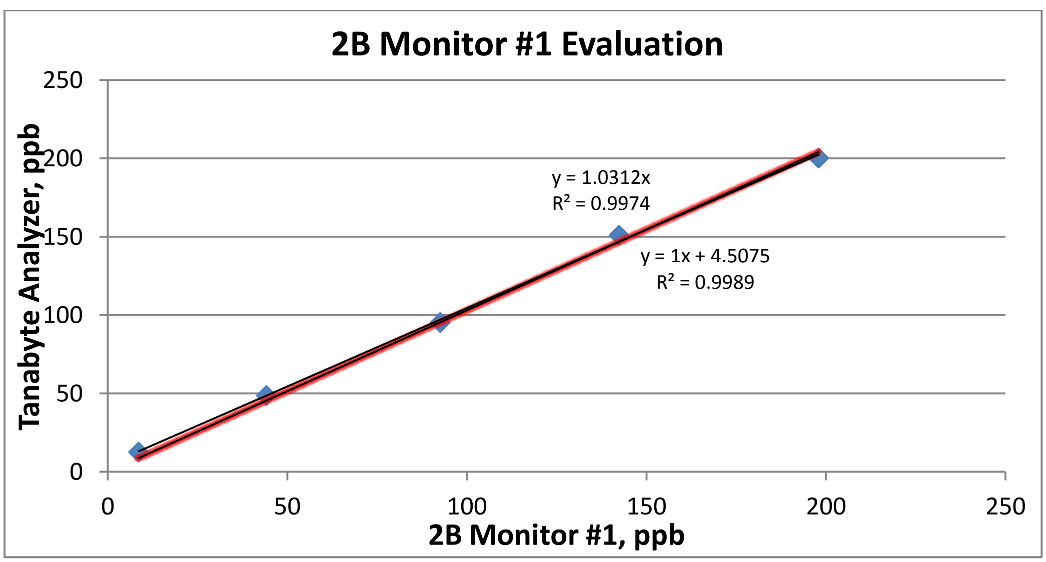


Figure B.15 Tanabyte Internal Analyzer vs. 2B Monitor #1

Table B.5 Concentration Values from the Tanabyte Analyzer and 2B Monitor using Standard Concentrations

8/3/12		
Standard Concentration	Tanabyte Analyzer	2B Monitor #2
0	10.03	7.1
50	50.20	44.2
100	99.57	91.4
150	150.03	137.9
200	198.70	188.1

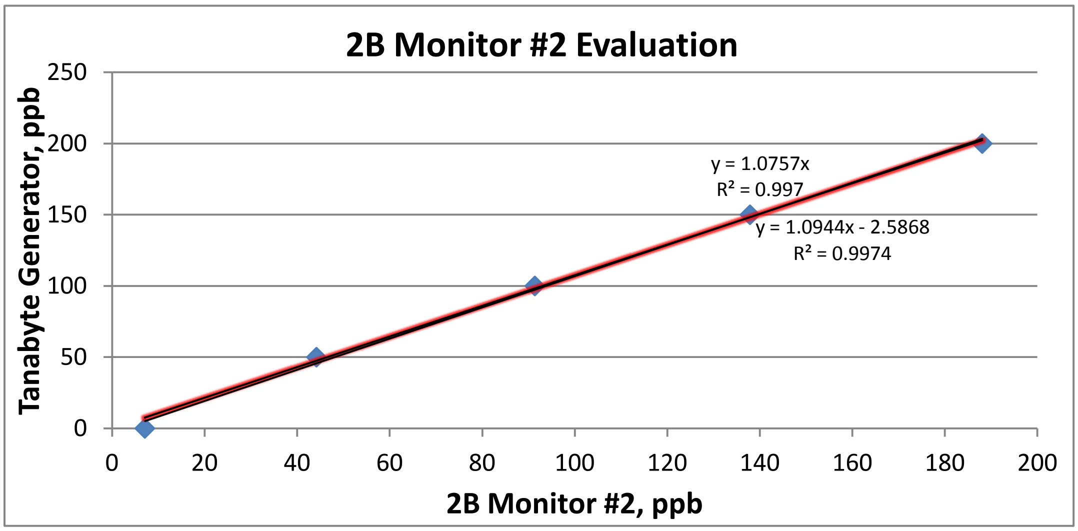


Figure B.16 Tanabyte Generated Ozone vs. 2B Monitor #2

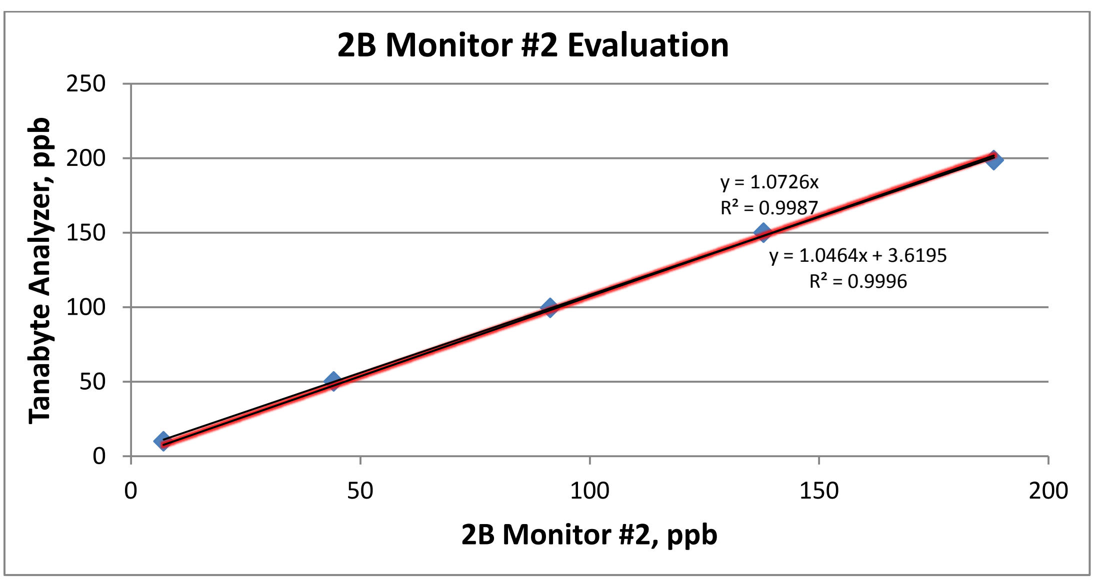


Figure B.17 Tanabyte Internal Analyzer vs. 2B Monitor #2

Table B.6 Concentration Values from the Tanabyte Analyzer and 2B Monitor using Standard Concentrations

9/5/12		
Standard Concentration	Tanabyte Analyzer	2B Monitor #1
0	6.11	2.1
50	49.66	46
100	99.06	93.4
150	149.35	144
200	198.59	195

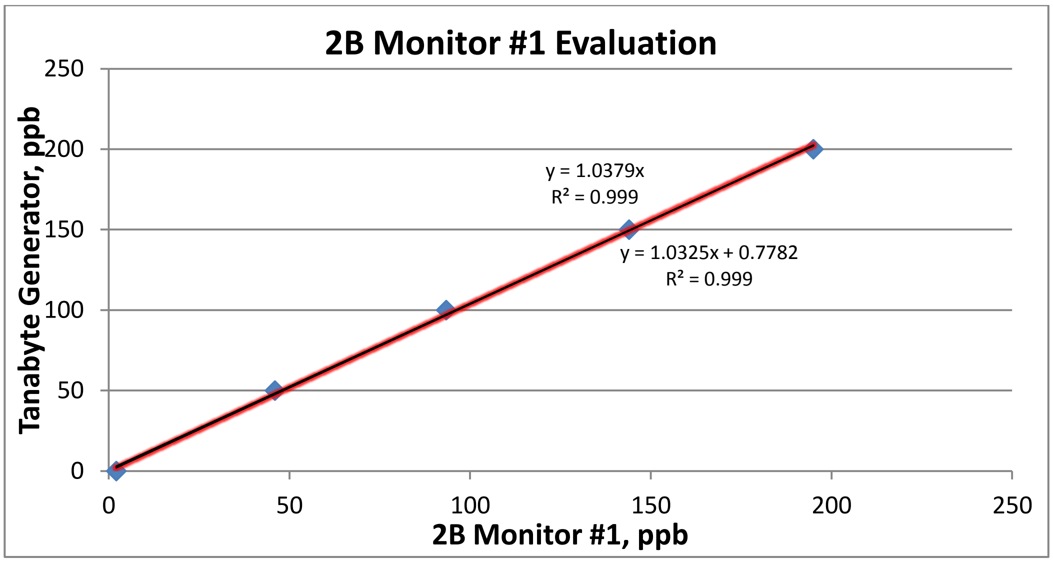


Figure B.18 Tanabyte Generated Ozone vs. 2B Monitor #1

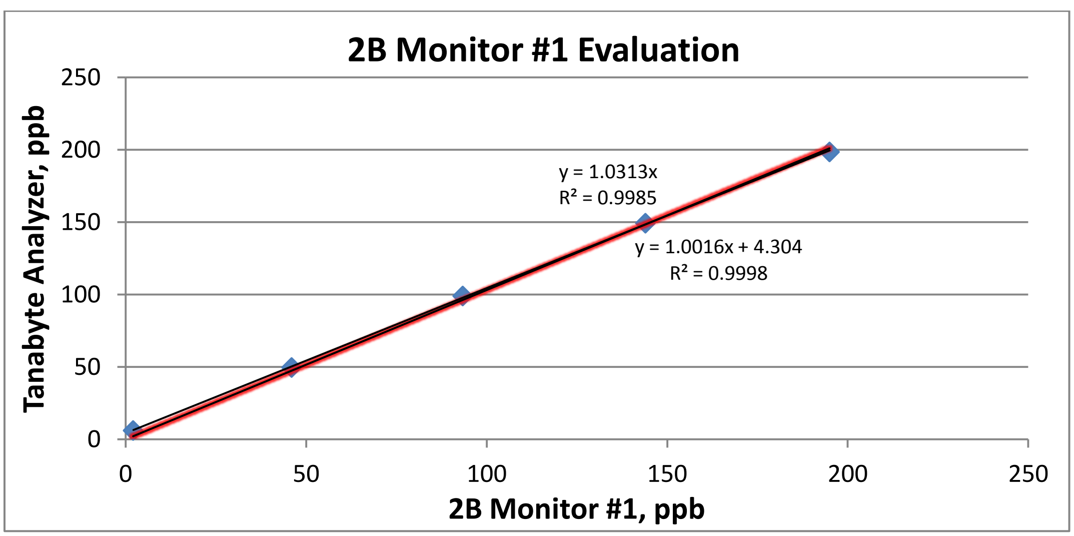


Figure B.19 Tanabyte Internal Analyzer vs. 2B Monitor #1

Table B.7 Concentration Values from the Tanabyte Analyzer and 2B Monitor using Standard Concentrations

9/5/12		
Standard Concentration	Tanabyte Analyzer	2B Monitor #2
0	5.81	7.6
50	49.64	45.6
100	100.22	92.9
150	149.38	140.1
200	198.00	188.5

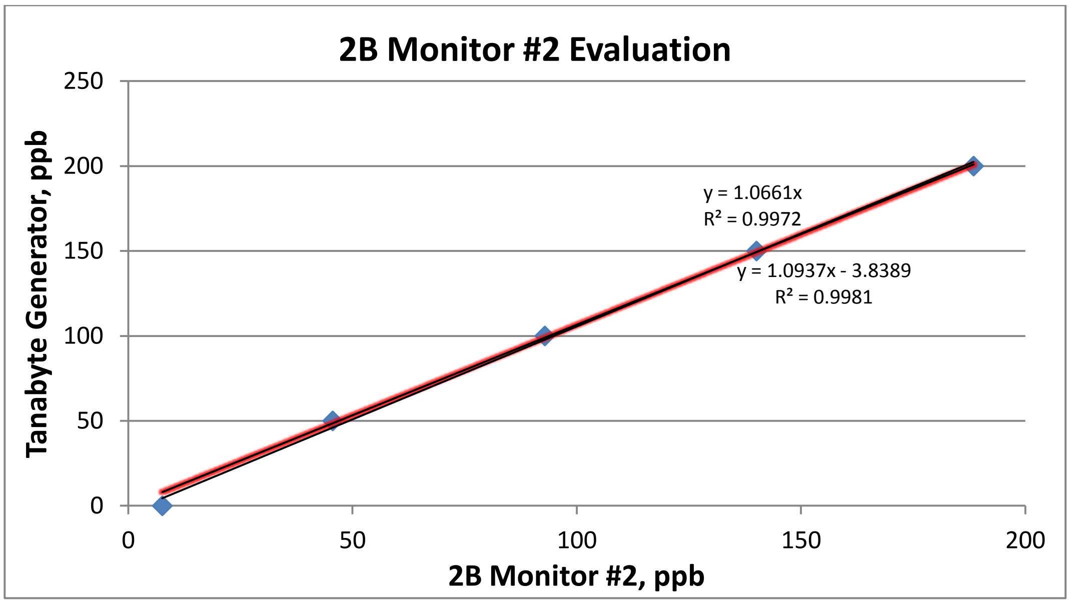


Figure B.20 Tanabyte Generated Ozone vs. 2B Monitor #2

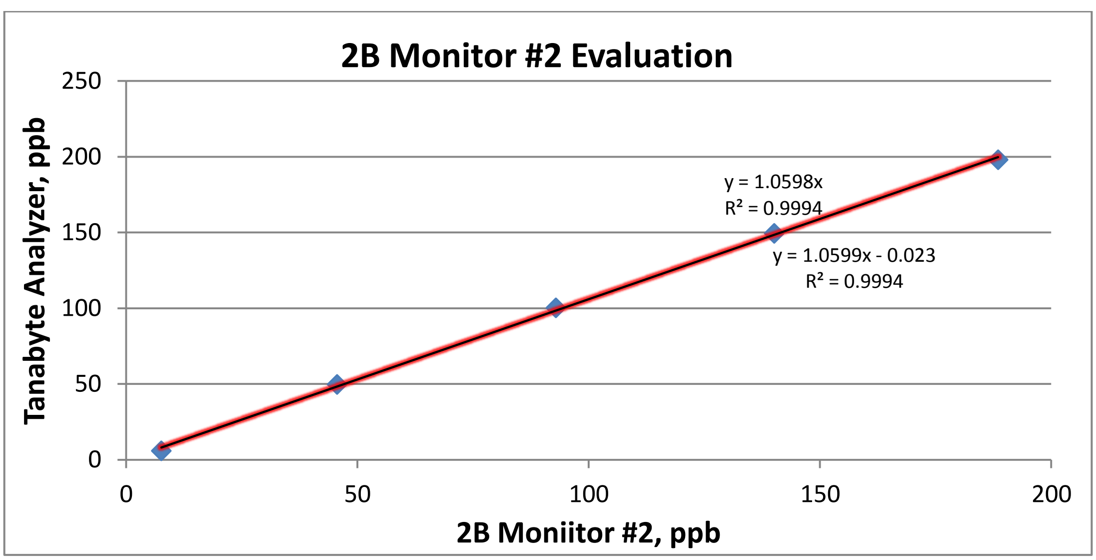


Figure B.21 Tanabyte Internal Analyzer vs. 2B Monitor #2

APPENDIX C: BUTTERFIELD LINEAR REGRESSION MODELS WITH CAMS 12 AND 41

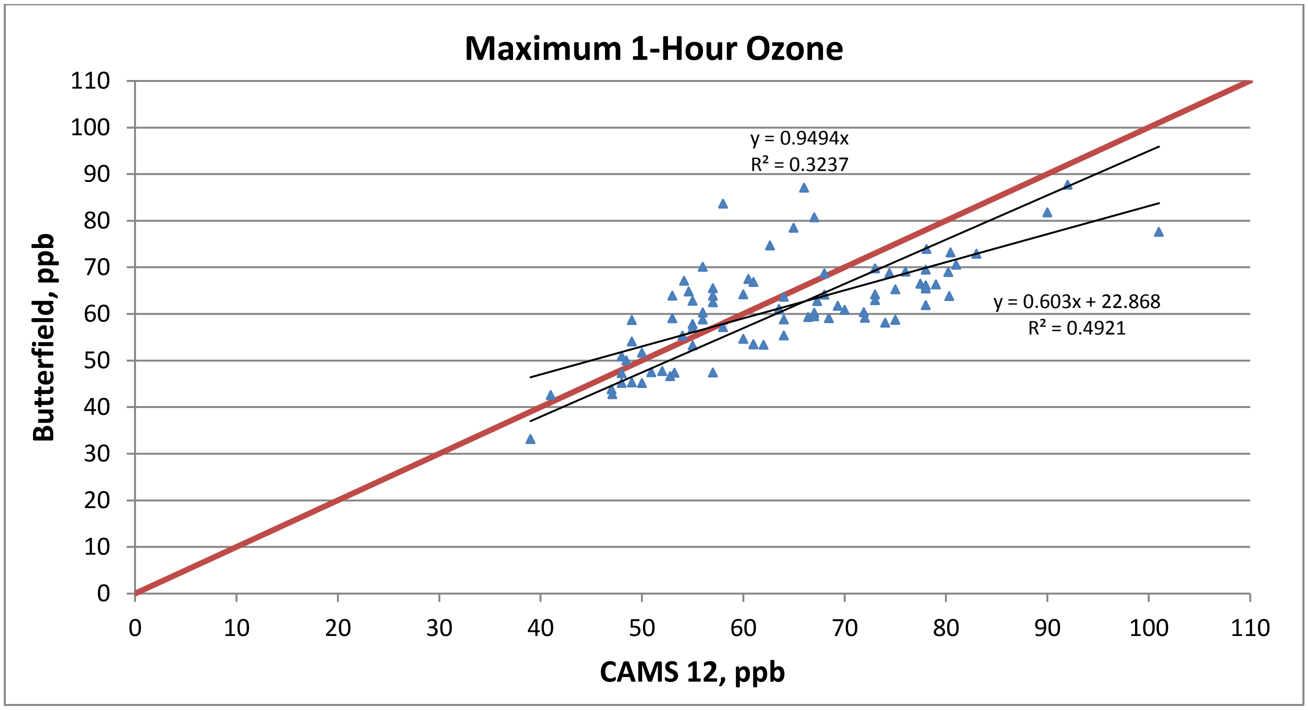


Figure C.1 Daily Maximum 1-hour averages dating from June 9, 2012 to September 1, 2012

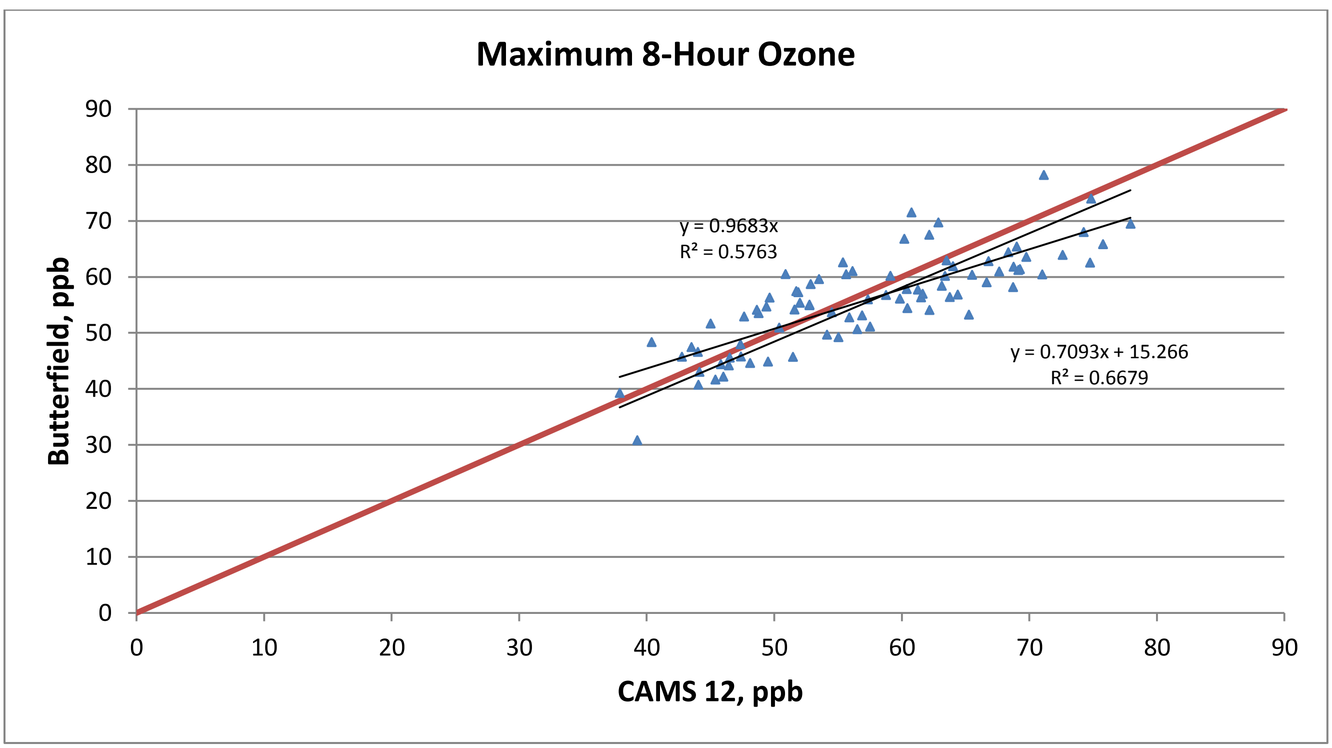


Figure C.2 Daily Maximum 8-hour average dating from June 9, 2012 to September 1, 2012

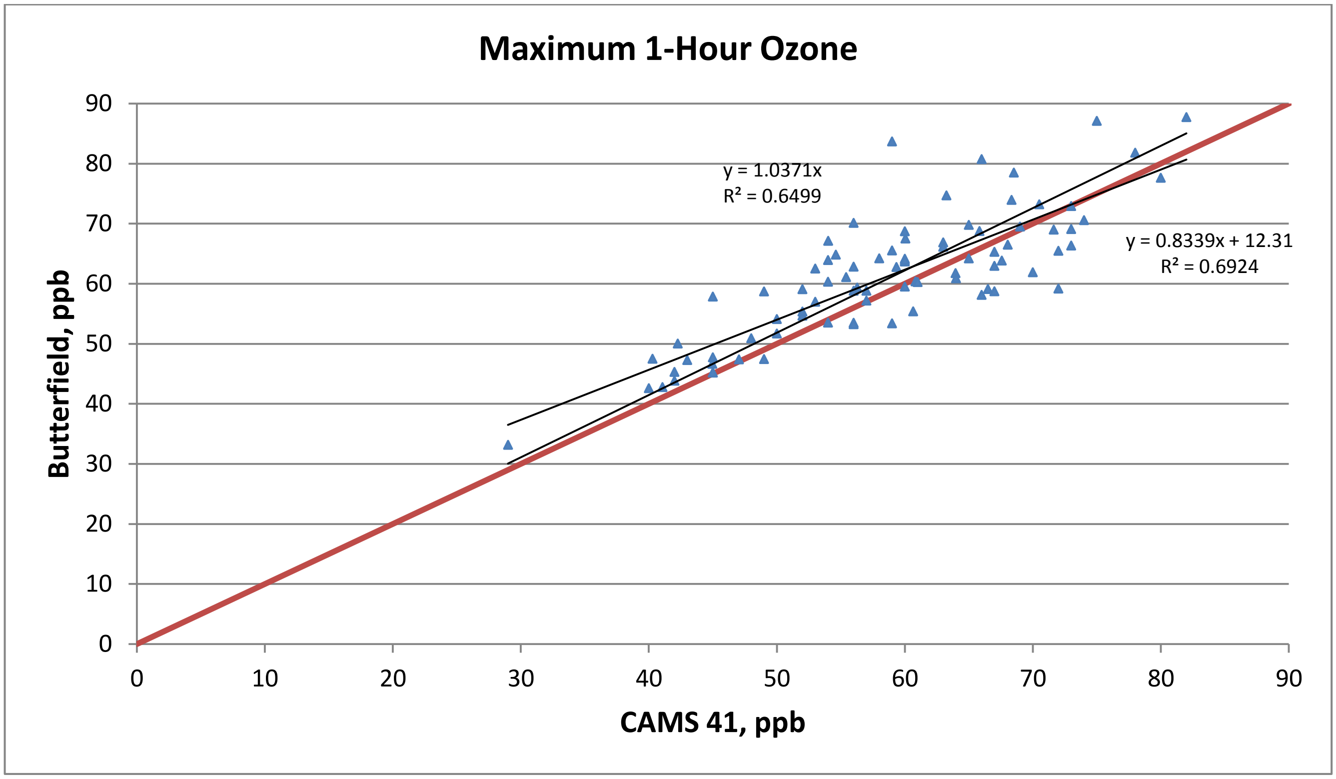


Figure C.3 Daily Maximum 1-hour averages dating from June 9, 2012 to September 1, 2012

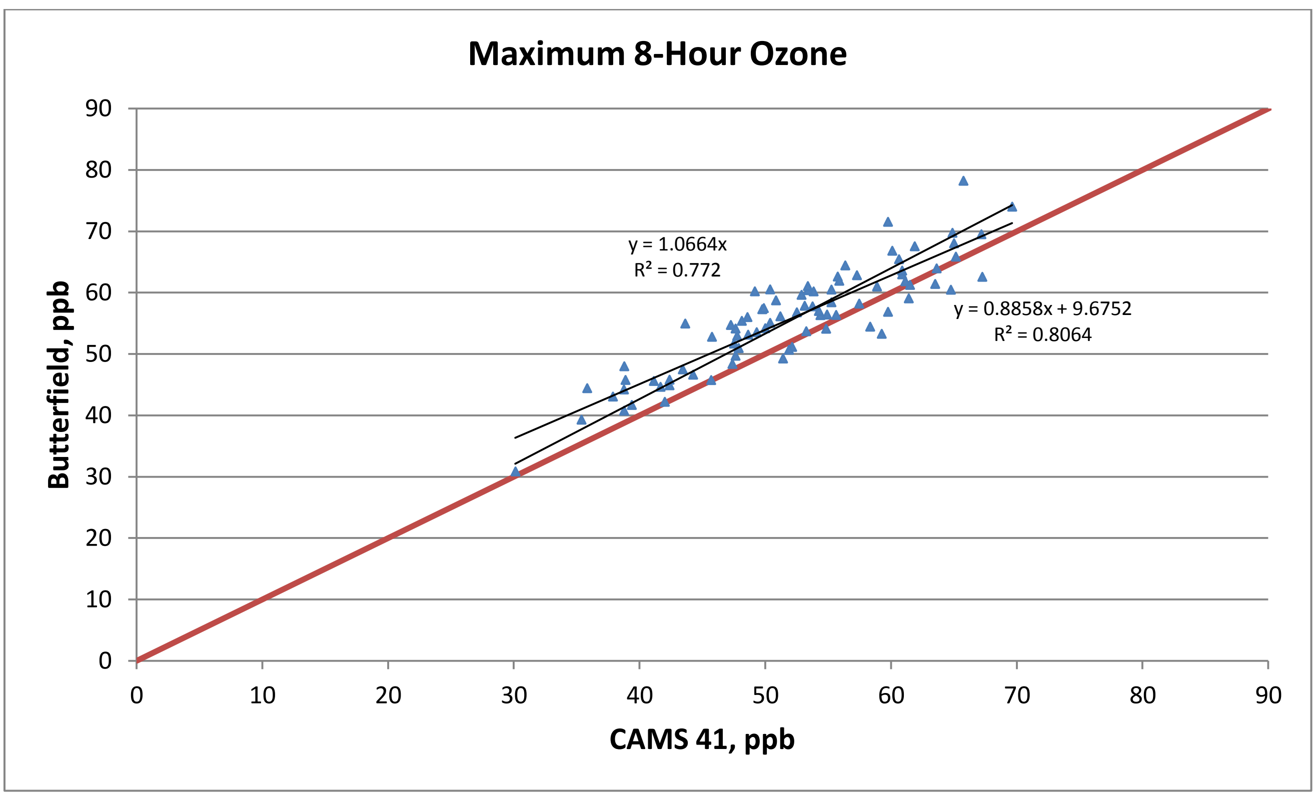
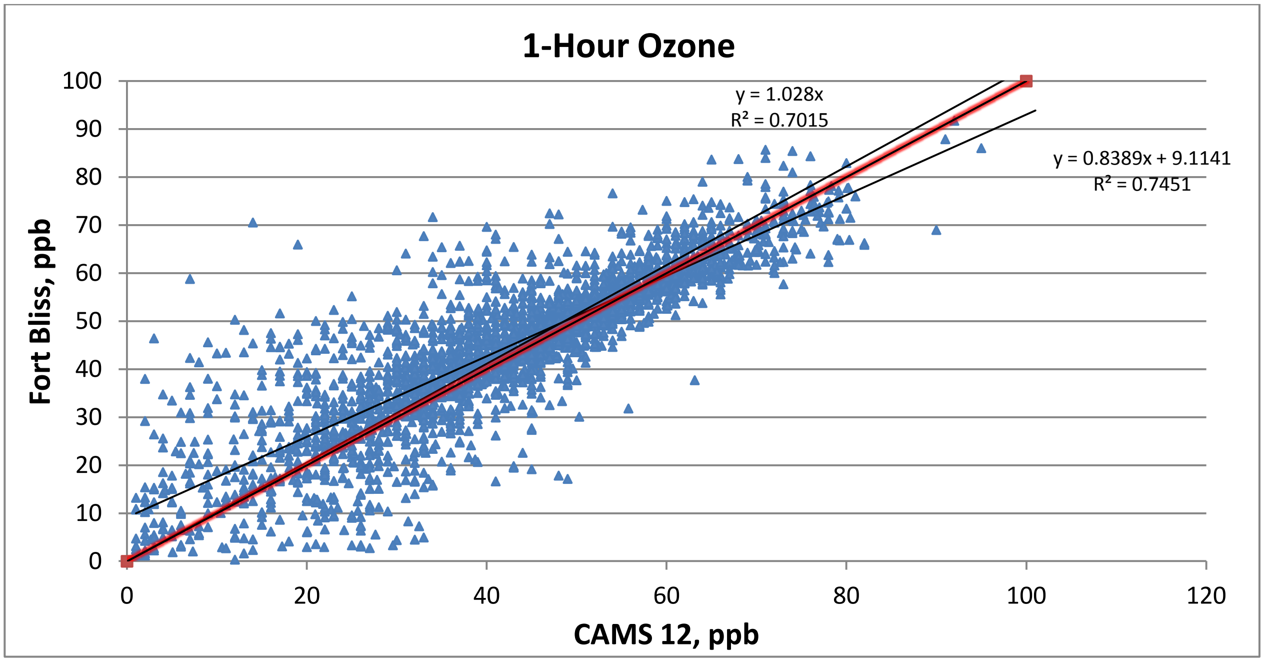
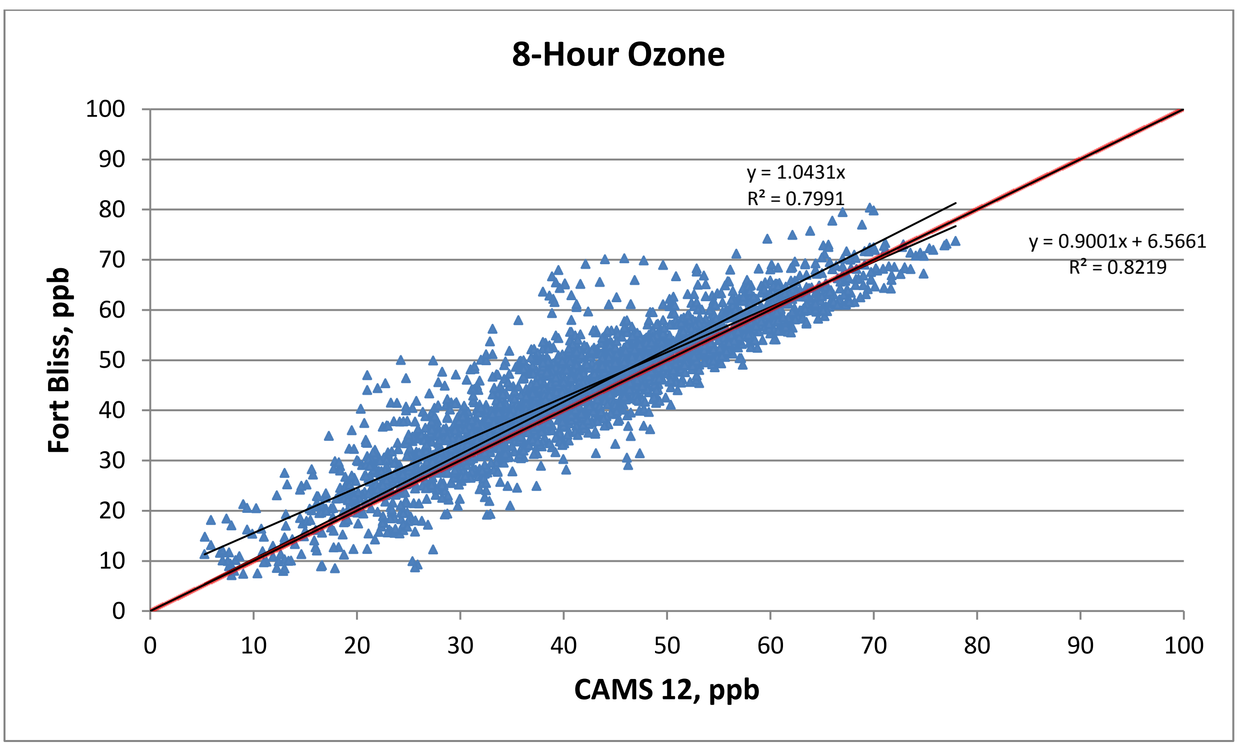


Figure C.4 Daily Maximum 8-hour average dating from June 9, 2012 to September 1, 2012

APPENDIX D: FINAL 1 AND 8-HOUR LINEAR REGRESSION MODELS OF FORT BLISS AND CAMS 12



D.1 Final 1-hour Linear Regression Model for Fort Bliss and CAMS 12



D.1 Final 1-hour Linear Regression Model for Fort Bliss and CAMS 12

VITA

Adrian Sandoval, only son of Rosa and Juan Sandoval attended Cathedral High School, El Paso, TX from 2001-2005. Once graduated from high school and for the following six years, Adrian worked as a PT Technician at Healthmasters Hand and Physical Therapy. Adrian began his college career in 2005 at the University of Texas at El Paso (UTEP) where he pursued a degree in Civil Engineering. He graduated with his Civil Engineering degree in Fall 2009 and pursued his graduate degree in Master of Science in Environmental Engineering in 2010. He was granted the opportunity to work as a research assistant in the Air Quality Lab under Professor Wen-Whai Li where he monitored and analyzed ozone at various sites around El Paso. In summer 2012 he was accepted to participate in the Border Air Quality Internship funded by the Environmental Protection Agency. For eight weeks he worked at El Paso Metropolitan Planning Organization continuing to monitor ozone in the PdN region, estimating cost per ton reductions for local ozone reduction strategies and counted heavy-duty trucks at truck stops to collect data needed for emissions inventory.

Permanent address: 6740 Morning Side Circle

El Paso, TX, 79904

This thesis/dissertation was typed by Adrian Michael Sandoval.