COLORADO

Air Pollution Control Division

Department of Public Health & Environment

Technical Services Program

2014 Air Quality Data Report

March 11, 2016

COLORADO AIR QUALITY DATA REPORT

2014

Air Pollution Control Division
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March 2016

This report is available electronically at http://www.colorado.gov/airquality/tech_doc_repository.aspx

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Glossary of Terms

APCD	Air Pollution Control Division
AQS	Air Quality System (EPA database)
ARS	Air Resources Specialists
BLM	Bureau of Land Management
CAMP	Continuous Air Monitoring Program
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Public Health and Environment
CFR	Code of Federal Regulations
CO	Carbon monoxide
EPA	U.S. Environmental Protection Agency
MSA	Metropolitan Statistical Area
NAAQS	National Ambient Air Quality Standards
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_x	Reactive nitrogen oxides
NO_y	Total reactive nitrogen
O_3	Ozone
Pb	Lead
$PM_{2.5}$	Particulate matter with an equivalent diameter less than or equal to 2.5 μm
PM_{10}	Particulate matter with an equivalent diameter less than or equal to 10 μm
ppb	Parts per billion (one part in 10^9)
ppm	Parts per million (one part in 10^6)
QA/QC	Quality Assurance/Quality Control
SIP	State Implementation Plan
SLAMS	State or Local Air Monitoring Stations
SO_2	Sulfur dioxide
SPM	Special Purpose Monitor
TSP	Total Suspended Paarticulates
μg	Microgram (10^{-6} grams)
USFS	U.S. Forest Service
VOC	Volatile Organic Compound

1

Introduction

The Air Pollution Control Division (APCD) of the Colorado Department of Public Health and Environment (CDPHE) has prepared the 2014 Air Quality Data Report as a companion document to the Colorado Air Quality Control Commission Report to the Public. The Air Quality Data Report addresses historical trends in air quality and includes a detailed examination of the monitoring data collected by the APCD in 2014. The Report to the Public discusses the policies and programs designed to improve and protect Colorado's air quality.

1.1 Overview of the Colorado Air Monitoring Network

The APCD currently operates monitors at 54 locations statewide. Ozone (O_3) and particulate matter (PM) monitors, including those for particulate matter < 10 μm in diameter (PM_{10}) and particulate matter < 2.5 μm in diameter ($PM_{2.5}$), are the most abundant and widespread. Currently, there are PM_{10} monitors at 28 separate locations, $PM_{2.5}$ monitors at 15 locations, and O_3 monitors at 20 locations. The APCD also operates 16 meteorological sites for the continuous measurement of wind speed, wind direction, and temperature.

1.1.1 APCD Monitoring History

The State of Colorado has been monitoring air quality statewide since the mid-1960s when high volume and tape particulate samplers, dustfall buckets, and sulfation candles were the state of the art for defining the magnitude and extent of the very visible air pollution problem. Monitoring for gaseous pollutants (CO, SO_2, NO_2, and O_3) began in 1965 when the federal government established the CAMP station in downtown Denver at the intersection of 21^{st} Street and Broadway, which was the area that was thought at the time to represent the best probability for detecting maximum levels of most of the pollutants of concern. Instruments were primitive by comparison with those of today and were frequently out of service.

Under provisions of the original Federal Clean Air Act of 1970, the Administrator of the U.S. EPA established National Ambient Air Quality Standards (NAAQS) designed to protect the public's health and welfare. Standards were set for total suspended particulates (TSP), CO, SO_2, NO_2, and O_3. In 1972, the first State Implementation Plan (SIP) was submitted to the EPA. It included an air quality surveillance system in accordance with EPA regulations of August 1971. That plan proposed a monitoring network of 100 monitors (particulate and gaseous) statewide. The system established as a result of that plan and subsequent modifications consisted of 106 monitors.

The 1977 Clean Air Act Amendments required States to submit revised SIPs to the EPA by January 1, 1979. The portion of the Colorado SIP pertaining to air monitoring was submitted separately on December 14, 1979, after a comprehensive review, and upon approval by the Colorado Air Quality Control Commission. The 1979 EPA requirements as set forth in 40 CFR 58.20 have resulted in considerable modification to the network. These and subsequent modifications are made to ensure consistency and compliance with Federal monitoring requirements. Station location, probe siting, sampling methodology, quality assurance practices, and data handling procedures are all maintained throughout any changes made to the network.

1.1.2 Description of Monitoring Regions in Colorado

The state has been divided into eight multi-county areas that are generally based on topography and have similar airshed characteristics. These areas are the Central Mountains, Denver Metro/North Front Range, Eastern High Plains, Pikes Peak, San Luis Valley, South Central, Southwestern, and Western Slope regions. Figure 1.1 shows the approximate boundaries of these regions.

In the past, this report has used a five-region classification system. While this served a topographic and climatologic purpose, the Division has determined the eight area approach to more accurately reflect local air pollution conditions.

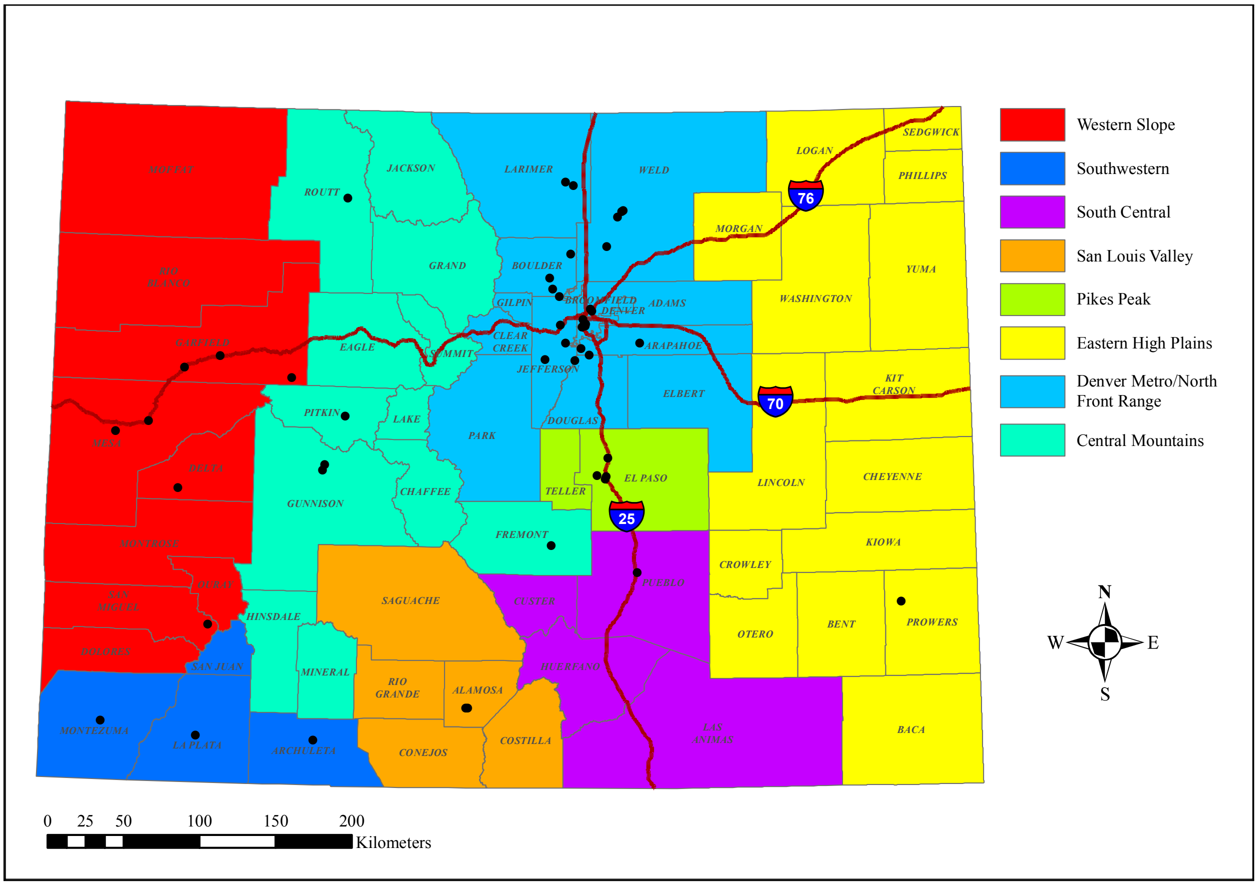


Figure 1.1: Counties and multi-county monitoring regions discussed in this report.

1.1.2.1 Central Mountains Region

The Central Mountains region consists of 12 counties in the central area of the state. The Continental Divide passes through much of this region. Mountains and mountain valleys are the dominant landscape features. Leadville, Steamboat Springs, Cañon City, Salida, Buena Vista, and Aspen represent the larger communities. The population of this region is about 256,642, according to 2010 U.S. Census Bureau data. Skiing, tourism, ranching, mining, and correctional facilities are the primary industries. Black Canyon of the Gunnison National Park is located in this region. All of the area complies with federal air quality standards.

The primary monitoring concern in this region is centered around particulate pollution from wood burning and road dust. Currently, there are five particulate monitoring sites operated by the APCD in the Central Mountains region. APCD does not currently operate any gaseous monitors in this region.

1.1.2.2 Denver Metro / North Front Range Region

The Denver-Metro/North Front Range region includes Adams, Arapahoe, Boulder, Broomfield, Clear Creek, Denver, Douglas, Elbert, Gilpin, Jefferson, Larimer, Park, and Weld counties. It includes the largest population area of the state, with 2.5 million people living in the seven-county Denver-metro area and another 847,000 living in the northern Front Range area of Boulder, Larimer, and Weld counties. This area includes Rocky Mountain National Park and several other wilderness areas.

Since 2002, the region complies with all National Ambient Air Quality Standards, except for ozone. The area has been exceeding the EPA's current ozone standards since the early 2000s, and in 2007 was formally designated as a "nonattainment" area. This designation was re-affirmed in 2012 when the EPA designated the region as a "marginal" nonattainment area after a more stringent ozone standard was adopted in 2008.

In the past, the Denver-metropolitan area has violated health-based air quality standards for carbon monoxide and fine particles. In response, the Regional Air Quality Council (RAQC), the Colorado Air Quality Control Commission (CAQCC), and the APCD developed, adopted, and implemented air quality improvement plans to reduce each of these pollutants.

For the rest of the Northern Front Range, Fort Collins, Longmont, and Greeley were nonattainment areas for carbon monoxide in the 1980s and early 1990s, but have met the federal standards since 1995. Air quality improvement plans have been implemented for each of these communities.

Currently, there are 27 gaseous pollutant monitors at 16 sites and 25 particulate monitors at 15 sites in the Northern Front Range Region, not including collocated monitors. There are six CO, 14 O_3, four NO_2, one NO_y, and three SO_2 monitoring sites. There are 10 PM_{10} and 13 $PM_{2.5}$ monitoring sites. There are two air toxics monitoring sites, one located at CAMP, and one at Platteville. The CAMP site monitors urban air toxics, while the Platteville site monitors air toxics in a region of oil and gas development.

1.1.2.3 Eastern High Plains Region

The Eastern High Plains region encompasses the counties on the plains of eastern Colorado. The area is semiarid and often windy. The area's population is approximately 137,009 according to U.S. Census Bureau estimates. Its major population centers have developed around farming, ranching, and trade centers such as Sterling, Fort Morgan, Limon, La Junta, and Lamar. The agricultural base includes both irrigated and dry land farming. All of the area complies with federal air quality standards.

Historically, there have been a number of communities that were monitored for particulates and meteorology but not for any of the gaseous pollutants. In the northeast along the I-76 corridor, the communities of Sterling, Brush, and Fort Morgan have been monitored. Along the I-70 corridor, only the community of Limon has been monitored for particulates. Along the US-50/Arkansas River corridor, the Division has monitored for particulates in the communities of La Junta and Rocky Ford. These monitoring sites were all discontinued in the late 1970s and early 1990s after a review showed that the concentrations were well below the standards and trending downward.

1.1.2.4 Pikes Peak Region

The Pikes Peak region includes El Paso and Teller counties. The area has a population of approximately 645,613 according to the 2010 U.S. Census. Eastern El Paso County is rural prairie, while the western part of the region is mountainous. The U.S. Government is the largest employer in the area, and major industries include Fort Carson and the U.S. Air Force Academy in Colorado Springs, both military installations. Aerospace and technology are also large employers in the area. All of the area is currently in compliance with federal air quality standards. However, some exceedances of the SO_2 standard have been recently observed at the Highway 24 site. These occasional high values have not yet resulted in a violation of the NAAQS.

Currently, there are four gaseous pollutants monitors at three sites and one particulate monitoring site in the Pikes Peak Region. There is one CO monitor, one SO_2 monitor, and two O_3 monitors, as well as one PM_{10} and one $PM_{2.5}$ monitor in the region.

1.1.2.5 San Luis Valley Region

Colorado's San Luis Valley region is in the south central portion of Colorado and is comprised of a broad alpine valley situated between the Sangre de Cristo Mountains on the northeast and the San Juan Mountains of the Continental Divide to the west. The valley is some 114 km wide and 196 km long, extending south into New Mexico. The average elevation is 2290 km. Principal towns include Alamosa, Monte Vista, and Del Norte. The population is about 45,315 according to U.S. Census Bureau estimates. Agriculture and tourism are the primary industries. The valley is semiarid and croplands of potatoes, head lettuce, and barley are typically irrigated. The valley is home to Great Sand Dunes National Park. All of the area complies with federal air quality standards.

Currently, there are no gaseous and two particulate monitoring sites in the area. The two PM_{10} monitoring sites are both located in Alamosa and have both recorded exceedance of the PM_{10} standard.

1.1.2.6 South Central Region

The South Central region is comprised of Pueblo, Huerfano, Las Animas, and Custer counties. Its population is approximately 185,536 according to the 2010 U.S. Census. Population centers include Pueblo, Trinidad, and Walsenburg. The region has rolling semiarid plains to the east and is mountainous to the west. All of the area complies with federal air quality standards. In the past the APCD has conducted particulate monitoring in both Walsenburg and Trinidad, but that monitoring was discontinued in 1979 and 1985, respectively, due to low concentrations. Currently, there are no gaseous pollutant monitoring sites and one particulate monitoring site in the South Central Region. There is one PM_{10} and one $PM_{2.5}$ monitor located in Pueblo.

1.1.2.7 Southwestern Region

The Southwestern region includes the Four Corners area counties of Montezuma, La Plata, Archuleta, and San Juan. The population of this region is about 89,652, according to the 2010 U.S. Census. The landscape includes mountains, plateaus, high valleys, and canyons. Durango and Cortez are the largest towns, while lands of the Southern Ute and Ute Mountain Ute tribes make up large parts of this region. The region is home to Mesa Verde National Park. Tourism and agriculture are the dominant industries, although the oil and gas industry is becoming increasingly important. All of the area complies with federal air quality standards.

Currently there is one gaseous and three particulate monitoring stations in the region. There is one O_3 monitor, two PM_{10} monitors, and one $PM_{2.5}$ monitor.

1.1.2.8 Western Slope Region

The Western Slope region includes nine counties on the far western border of Colorado. A mix of mountains on the east, and mesas, plateaus, valleys, and canyons to the west form the landscape of this region. Grand Junction is the largest urban area, and other cities include Telluride, Montrose, Delta, Rifle, Glenwood Springs, Meeker, Rangely, and Craig. The population of this region is about 309,660, according to the 2010 U.S. Census. Primary industries include ranching, agriculture, mining, energy development, and tourism. Dinosaur and Colorado National Monuments are located in this region.

The Western Slope, along with the central mountains, are projected to be the fastest growing areas of Colorado through 2020 with greater than two percent annual population increases, according to the Colorado Department of Local Affairs. All of the area complies with federal air quality standards.

1.1.3 Monitoring Site Locations and Parameters Monitored

Table 1.1: Summary of parameters monitored at APCD monitoring sites discussed in this report. Detailed site descriptions can be found in Appendix A.

AQS Site Number	Site Name	County	Parameters Monitored						
			O_3	CO	NO_2	SO_2	PM_{10}	$PM_{2.5}$	Met
08-001-0006	Alsup	Adams					X	X	X
08-001-3001	Welby	Adams	X	X	X	X	X		X
08-003-0001	Alamosa - ASC	Alamosa					X		
08-003-0003	Alamosa - Mun. Bldg.	Alamosa					X		
08-005-0002	Highland Reservoir	Arapahoe	X						X
08-005-0005	Arapaho Comm. College (ACC)	Arapahoe						X	
08-005-0006	Aurora - East	Arapahoe	X						X
08-007-0001	Pagosa Springs School	Archuleta					X		
08-013-0003	Longmont - Mun. Bldg.	Boulder					X	X	
08-013-0011	South Boulder Creek	Boulder	X						
08-013-0012	Boulder Chamber of Comm.	Boulder					X	X	
08-029-0004	Delta - Health Dept.	Delta					X		
08-031-0002	CAMP	Denver	X	X	X	X	X	X	X
08-031-0017	Denver Visitor Center	Denver					X		
08-031-0026	La Casa	Denver	X	X	X	X	X	X	X
08-031-0027	I-25 Denver	Denver		X	X		X	X	X
08-035-0004	Chatfield State Park	Douglas	X					X	X
08-041-0013	U.S. Air Force Academy	El Paso	X						
08-041-0015	Highway 24	El Paso		X		X			
08-041-0016	Manitou Springs	El Paso	X						
08-041-0017	Colorado College	El Paso					X	X	
08-043-0003	Cañon City	Fremont					X		
08-045-0005	Parachute	Garfield					X		
08-045-0007	Rifle - Henry Bldg.	Garfield					X		
08-045-0012	Rifle - Health Dept.	Garfield	X						
08-045-0018	Carbondale	Garfield					X		
08-051-0004	Crested Butte	Gunnison					X		
08-051-0007	Mt. Crested Butte	Gunnison					X		
08-059-0005	Welch	Jefferson	X						X
08-059-0006	Rocky Flats - N	Jefferson	X						X
08-059-0011	NREL	Jefferson	X						
08-059-0013	Aspen Park	Jefferson	X						X
08-067-0004	Durango	La Plata					X		
08-069-0009	Ft. Collins - CSU	Larimer					X	X	
08-069-0011	Ft. Collins - West	Larimer	X						
08-069-1004	Ft. Collins - Mason	Larimer	X	X					X
08-077-0017	Grand Junction - Powell Bldg.	Mesa					X	X	
08-077-0018	Grand Junction - Pitkin	Mesa		X					X
08-077-0020	Palisade	Mesa	X						X
08-081-0002	Lay Peak	Moffat	X						X
08-083-0006	Cortez - Health Dept.	Montezuma	X					X	
08-097-0006	Aspen - Library	Pitkin					X		
08-099-0002	Lamar - Mun. Bldg.	Prowers					X		
08-101-0015	Pueblo	Pueblo					X	X	
08-107-0003	Steamboat Springs	Routt					X		
08-113-0004	Telluride	San Miguel					X		
08-123-0006	Greeley - Hospital	Weld					X	X	
08-123-0008	Platteville	Weld						X	
08-123-0009	Greeley - County Tower	Weld	X						X
08-123-0010	Greeley - West Annex	Weld		X					

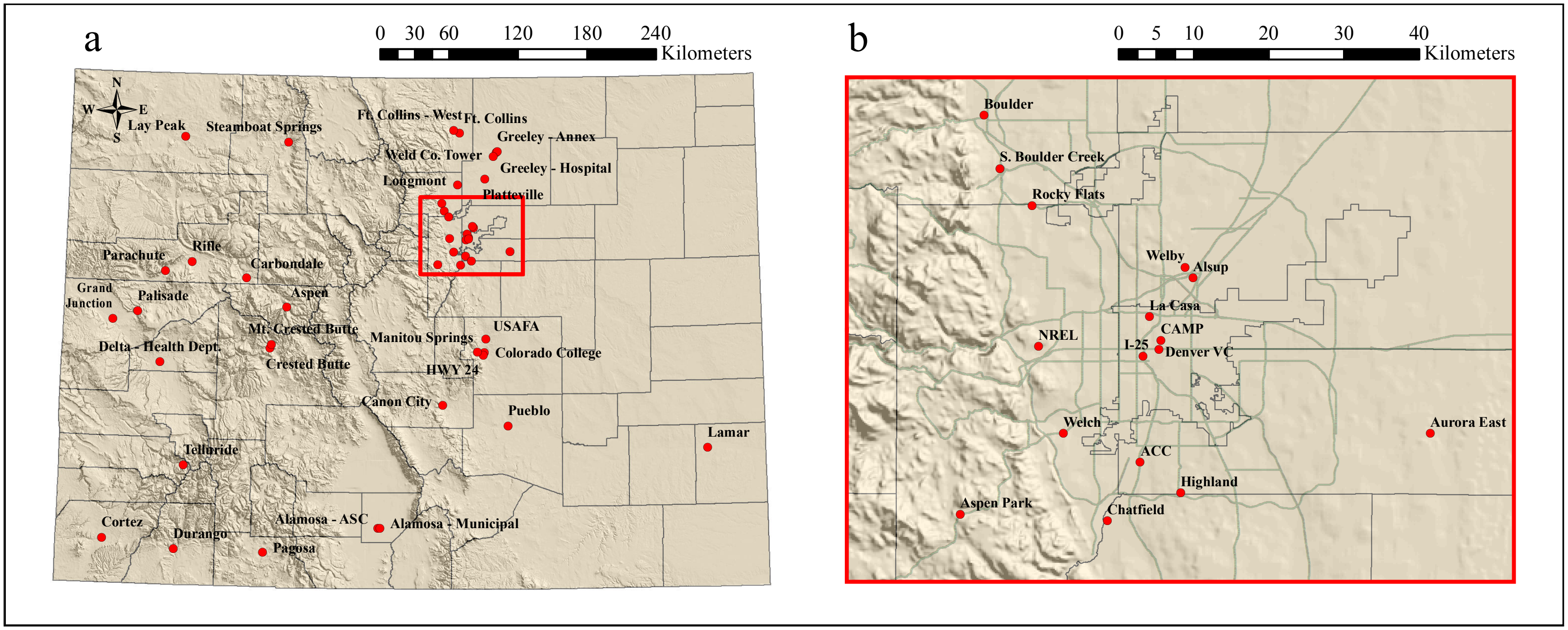


Figure 1.2: Map of (a) Colorado with an inset map of (b) the Denver metropolitan area showing the location of all monitoring sites operated by the APCD and listed in Table 1.1. For the purpose of improving the readability of (a), site labels for the Ft. Collins - CSU and Ft. Collins - Mason sites have been combined as "Ft. Collins," the Rifle - Henry Bldg. and Rifle - Health Dept. site labels have been combined as "Rifle" and the Grand Junction - Powell Bldg. and Grand Junction - Pitkin site labels have been combined as "Grand Junction." Detailed site information, including AQS identification numbers, site descriptions and histories, addresses and coordinates, monitoring start dates, site elevations, site orientation/scale designations, etc., can be found in Appendix A.

2

Criteria Pollutants

Criteria pollutants are those for which the federal government has established National Ambient Air Quality Standards in the Federal Clean Air Act and its amendments. There are six criteria pollutants. They are carbon monoxide (CO), ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), lead (Pb), and particulate matter which is currently split into PM_{10} and $PM_{2.5}$ size fractions. The primary $PM_{2.5}$ standard was lowered from 15 µg m^{-3} to 12 µg m^{-3} by the EPA on Dec. 14th 2012. The final rule making was effective on March 18th 2013. This rule making was an effort to provide increased protection from the health effects associated with $PM_{2.5}$ air pollution. The standards for criteria pollutants are established to protect the most sensitive members of society. These are usually defined as those with heart and/or respiratory problems, the very young, and the elderly. The standards for each of the criteria pollutants are discussed in the following sections. A summary of these levels is presented in Table 2.1. The primary standards are set to protect human health. The secondary standards are set to protect public welfare, and take into consideration such factors as crop damage, architectural damage, damage to ecosystems, and visibility in scenic areas.

Table 2.1: National Ambient Air Quality Standards (NAAQS) for criteria pollutants.

Pollutant	**Primary / Secondary**	**Averaging Time**	**Level**	**Form**
Carbon Monoxide (CO)	Primary	8-hr	9 ppm	Not to be exceeded more than once per year
		1-hr	35 ppm	
Nitrogen Dioxide (NO_2)	Primary	1-hr	100 ppb	98th percentile of 1-hour daily maximum concentrations, averaged over 3 years
	Primary and Secondary	Annual	53 ppb	Annual mean
Sulfur Dioxide (SO_2)	Primary	1-hr	75 ppb	99th percentile of 1-hour daily maximum concentrations, averaged over 3 years
	Secondary	3-hr	0.5 ppm	Not to be exceeded more than once per year
Ozone (O_3)	Primary and Secondary	8-hr	0.075 ppm	Annual fourth-highest daily maximum 8-hr concentration, averaged over 3 years
PM_{10}	Primary and Secondary	24-hr	150 µg m^{-3}	Not to be exceeded more than once per year on average over 3 years
$PM_{2.5}$	Primary	Annual	12 µg m^{-3}	Annual mean, averaged over 3 years
	Secondary	Annual	15 µg m^{-3}	Annual mean, averaged over 3 years
	Primary and Secondary	24-hr	35 µg m^{-3}	98th percentile, averaged over 3 years

2.1 Summary of Exceedances

Table 2.2 is a summary of the APCD sites that have recorded exceedances of the ambient air quality standards in the last two years, with the number of days in exceedance listed. An exceedance of a NAAQS is defined in 40 CFR 50.1 as "one occurrence of a measured or modeled concentration that exceeds the specified concentration level of such standard for the averaging period specified by the standard." A violation of the NAAQS consists of one or more exceedances of a NAAQS. The precise number of exceedances necessary to cause a violation depend on the form of the standard and other factors, including data quality, defined in federal rules such as 40 CFR 50. Exceedances that have been flagged by the Division as exceptional events are shown in parentheses in Table 2.2. See subsubsection 2.2.5.4 for an explanation of exceptional events.

Table 2.2: Exceedance summary table for APCD monitoring sites in 2013 and 2014. Numbers in parenthesis are additional exceedance events (or subsets) that the Division has flagged as exceptional events.Exceptional events are periods of high pollutant concentrations that cannot reasonably be prevented using typical air pollution control strategies.

AQS Site Number	**Site Name**	**2013**				**2014**			
		O_3	PM_{10}	$PM_{2.5}$	SO_2	O_3	PM_{10}	$PM_{2.5}$	SO_2
08-001-0006	Alsup							3	
08-001-3001	Welby	4 (1)							
08-003-0001	Alamosa - ASC		(4)				(1)		
08-003-0003	Alamosa - Mun. Bldg.		(3)				(2)		
08-005-0002	Highland Reservoir	4(2)							
08-005-0006	Aurora - East	2				1			
08-007-0001	Pagosa Springs School		(3)						
08-013-0003	Longmont - Mun. Bldg.							2	
08-013-0011	South Boulder Creek	4							
08-013-0012	Boulder Chamber of Comm.							1	
08-031-0002	CAMP			2				5	
08-031-0026	La Casa	2						2	
08-031-0027	I-25 Denver							3	
08-035-0004	Chatfield State Park	8 (3)				2		1	
08-041-0013	U.S. Air Force Academy	1 (1)							
08-041-0015	Highway 24				2				1
08-041-0016	Manitou Springs	2							
08-051-0007	Mt. Crested Butte		(1)						
08-059-0005	Welch	3 (2)							
08-059-0006	Rocky Flats - N	10 (2)				4			
08-059-0011	NREL	8 (3)				4			
08-059-0013	Aspen Park	3 (2)							
08-067-0004	Durango		(1)						
08-069-0009	Fort Collins - CSU							1	
08-069-0011	Fort Collins - West	5 (1)				3			
08-069-1004	Fort Collins - Mason	1 (1)							
08-077-0017	Grand Junction - Powell Bldg.			4					
08-099-0002	Lamar - Mun. Bldg.		(7)				(9)		
08-101-0015	Pueblo		(1)						
08-113-0004	Telluride		(1)						
08-123-0006	Greeley - Hospital							1	
08-123-0008	Platteville							2	
08-123-0009	Greeley - County Tower	(1)				1			

2.2 General Statistics for Criteria Pollutants

In this section, historical trends in ambient pollutant concentrations are evaluated by averaging NAAQS design values over varying spatial and temporal scales. This evaluation is for reference only as the NAAQS apply only to individual stations over the averaging periods shown in Table 2.1, and concentrations from different sites are not averaged for comparison to the standards. Chapter 4 below includes an evaluation of concentrations in a manner directly comparable to the NAAQS.

2.2.1 Carbon Monoxide

CO is a colorless and odorless gas formed when carbon compounds in fuel undergo incomplete combustion. The majority of CO emissions to ambient air originate from mobile sources (i.e., transportation), particularly in urban areas, where as much as 85% of all CO emissions may come from automobile exhaust. CO can cause harmful health effects by reducing oxygen delivery to the body's organs and tissues. High concentrations of CO generally occur in areas with heavy traffic congestion. In Colorado, peak CO concentrations typically occur during the colder months of the year when CO automotive emissions are highest and nighttime temperature inversions are more frequent.[1]

The National Emissions Inventory[2] estimates that 32% of CO emissions are from highway vehicle sources. They also estimate that off-highway transportation sources, including all off-road mobile sources that use gasoline, diesel, and other fuels, contribute an additional 21% of emissions, making transportation approximately 50% of the total CO emissions nationwide. Figure 2.1 illustrates the trend of national CO emissions from 1970 through 2013.

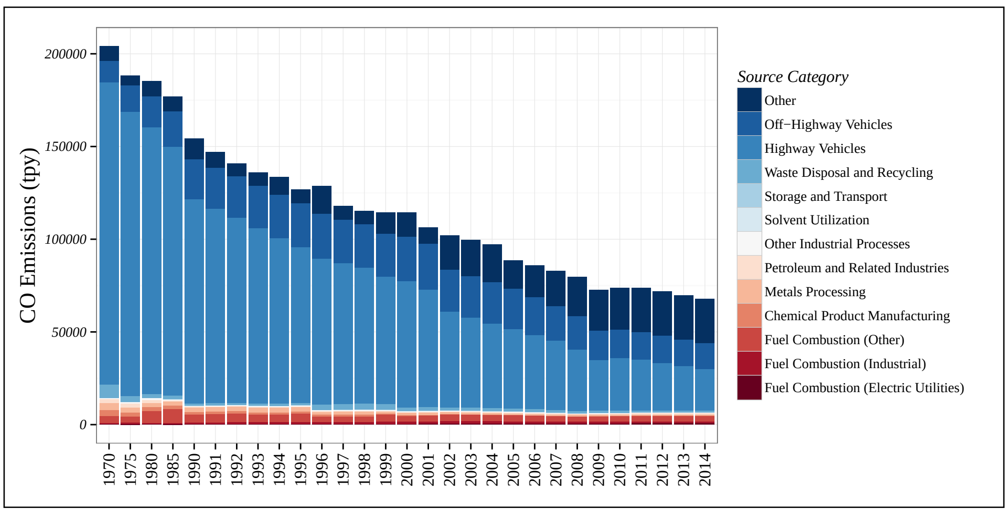


Figure 2.1: Trends in national carbon monoxide emissions from 1970 to 2014.

2.2.1.1 Standards

The EPA first set air quality standards for CO in 1971. For protection of both public health and welfare, EPA set an 8-hour primary standard at 9 parts per million (ppm) and a 1-hour primary standard at 35 ppm. In a review of the standards completed in 1985, the EPA revoked the secondary standards (for public welfare) due to a lack of evidence of adverse effects on public welfare at or near ambient concentrations. The last review of the CO NAAQS was completed in 1994 and the EPA chose not to revise the standards at that time.

[1] Reddy, P. J., Barbarick, D. E., Osterburg, R. D. (1995). Development of a statistical model for forecasting episodes of visibility degradation in the Denver metropolitan area. Journal of Applied Meteorology, 34(3), 616-625

[2] http://www.epa.gov/air-emissions-inventories/

The 1-hour and 8-hour NAAQS standards are not to be exceeded more than once in a year at the same location. A site will violate the standard with a second exceedance of either the 1-hour or 8-hour standard in the same calendar year. An EPA directive states that the comparison with the CO standards will be made in integers. Fractions of 0.5 or greater are rounded up; therefore, actual concentrations of 9.5 ppm and 35.5 ppm or greater are necessary to exceed the 8-hour and 1-hour standards, respectively.

The 7 CO monitors currently operated by the APCD are associated with both State Maintenance Plan requirements and federal regulatory requirements. Recently, the EPA has revised the minimum requirements for CO monitoring by requiring CO monitors to be sited near roads in certain urban areas. EPA has also specified that monitors required in metropolitan areas of 2.5 million or more persons are to be operational by January 1, 2015, and that monitors required in CBSAs of one million or more persons are required to be operational by January 1, 2017. A monitor has been installed at the near roadway NO_2 site (I-25 Denver) to satisfy these requirements.

2.2.1.2 Health Effects

CO affects the central nervous system by depriving the body of oxygen. It enters the body through the lungs, where it combines with hemoglobin in the red blood cells, forming carboxyhemoglobin. Normally, hemoglobin carries oxygen from the lungs to the cells. The oxygen attached to the hemoglobin is exchanged for the carbon dioxide generated by the cell's metabolism. The carbon dioxide is then carried back to the lungs where it is exhaled from the body. Hemoglobin binds approximately 240 times more readily with CO than with oxygen. How quickly the carboxyhemoglobin builds up is a factor of the concentration of the gas being inhaled (measured in ppm) and the duration of the exposure. Compounding the effects of the exposure is the long half-life (approximately 5 hours) of carboxyhemoglobin in the blood. Half-life is a measure of how quickly levels return to normal. This means that for a given exposure level, it will take about 5 hours for the level of carboxyhemoglobin in the blood to drop to half its current level after the exposure is terminated.

The health effects of CO vary with concentration. At low concentrations, effects include fatigue in healthy people and chest pain in people with heart disease. At moderate concentrations, angina, impaired vision, and reduced brain function may result. At higher concentrations, effects include impaired vision and coordination, headaches, dizziness, confusion, and nausea. It can cause flu-like symptoms that clear up after leaving the polluted area. CO is fatal at very high concentrations. The EPA has concluded that the following groups may be particularly sensitive to CO exposures: angina patients, individuals with other types of cardiovascular disease, persons with chronic obstructive pulmonary disease, anemic individuals, fetuses, and pregnant women. Concern also exists for healthy children because of increased oxygen requirements that result from their higher metabolic rate.

2.2.1.3 Statewide Summaries

CO concentrations have dropped dramatically since the early 1970s. This change is evident in both the concentrations measured and the number of monitors that have exceeded the level of the 8-hour standard. In 1975, 9 of 11 (81%) state-operated monitors exceeded the 8-hour standard. In 1980, 13 of 17 (77%) state-operated monitors exceeded the 8-hour standard. Since 1996, no state-operated monitors have recorded a violation of the 8-hour standard. In 2014 the highest statewide second maximum 8-hour concentration was 1.8 ppm as recorded at the La Casa station. Historical trends in CO design value for the CAMP and Welby stations are shown in Figure 2.2 and Figure 2.3 for illustration purposes.

Figure 2.4 shows the median and interquartile range of 1-hour CO design values recorded statewide between 1965 and 2014. The maximum 1-hour concentration ever recorded at any of the state-operated monitors was a 79.0 ppm, which was recorded at the Denver CAMP monitor in 1968. In 2014, the second maximum 1-hour concentration recorded was 3.4 ppm as recorded at the Highway 24 (Colorado Springs) station. The 1-hour annual maximum concentrations have declined from more than twice the standard in the late 1960s to about one quarter of the standard today.

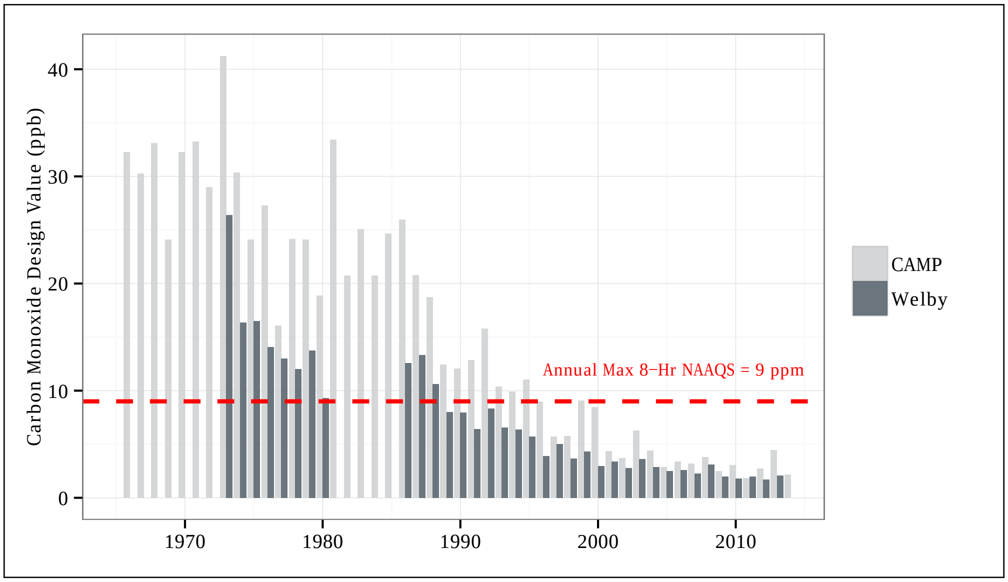


Figure 2.2: Historical record of 8-hr carbon monoxide design values at the CAMP and Welby stations.

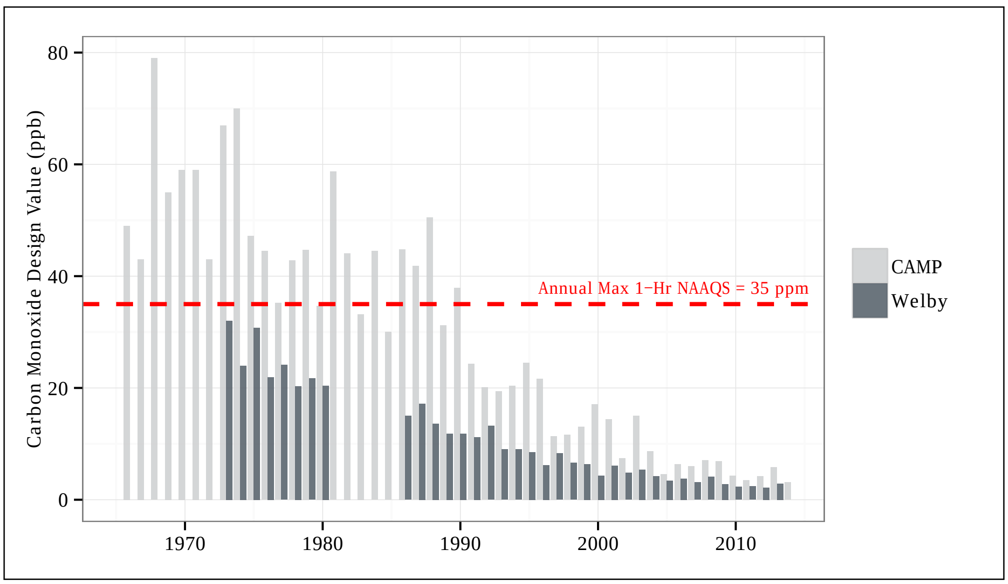


Figure 2.3: Historical record of 1-hr carbon monoxide design values at the CAMP and Welby stations.

2.2.2 Sulfur Dioxide

Sulfur dioxide (SO_2) is one of a group of highly reactive gasses known as "oxides of sulfur," or sulfur oxides (SO_x). The largest sources of SO_2 emissions are from fossil fuel combustion at power plants (73%) and other industrial facilities (20%), as shown in Figure 2.5. Smaller sources of SO_2 emissions include industrial processes such as extracting metal from ore, and the burning of high sulfur containing fuels by locomotives, large ships, and non-road equipment. SO_2 is linked with a number of adverse effects on the respiratory system.[3] Furthermore, SO_2 dissolves in water and is oxidized to form sulfuric acid, which is a major contributor to acid rain, as well as fine sulfate particles in the $PM_{2.5}$ fraction, which degrade visibility and represent a human health hazard.

[3]Ware, J. H., Ferris Jr, B. G., Dockery, D. W., Spengler, J. D., Stram, D. O., Speizer, F. E. (1986). Effects of ambient sulfur oxides and suspended particles on respiratory health of preadolescent children. The American Review of Respiratory Disease, 133(5), 834-842

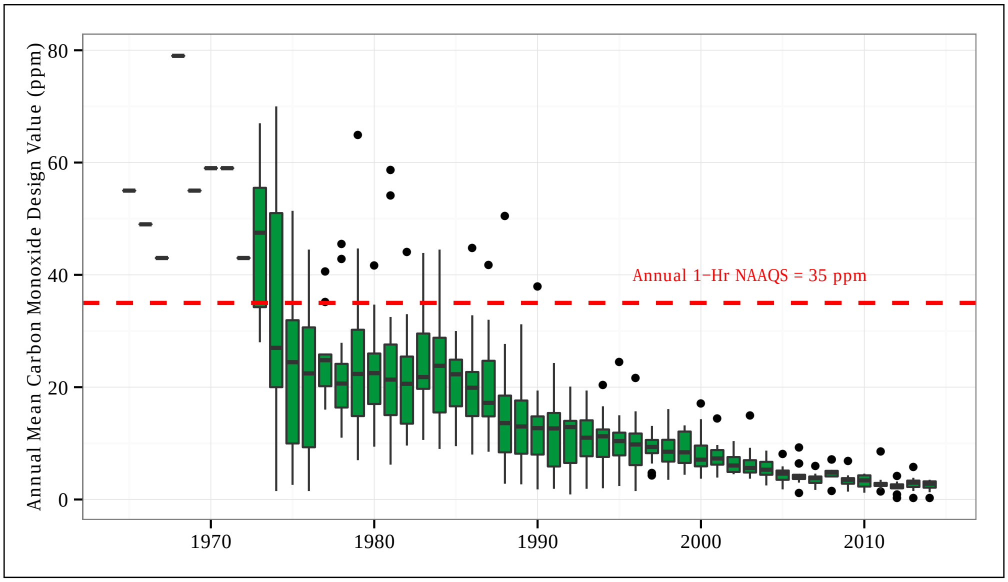


Figure 2.4: Statewide historical record of 1-hr carbon monoxide design values. The box plot shows the mean design value statewide for each year, as well as the interquartile range (box) of values observed at monitoring sites throughout the state and the minimum and maximum values. Outliers are indicated by black points.

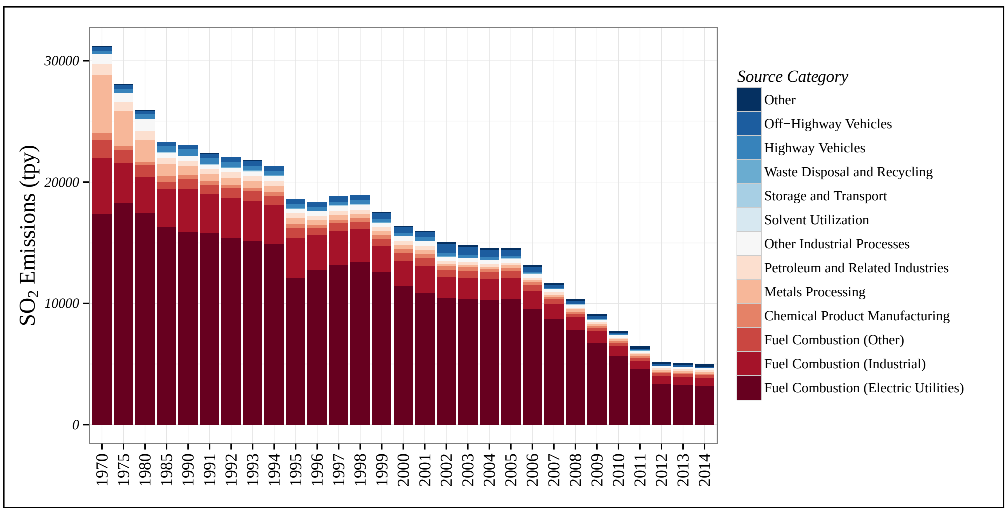


Figure 2.5: Trends in national sulfur dioxide emissions from 1970 to 2014.

2.2.2.1 Standards

The EPA first promulgated standards for SO_2 in 1971, setting a 24-hour primary standard at 140 ppb and an annual average standard at 30 ppb (to protect health). A 3-hour average secondary standard at 500 ppb was also adopted to protect the public welfare. In 1996, the EPA reviewed the SO_2 NAAQS and chose not to revise the standards. However, in 2010, the EPA revised the primary SO_2 NAAQS by establishing a new 1-hour standard at a level of 75 parts per billion (ppb). The two existing primary standards were revoked because they were deemed inadequate to provide additional public health protection given a 1- hour standard at 75 ppb.

The APCD has monitored SO_2 at eight locations in Colorado in the past. Currently, there are four monitoring sites in operation. No area of the country has been found to be out of compliance with the current SO_2 standards.

2.2.2.2 Health Effects

High concentrations of sulfur dioxide can result in temporary breathing impairment for asthmatic children and adults who are active outdoors. Short-term exposures of asthmatic individuals to elevated sulfur dioxide levels during moderate activity may result in breathing difficulties that can be accompanied by symptoms such as wheezing, chest tightness, or shortness of breath. Other effects that have been associated with longer-term exposures to high concentrations of sulfur dioxide, in conjunction with high levels of particulate matter, include aggravation of existing cardiovascular disease, respiratory illness, and alterations in the lungs' defenses. The subgroups of the population that may be affected under these conditions include individuals with heart or lung disease, as well as the elderly and children.

2.2.2.3 Statewide Summaries

The concentrations of sulfur dioxide in Colorado have never been a major health concern as there are few industries that burn large amounts of coal in the state. Additionally, western coal that is mined or imported into Colorado is naturally low in sulfur. The concern in Colorado with sulfur dioxide has been associated with acid deposition and its effects on mountain lakes and streams, as well as the formation of fine aerosols. Historically, the site with the highest annual average of 1-hour average concentrations recorded by APCD monitors was 18 ppb in 1979 at the Denver CAMP monitor. Since 1990, the annual average at the Denver CAMP monitor has declined from a high in 1992 of 10 ppb to 3.1 ppb in 2014. Observed 1-hour SO_2 annual design values at the CAMP station declined from 148.8 ppb to 13.4 ppb during this same time period, as is shown in Figure 2.6. Figure 2.7 shows the declining trend in sulfur dioxide readings over the last several decades, with relatively low concentrations of sulfur dioxide recorded at the APCD's monitors. This same trend is evident, although not as pronounced, in the 3-hour and 24-hour averages. The Highway 24 (Colorado Springs) site was outfitted with an SO_2 monitor in January of 2013. The site has shown two exceedances of the standard in the first year of monitoring. A meteorological tower has recently been installed at the site in an effort to obtain a better understanding of the factors driving these elevated concentration events.

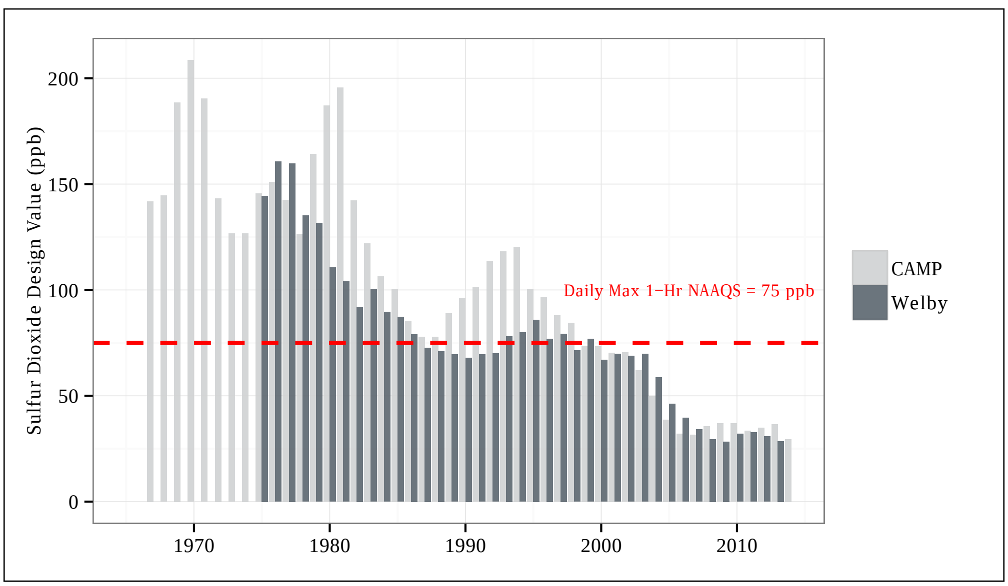


Figure 2.6: Historical record of 1-hr sulfur dioxide design values at the CAMP and Welby stations.

2.2.3 Ozone

O_3 is an atmospheric oxidant composed of three oxygen atoms. It is not usually emitted directly into the air, but at ground-level is formed via photochemical reactions among NO_x and volatile organic compounds (VOCs) in the presence of sunlight . Emissions from industrial facilities and electric utilities, motor vehicle exhaust, gasoline vapors,

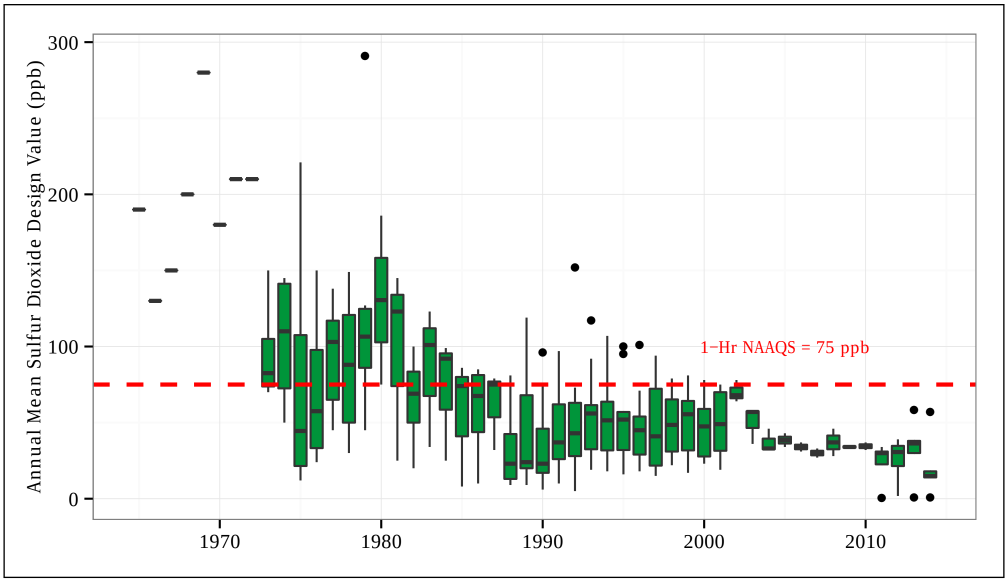


Figure 2.7: Statewide historical record of 1-hr sulfur dioxide design values. The box plot shows the mean design value statewide for each year, as well as the interquartile range (box) of values observed at monitoring sites throughout the state and the minimum and maximum values. Outliers are indicated by black points.

and chemical solvents are some of the major sources of NO_x and VOCs (see Figure 2.8 and Figure 2.11). Breathing ozone can trigger a variety of health problems, particularly for children, the elderly, and people of all ages who have lung diseases such as asthma.[4] Urban areas generally experience the highest ozone concentrations, but even rural areas may be subject to increased ozone levels because air masses can carry ozone and its precursors hundreds of kilometers away from their original source regions.

Sunlight and warm weather facilitate the ozone formation process and can lead to high concentrations. Ozone is therefore considered to be primarily a summertime pollutant, with an "ozone season" being active in Colorado from March to September, when hot summer days provide the conditions for the precursor chemicals to react and form ozone. However, ozone can also be a wintertime pollutant in some areas. Emerging science is indicating that snow-covered oil and gas-producing basins in the western U.S. are subject to wintertime ozone concentrations well in excess of current air quality standards. High ozone concentrations in winter are thought to occur when stable atmospheric conditions allow for a build-up of precursor chemicals, and the reflectivity of the snow cover increases the rate of UV-driven reactions during the day. Ozone and its precursors are then effectively trapped under the inversion. The Upper Green River Basin in Wyoming has been studied to model such effects.[5] Due to these high concentration events, the EPA has recently redefined Colorado's ozone season as January through December.

2.2.3.1 Standards

In 1971, the EPA promulgated the first NAAQS for photochemical oxidants, setting a 1-hour primary standard at 80 pbb (O_3 is one of a number of chemicals that are common atmospheric oxidants). The level of the primary standard was then revised in 1979 from 80 ppb to 120 ppb and the chemical designation of the standard was changed from "photochemical oxidants" to "ozone." In 1993, the EPA reviewed the O_3 NAAQS and chose not to revise the standards. However, in 1997, the EPA promulgated a new level of the NAAQS for O_3 of 80 ppb as an annual fourth-highest daily maximum eight-hour concentration, averaged over three years. The O_3 NAAQS was then revised again in 2008 when the EPA set an 8-hour standard of 75 ppb. This change had a significant impact on the number of O_3 monitors in Colorado that were in violation of the standard, with the APCD now operating 4 sites out of 19 (5 sites including

[4]Kampa, M., Castanas, E. (2008). Human health effects of air pollution. Environmental pollution, 151(2), 362-367

[5]Carter, W. P., Seinfeld, J. H. (2012). Winter ozone formation and VOC incremental reactivities in the Upper Green River Basin of Wyoming. Atmospheric Environment, 50, 255-266

Highland, which is not currently in operation) that have three-year design values (2012-2014) in excess of the current eight-hour O_3 NAAQS standard of 75 ppb (only three of these sites have design values in excess of 80 ppb). On November 26, 2014, the EPA again proposed lowering the O_3 NAAQS standard from its current value of 75 ppb to a level between 65 ppb and 70 ppb. In November 2015, the EPA set the standard at 70 ppb as an annual fourth-highest daily maximum eight-hour concentration, averaged over three years.

2.2.3.2 Health Effects

Exposure to ozone has been linked to a number of health effects, including significant decreases in lung function, inflammation of the airways, and increased respiratory symptoms, such as cough and pain when taking a deep breath.[6] Exposure can also aggravate lung diseases such as asthma, leading to increased medication use and increased hospital admissions and emergency room visits. Active children are the group at highest risk from ozone exposure because they often spend a large part of the summer playing outdoors. Children are also more likely to have asthma, which may be aggravated by ozone exposure. Other at-risk groups include adults who are active outdoors (e.g., some outdoor workers) and individuals with lung diseases such as asthma and chronic obstructive pulmonary disease. In addition, long-term exposure to moderate levels of ozone may cause permanent changes in lung structure, leading to premature aging of the lungs and worsening of chronic lung disease.

Ozone also affects vegetation and ecosystems, leading to reductions in agricultural crop and commercial forest yields, reduced growth and survivability of tree seedlings, and increased plant susceptibility to disease, pests, and other environmental stresses (e.g., harsh weather)[7]. In long-lived species, these effects may become evident only after several years or even decades and may result in long-term effects on forest ecosystems. Ground level ozone injury to trees and plants can lead to a decrease in the natural beauty of our national parks and recreation areas.

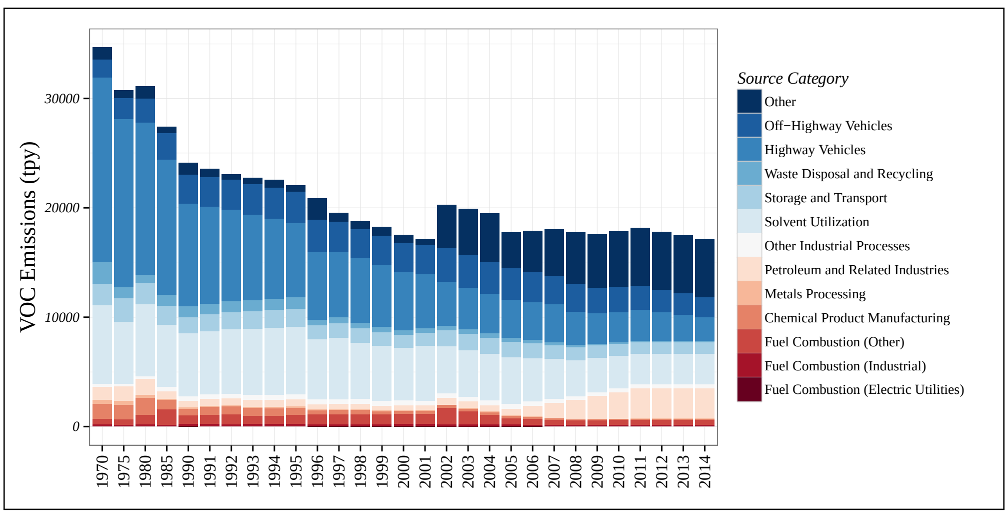


Figure 2.8: Trends in national VOC emissions from 1970 to 2014.

2.2.3.3 Statewide Summaries

As illustrated in Figure 2.9, statewide average O_3 design values have historically fluctuated around the standard. In recent years, the trend has been up-ward in regards to ozone concentrations, although concentrations in 2014 were somewhat lower than previous years. APCD believes this trend can be linked to the recent oil and gas development in Colorado and the uptick in the overall economy since about 2010.

[6] Lippmann, M. (1989). Health effects of ozone: a critical review. Journal of the Air Pollution Control Association, 39(5), 672-695.
[7] Ashmore, M. R. (2005). Assessing the future global impacts of ozone on vegetation. Plant, Cell Environment, 28(8), 949-964.

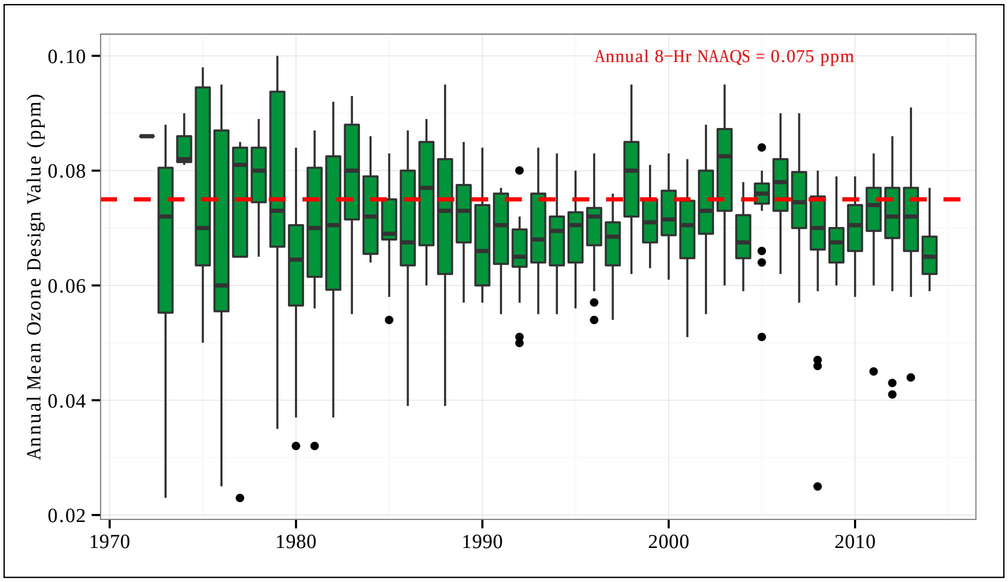


Figure 2.9: Statewide historical record of 8-hr ozone design values. The box plot shows the mean design value statewide for each year, as well as the interquartile range (box) of values observed at monitoring sites throughout the state and the minimum and maximum values. Outliers are indicated by black points.

Ozone monitoring began in 1972 at the Denver CAMP station, and eight exceedances of the then-applicable 1-hour standard were recorded that year. The highest 8-hour average ozone concentration measured at an APCD site during 2014 was 77 ppb as recorded at the Rocky Flats - North station. Typically ground level ozone concentrations are higher in the summer such as seen by Rocky Flats - North, in contrast to BLM Rangely which showed elevated ozone concentrations due to winter time inversions. The historical trend of 8-hour ozone concentrations at the Welby station are shown in Figure 2.10 for illustration purposes.

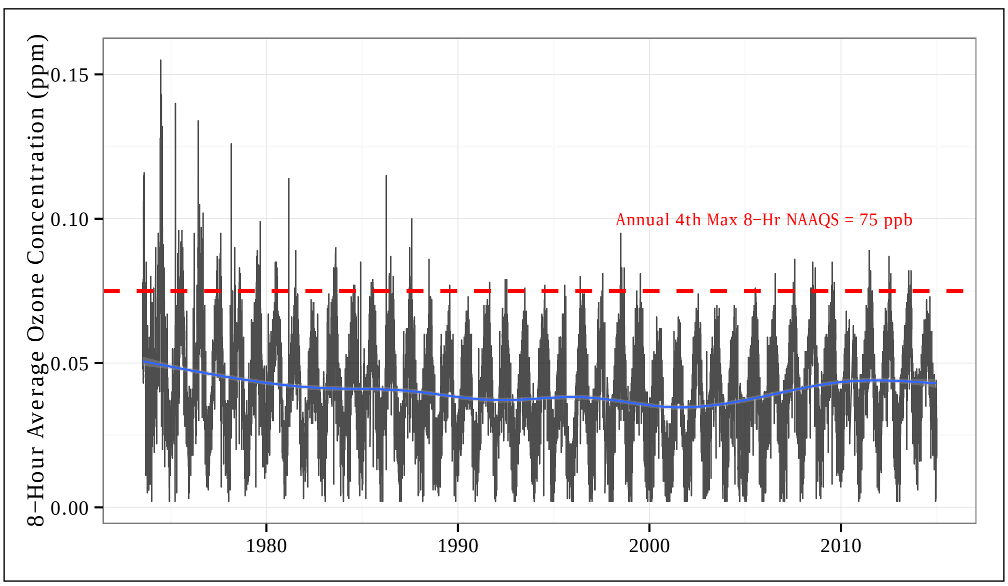


Figure 2.10: Historical record of 8-hour average ozone concentrations at the Welby station. The mean trend obtained using a generalized additive model is shown as a light blue line.

2.2.4 Nitrogen Dioxide

NO_2 is one of a group of highly reactive gasses known as "oxides of nitrogen," or nitrogen oxides (NO_x). Other NO_x species include nitric oxide (NO), nitrous acid (HNO_2), and nitric acid (HNO_3). The EPA's National Ambient Air Quality Standard uses NO_2 as the indicator for the larger group of nitrogen oxides. NO_2 forms quickly from emissions from motor vehicles, power plants, and off-road equipment, with on and off-road vehicles accounting for over 50% of emissions nationally. In addition to contributing to the formation of ground-level ozone and fine particle pollution, NO_2 is linked with a number of adverse effects on the respiratory system.[8]

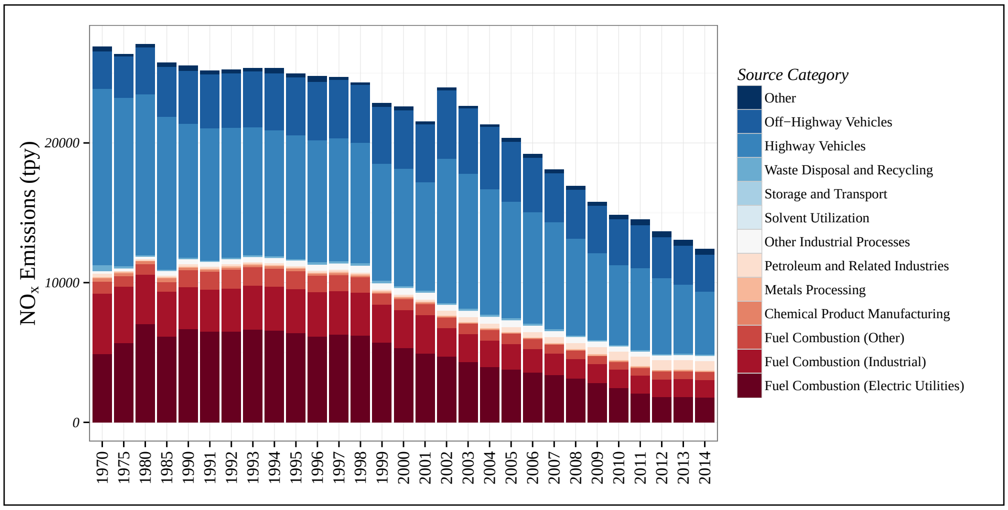


Figure 2.11: Trends in national NO_x emissions from 1970 to 2014.

2.2.4.1 Standards

The EPA first set standards for NO_2 in 1971, setting both a primary standard (to protect health) and a secondary standard (to protect the public welfare) at 0.053 parts per million (53 ppb), averaged annually. The Agency has reviewed the standards twice since that time, but chose not to revise the annual standards at the conclusion of each review. In January 2010, the EPA established an additional primary standard at 100 ppb, averaged over one hour. Together the primary standards protect public health, including the health of sensitive populations; i.e., people with asthma, children, and the elderly.

The EPA has established requirements for an NO_2 monitoring network that will include monitors at locations where maximum NO_2 concentrations are expected to occur, including within 50 meters of major roadways, as well as monitors sited to measure area-wide NO_2 concentrations that occur more broadly across communities. Per these requirements, at least one monitor must be located near a major road in any urban area with a population greater than or equal to 500,000 people. A second monitor is required near another major road in areas with either: (1) population greater than or equal to 2.5 million people, or (2) one or more road segments with an annual average daily traffic (AADT) count greater than or equal to 250,000 vehicles. Near-roadway monitoring is conducted at the I-25 Denver site (installed in 2013). In addition to the near roadway monitoring, there must be one monitoring station in each metropolitan area with a population of 1 million or more persons to monitor a location of expected highest NO_2 concentrations representing the neighborhood or larger spatial scales. The CAMP and Welby sites satisfy this requirement.

[8]Weinmayr, G., Romeo, E., De Sario, M., Weiland, S. K., Forastiere, F. (2010). Short-term effects of PM_{10} and NO_2 on respiratory health among children with asthma or asthma-like symptoms: a systematic review and meta-analysis. Environmental Health Perspectives, 118(4), 449-57.

2.2.4.2 Health Effects

Elevated concentrations of nitrogen dioxide cause respiratory distress, degradation of vegetation, clothing, visibility, and increased acid deposition. Nitrogen dioxide also causes concern with the formation of fine aerosols. Nitrate aerosols, which result from NO and NO_2 combining with water vapor in the air, have been consistently linked to Denver's visibility problems.[9]

2.2.4.3 Statewide Summaries

Colorado exceeded the annual mean NO_2 standard of 53 ppb in 1977 at the Denver CAMP monitor, but concentrations have shown a gradual decline since this time. Figure 2.12 and Figure 2.13 show that levels have declined minimally at both the Welby and CAMP monitors over the past ten years in terms of both the annual mean and 1-hour design values, respectively. The statewide historical trend is summarized in Figure 2.14.

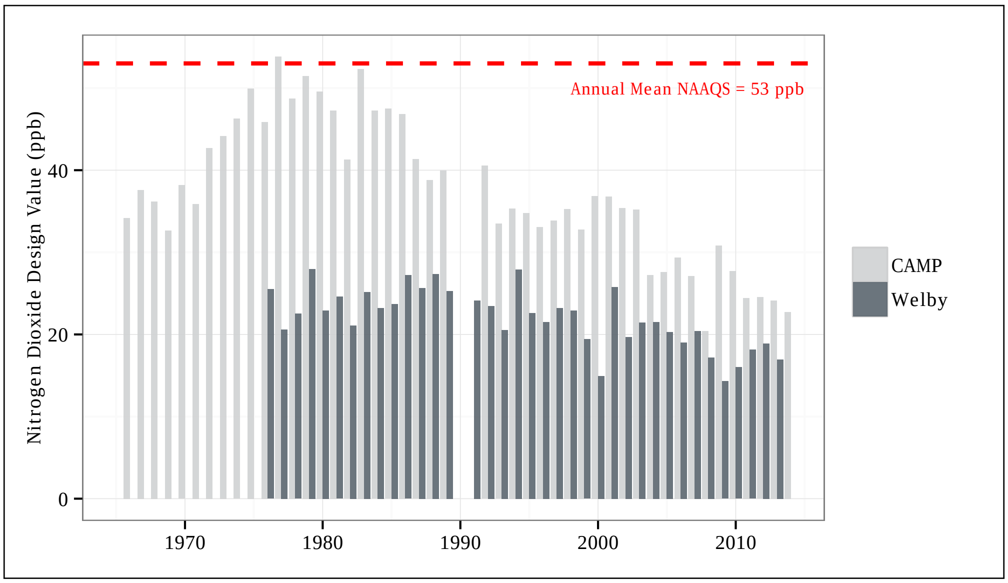


Figure 2.12: Historical record of annual mean nitrogen dioxide design values at the CAMP and Welby stations.

2.2.5 Particulate Matter

Atmospheric particulate matter (PM) consists of microscopic solid or liquid particles suspended in the air. PM can be made up of a number of different components, including acidic aerosols (i.e., nitrates and sulfates), organic carbon, metals, soil or dust particles, and allergens (such as fragments of pollen or mold spores). Some of these particles are carcinogenic and others have health effects due to their size, morphology, or composition.

2.2.5.1 Health Effects

Particle size is the factor most directly linked to the health impacts of atmospheric PM. Particles of less than 10 micrometers (μm) in aerodynamic diameter (PM_{10}) are inhalable and thus pose a health threat. Particles less than 2.5 μm in aerodynamic diameter ($PM_{2.5}$) can penetrate deeply into the alveoli, while the smallest particles, such as those less than 0.1 μm in aerodynamic diameter (ultrafine particles), can penetrate all the way into the bloodstream. Exposure to such particles can affect the lungs, the heart, and the cardiovascular system. Particles with diameters

[9] Sloane, C. S., Watson, J., Chow, J., Pritchett, L., Richards, L. W. (1991). Size-segregated fine particle measurements by chemical species and their impact on visibility impairment in Denver. Atmospheric Environment. Part A. General Topics, 25(5), 1013-1024.

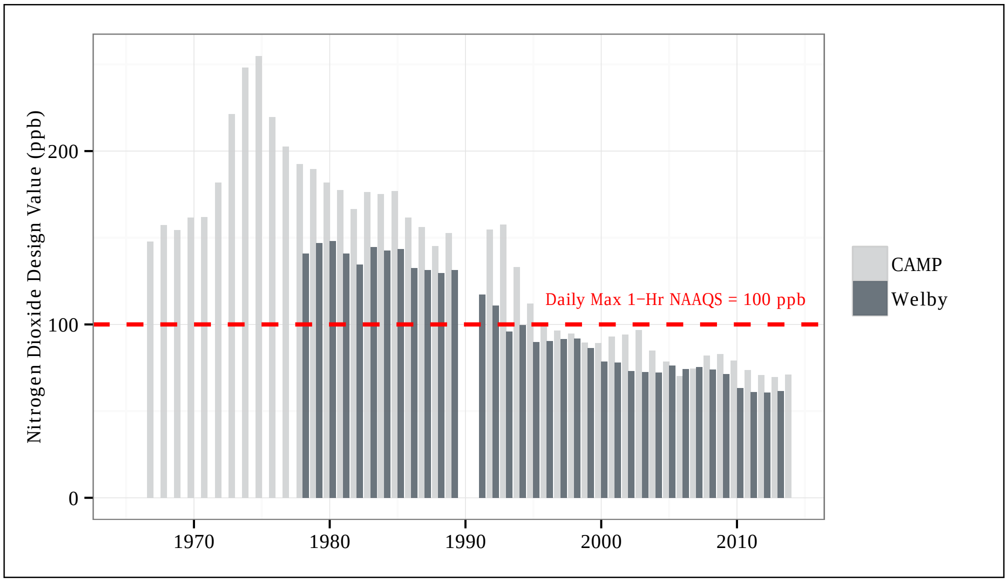


Figure 2.13: Historical record of 1-hr nitrogen dioxide design values at the CAMP and Welby stations.

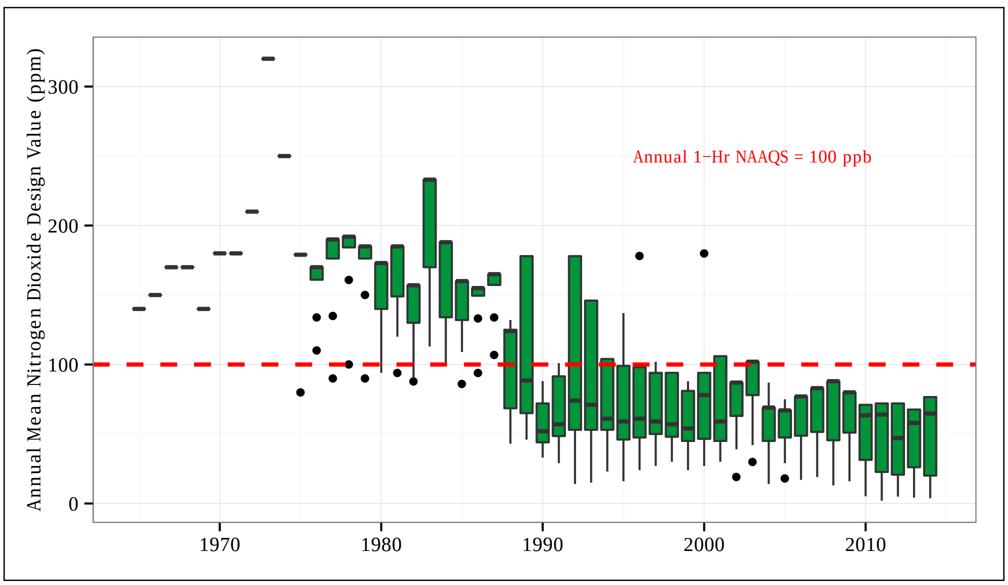


Figure 2.14: Statewide historical record of 1-hr nitrogen dioxide design values. The box plot shows the mean design value statewide for each year, as well as the interquartile range (box) of values observed at monitoring sites throughout the state and the minimum and maximum values. Outliers are indicated by black points.

between 2.5 µm and 10 µm ($PM_{10\text{-}2.5}$) represent less of a health concern, although they can irritate the eyes, nose, and throat, and cause serious harm due to inflammation in the airways of people with respiratory diseases such as asthma, chronic obstructive pulmonary disease, and pneumonia. Note that PM_{10} encompasses all particles smaller than 10 µm, including the $PM_{2.5}$ and ultrafine fractions.

The welfare effects of particulate exposure may be the most widespread of all the pollutants. No place on earth has been spared from the particulate pollution generated by urban and rural sources. This is due to the potential for extremely long-range transport of fine particles and chemical reactions that occur from gasses in the atmosphere to create secondary particulate matter in the form of microscopic liquid droplets. The effects of particulates range from visibility degradation to climate changes and vegetation damage. General soiling, commonly thought to be just a nuisance, can have long-term adverse effects on building paints and other materials. Acid deposition as particulates can be detected in the most remote areas of the world.

2.2.5.2 Emissions and Sources

The majority of PM_{10} pollution comes from miscellaneous sources, which are mainly fugitive dust sources rather than stack emissions or combustion sources. Fugitive emissions are those not caught by a capture system and are often due to equipment leaks, earth moving equipment vehicles, and windblown disturbances. $PM_{2.5}$, on the other hand, is typically formed in atmosphere via gas to particle conversion and consists primarily of nitrates, sulfates, and organic carbon (black carbon from combustion can be an important primary source of particles in the $PM_{2.5}$ size fraction). The historical tend in national PM emissions from 1990 to 2014 is show in Figure 2.15 for illustration purposes.

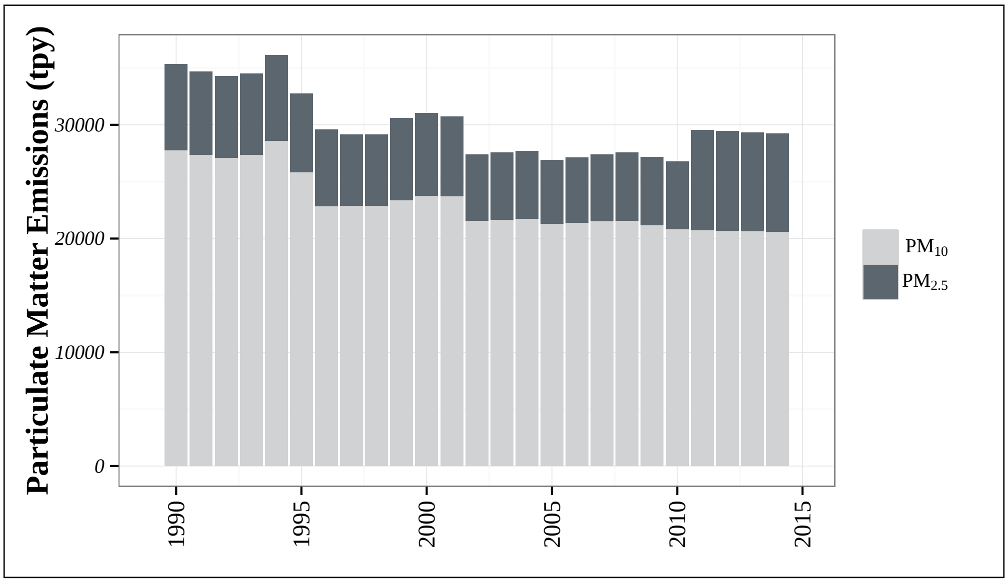


Figure 2.15: Trends in national particulate matter emissions from 1990 to 2014.

2.2.5.3 Standards

EPA first established standards for PM in 1971. The reference method specified for determining attainment of the original standards was the high-volume sampler, which collects PM up to a nominal size of 25 to 45 μm (referred to as total suspended particulates or TSP). The primary standards, as measured by the indicator TSP, were 260 μg m^{-3} (as a 24-hour average) not to be exceeded more than once per year, and 75 μg m^{-3} (as an annual geometric mean). In October 1979, the EPA announced the first periodic review of the air quality criteria and NAAQS for PM, and significant revisions to the original standards were promulgated in 1987. In that decision, the EPA changed the indicator for particles from TSP to PM_{10}. EPA also revised the level and form of the primary standards. The EPA promulgated significant revisions to the NAAQS again in 1997. In that decision, the EPA revised the PM NAAQS in several respects. While it was determined that the PM NAAQS should continue to focus on particles less than or equal to 10 μm in diameter (i.e., PM_{10}), the EPA also decided that the fine and coarse fractions of PM_{10} should be considered separately. The Agency's decision to modify the standards was based on evidence that serious health effects were associated with short- and long-term exposure to fine particles in areas that met the existing PM_{10} standards. The EPA added new standards, using $PM_{2.5}$ as the indicator for fine particles and using PM_{10} as the indicator for the $PM_{10-2.5}$ fraction. The EPA established two new $PM_{2.5}$ standards: an annual standard of 15 μg m^{-3}, based on the 3-year average of annual arithmetic mean $PM_{2.5}$ concentrations from single or multiple community-oriented monitors, and a 24-hour standard of 65 μg m^{-3}, based on the 3-year average of the 98th percentile of 24-hour $PM_{2.5}$ concentrations at each population-oriented monitor within an area. These standards were modified again in 2006 and 2012. The current

NAAQS for PM_{10} is a primary 24-hour standard of 150 µg m^{-3} not to be exceeded more than once per year on average over 3 years. There are currently three NAAQS for $PM_{2.5}$: (1) a primary annual standard of 12 µg m^{-3}, based on the 3-year average of annual arithmetic mean $PM_{2.5}$ concentrations, (2) a secondary annual standard of 15 µg m^{-3}, based on the 3-year average of annual arithmetic mean $PM_{2.5}$ concentrations, and (3) and a 24-hour standard of 35 µg m^{-3}, based on the 3-year average of the 98th percentile of 24-hour $PM_{2.5}$ concentrations.

2.2.5.4 A Brief Explanation of Exceptional Events

Often times air pollution episodes originate from natural sources that are not preventable and cannot be reasonably controlled by humans. These include events like volcanic eruptions, large regional dust storms, and wildfires. If an exceedance of the NAAQS (PM_{10} concentrations greater than 150 µg m^{-3} in attainment areas and greater than 98 µg m^{-3} in PM_{10} non-attainment areas) can be shown to have resulted from a natural event and can be documented with scientific evidence, the event can be excluded from NAAQS calculations. For example, one such event was the large wind and dust storm that occurred on March 31, 1999 when monitors from Steamboat Springs to Telluride reported high PM_{10} concentrations. Similar exceptional events have been documented in Lamar, Alamosa, Crested Butte, Durango, Grand Junction, Pagosa Springs and Pueblo. These events are not included in NAAQS determinations, not because they are without any health risk but because they are naturally occurring events that cannot be reasonably prevented or controlled. The EPA may concur on events that the Division flags and documents as exceptional events in the EPA's AQS database. The Exceptional Events Rule was revised on March 22, 2007, with an effective date of May 21, 2007. The EPA has been much more restrictive on concurring natural events since the revision. Concentrations between 98 and 155 µg m^{-3} that are located in State Implementation Plan maintenance areas are also allowed by the Exceptional Events Rule to be flagged and documented as exceptional events. More details can be found at `http://www.epa.gov/air-quality-analysis/treatment-data-influenced-exceptional-events/`.

2.2.5.5 Statewide Summaries

PM_{10} PM_{10} data have been collected in Colorado since 1985. The samplers were subsequently modified to conform to the requirements of a new standard when it was established in July of 1987. Therefore, annual trends are only valid back to July 1987. Since 1988, at least one Colorado monitor has exceeded the level of the 24-hour PM_{10} standard (150 µg m^{-3}) every year except for 2004. By contrast, no monitor with at least 75 percent data recovery per calendar quarter, which is required for NAAQS comparisons, has exceeded the level of the former annual standard (50 µg m^{-3} as an annual arithmetic mean averaged over 3 years).

In cases other than exceptional events and more so than for other pollutants, PM_{10} pollution is a localized phenomenon and concentrations can vary considerably in Colorado on both spatial and temporal scales. Therefore, local averages and maximum concentrations of PM_{10} are more meaningful than averages covering large regions or the entire state. However, the statewide averages are shown in Figure 2.16 for illustration purposes. The data shown in Figure 2.16 include those concentrations that are the result of exceptional events (see subsubsection 2.2.5.4). There have been several of these events documented in Colorado since PM_{10} monitoring began in 1988, including the maximum 24-hour PM_{10} concentration of 1220 µg m^{-3} recorded at the Lamar Municipal station during in 2013.

$PM_{2.5}$ Monitoring for $PM_{2.5}$ in Colorado began in 1999 with the establishment of sites in Denver, Grand Junction, Steamboat Springs, Colorado Springs, Greeley, Fort Collins, Platteville, Boulder, Longmont, and Elbert County. Additional sites were established nearly every month until full implementation of the base network was achieved in July of 1999. In 2004, there were 20 $PM_{2.5}$ monitoring sites in Colorado. Thirteen of the 20 sites were selected based on the population of the metropolitan statistical areas. This is a federal selection criterion that was developed to protect the public health in the highest population centers. In addition, there were seven special-purpose-monitoring (SPM) sites. These sites were selected due to historically elevated concentrations of PM_{10} or because citizens or local governments had concerns about possible high $PM_{2.5}$ concentrations in their communities. All SPM sites were removed as of December 31, 2006 due to low concentrations and a lack of funding.

Figure 2.17 and Figure 2.18 show the historical trends in annual mean and 24-hour maximum $PM_{2.5}$ design values, respectively. Although data has only been collected for the past 12 years, the trend in the average levels of $PM_{2.5}$

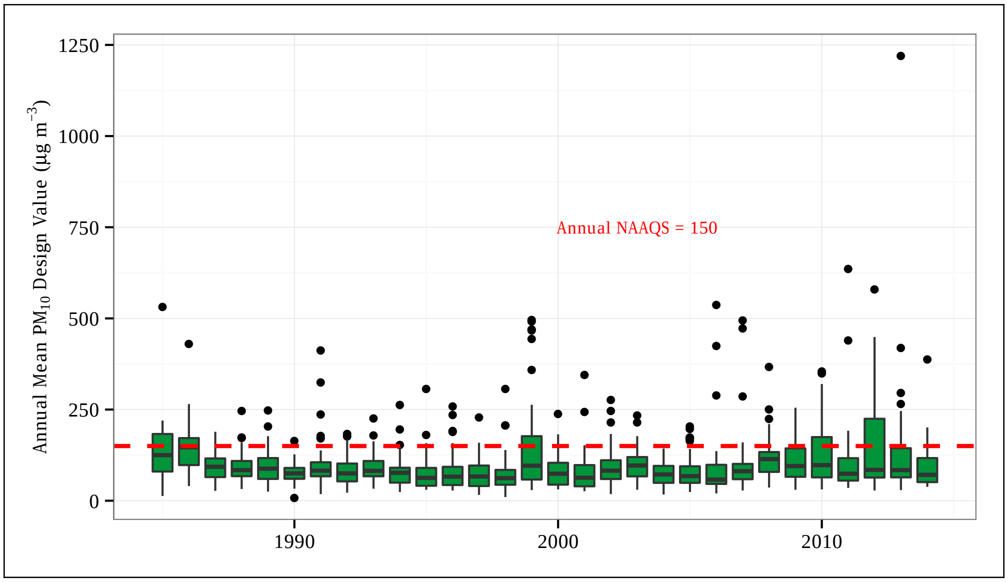


Figure 2.16: Statewide historical record of 24-hour PM_{10} design values. The box plot shows the mean design value statewide for each year, as well as the interquartile range (box) of values observed at monitoring sites throughout the state and the minimum and maximum values. Outliers are indicated by black points.

appears to be essentially flat. Since the standard is based on a three-year average of the highest 98^{th} percentile of samples run, the 24-hour standard has not been violated at any site. Neither has the three-year average annual standard of 12 $\mu g\ m^{-3}$.

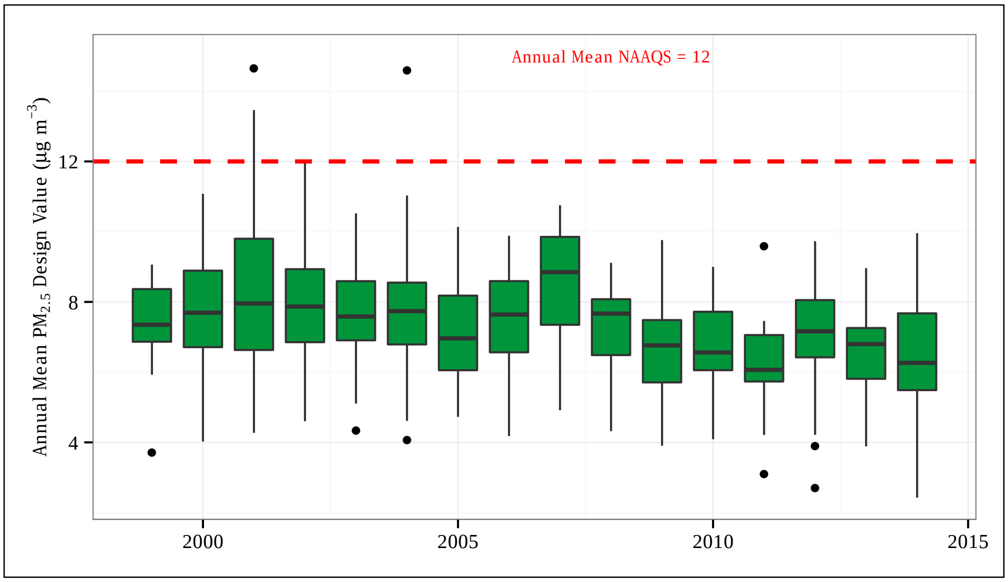


Figure 2.17: Statewide historical record of annual mean $PM_{2.5}$ design values. The box plot shows the mean design value statewide for each year, as well as the interquartile range (box) of values observed at monitoring sites throughout the state and the minimum and maximum values. Outliers are indicated by black points.

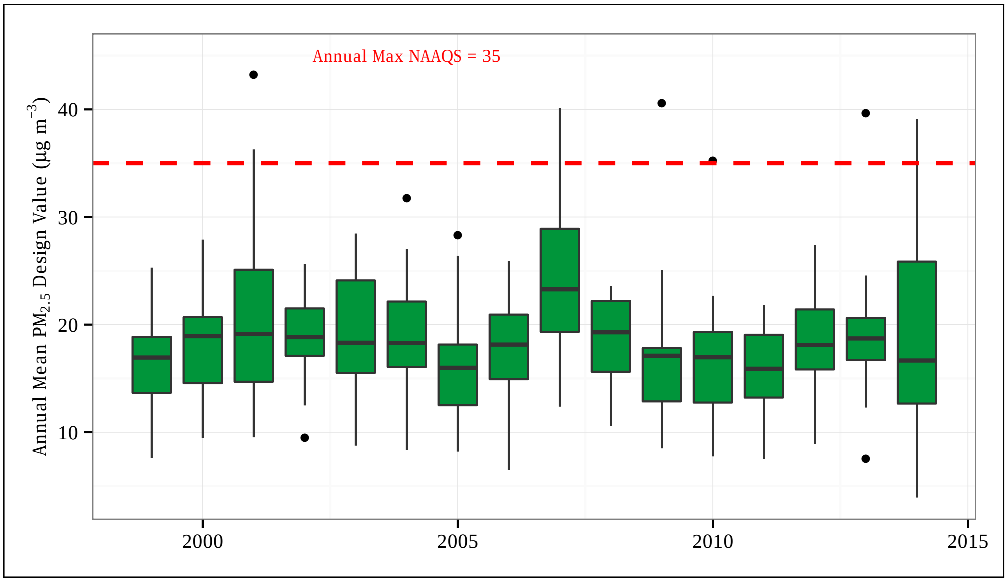


Figure 2.18: Statewide historical record of 24-hour maximum $PM_{2.5}$ design values. The box plot shows the mean design value statewide for each year, as well as the interquartile range (box) of values observed at monitoring sites throughout the state and the minimum and maximum values. Outliers are indicated by black points.

2.2.6 Lead

Lead is a metal found naturally in the environment and in manufactured products. The major sources of lead in ambient air have historically been motor vehicles (such as cars and trucks) and industrial sources (such as lead smelters). Due to the phase out of leaded gasoline for automobiles, piston engine aircraft and metals processing are now the major sources of lead emissions in the air today. The highest levels of lead in air are generally found near lead smelters and general aviation airports. Other stationary sources include waste incinerators, utilities, and lead-acid battery manufacturers.

2.2.6.1 Standards

The Clean Air Act requires EPA to review the latest scientific information and standards every five years. Before new standards are established, policy decisions undergo rigorous review by the scientific community, industry, public interest groups, the general public, and the Clean Air Scientific Advisory Committee (CASAC).

On October 15, 2008, EPA strengthened the National Ambient Air Quality Standards for lead. The level for the previous lead standard was 1.5 $\mu g\ m^{-3}$, not to be exceeded as an average for a calendar quarter, based on an indicator of lead in total suspended particulates (TSP). The new standard, measured in either TSP or low-volume PM_{10} samples, has a level of 0.15 $\mu g\ m^{-3}$, not to be exceeded as an average for any rolling three-month period within three years. On December 30, 2009 (effective January 26, 2011), EPA revised the requirements for monitoring lead in air (74 FR 69050). The EPA changed the non-source oriented monitoring requirements such that monitoring agencies are now required to only monitor at NCore sites with populations greater than half a million instead of all urban areas with greater than half a million people. In addition, the EPA also lowered the emissions threshold that required lead monitoring near 1 ton per year or greater industrial sources to require monitoring at 0.5 ton per year or greater near industrial lead sources. Airports maintain an emission threshold of 1 ton per year, and the EPA is studying the potential need for monitoring at less than 1 ton per year lead emissions. On December 14, 2010, EPA made final revisions to the ambient monitoring requirements for measuring lead in the air. These amendments expanded the nation's lead monitoring network to better assess compliance with the 2008 National Ambient Air Quality Standards for lead.

2.2.6.2 Health Effects

Exposure to lead occurs mainly through inhalation of air and ingestion of lead in food, water, soil, or dust. It accumulates in the blood, bones, and soft tissues and can adversely affect the kidneys, liver, nervous system, and other organs. Excessive exposure to lead may cause neurological impairments such as seizures, intellectual disability, and behavioral disorders. Even at low doses, lead exposure is associated with damage to the nervous systems of fetuses and young children, resulting in learning deficits and lowered IQ. Recent studies also show that lead may be a factor in high blood pressure and subsequent heart disease. Lead can also be deposited on the leaves of plants, presenting a hazard to grazing animals and humans through ingestion.

2.2.6.3 Statewide Summaries

In Colorado the last violation of the previous 1.5 $\mu g\ m^{-3}$ lead standard occurred in the first quarter of 1980 at the Denver CAMP monitor. Since then, the concentrations recorded at all monitors have showed a steady decline. This decline is the direct result of the use of unleaded gasoline and the replacement of older cars with newer ones that do not require leaded gasoline. The reduction in atmospheric lead shows what pollution control strategies can accomplish. In 2006, monitoring for lead by the APCD was reduced from six locations to one. In 2007, that lead monitor was moved from the Denver CAMP location to the Denver Municipal Animal Shelter NCore site at 678 S. Jason St. In the beginning of 2013 that lead monitor was moved to the new NCore site (LaCasa) at 4545 Navajo St. in Denver.

Colorado currently operates two lead monitors. Figure 2.19 illustrates statewide trends in Pb since 2010. The APCD lead data will not be discussed further in this report.

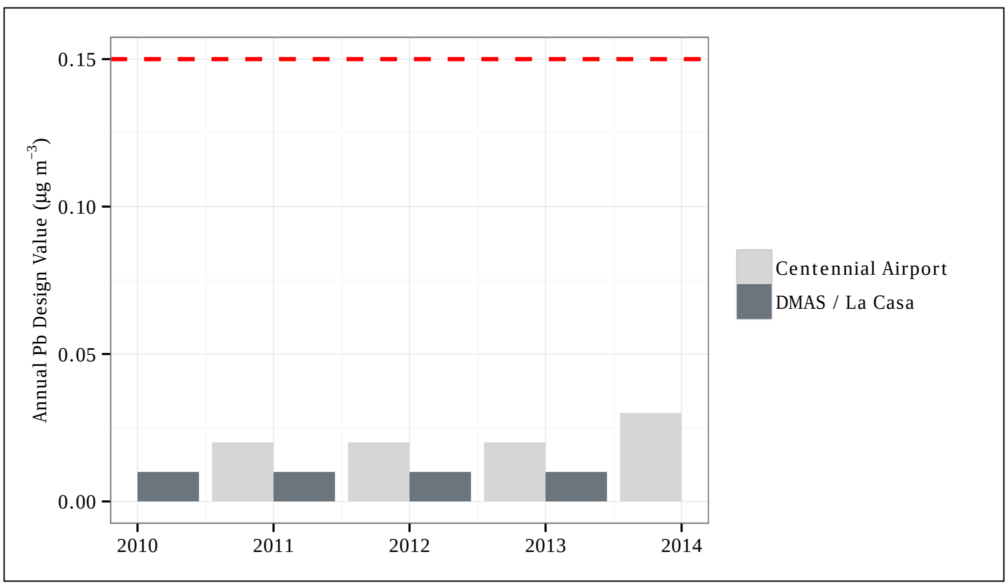


Figure 2.19: Annual Pb design values at the Centennial Airport and DMAS / La Casa stations.

3

Non-Criteria Pollutants

Non-criteria pollutants are those pollutants for which there are no current national ambient air quality standards. These include but are not limited to visibility, certain oxides of nitrogen species, total suspended particulates, some continuous particulate monitoring, and air toxics. Meteorological measurements of wind speed, wind direction, temperature, and humidity are also included in this group, as is chemical speciation of $PM_{2.5}$ analyses.

3.1 Visibility

Visibility is unique among air pollution effects in that it involves human perception and judgment. It has been described as the maximum distance that an object can be perceived against the background sky. Visibility also refers to the clarity with which the form and texture of distant, middle, and near details can be seen as well as the sense of the trueness of their apparent coloration. As a result, measures of visibility serve as surrogates of human perception. There are several ways to measure visibility but none of them tell the whole story or completely measure visibility as we experience it.

3.1.1 Standards

The Colorado Air Quality Control Commission established a visibility standard in 1990 for the Denver Metropolitan "AIR Program" area. The standard, an atmospheric extinction of 0.076 per inverse kilometer, was based on the public's definition of unacceptable amounts of haze as judged from slides of different haze levels taken in the Denver area. At the standard, 7.6% of the light is extinguished in each kilometer of air, and the standard is violated when the four-hour average extinction exceeds 7.6%. The standard applies from 8 A.M. to 4 P.M. each day, during those hours when the relative humidity is less than 70%. Visibility, along with meteorology and concentrations of other pollutants for which National Ambient Air Quality Standards exist, is used to determine the need for mandatory wood burning and voluntary driving restrictions.

There is no quantitative visibility standard for Colorado's pristine and scenic rural areas. However, in the 1977 amendments to the Federal Clean Air Act, Congress added Section 169a (Clean Air Act as amended in 1977, Section 169a 1977) and established a national visibility goal that created a qualitative standard of "the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I federal areas which impairment results from man-made air pollution." The implementation of Section 169a has led to federal requirements to protect visual air quality in large national parks and wilderness areas (Visibility Protection for Federal Class 1 Areas n.d.). Twelve of these Class I areas are located in Colorado. Federal and state law prohibits visibility impairment in national parks and wildernesses due to large stationary sources of air pollution.

3.1.2 Impacts on Public Welfare

Visual air quality is an element of public welfare. Specifically, it is an important aesthetic, natural, and economic resource of the State of Colorado. EPA, the US Forest Service, and the US National Park Service have conducted studies that show that good visibility is something that people undeniably value. They have also shown that impaired visibility affects the enjoyment of a recreational visit to a scenic mountain area.

While the value of visibility is difficult to measure, the APCD believes that people prefer to have clear views from their homes and offices. These concerns are reflected in residential property values and office rents. Any loss in visual air quality may contribute to corresponding losses in tourism and usually make an area less attractive to residents, potential newcomers, and industry. Researchers have found this link strongest with concentrations of fine particles, which are the main contributor to visibility impairment. In July 1997, the EPA developed a NAAQS for $PM_{2.5}$ (more details are subsubsection 2.2.5.3). Any control strategies to lower ambient concentrations of fine particulate matter for health reasons will also improve visibility.

3.1.3 Sources

The cause of visibility impairment in Colorado is most often fine particles in the 0.1 to 2.5 μm size range. Light passing from a vista to an observer is either scattered away from the sight path or absorbed by the atmospheric fine particulates. Sunlight entering the pollution cloud may be scattered into the sight path adding brightness to the view and making it difficult to see elements of the vista. Sulfate, nitrate, elemental carbon, and organic carbon are the types of particulate matter most effective at scattering and/or absorbing light. The man-made sources of these particulates include wood burning, electric power generation, industrial combustion of coal or oil, and emissions from cars, trucks, and buses.

Visibility conditions vary considerably across the state. Usually, visibility in Colorado is among the best in the country. Our prized western vistas exist due to unique combinations of topography and scenic features. Air in much of the West contains low humidity and minimal levels of visibility-degrading pollution. Nevertheless, visibility problems occur periodically throughout the state. Wood burning haze is a concern in several mountain communities each winter and Denver has its "Brown Cloud" pollution episodes.[1] Even national parks, monuments, and wilderness areas experience pollution related visibility impairment on occasion due to regional haze, interstate traffic or even regional or global-scale transport of visibility-degrading pollution.[2] The visibility problems across the state have raised public concern and spurred research. The goal of Colorado's visibility program is to protect visual air quality where it is presently acceptable and improve visibility where it is degraded.

3.1.4 Class I Areas in Colorado

Phase 1 of the visibility program, also known as Reasonably Attributable Visibility Impairment (RAVI), addresses impacts in Class I areas by establishing a process to evaluate source specific visibility impacts, or plume blight, from individual sources or small groups of sources. Figure 3.1 illustrates these areas in Colorado.

Section 169B was added to the Clean Air Act Amendments of 1990 to address Regional Haze. Since Regional Haze and visibility problems do not respect state and tribal boundaries, the amendments authorized EPA to establish visibility transport regions as a way to combat regional haze.

Phase 2 of the visibility program addresses Regional Haze. This form of visibility impairment focuses on overall decreases in visual range, clarity, color, and ability to discern texture and details in Class I areas. The responsible air pollutants can be generated in the local vicinity or carried by the wind often many hundreds or even thousands of miles from where they originated.

[1]Neff, W. D. (1997). The Denver Brown Cloud studies from the perspective of model assessment needs and the role of meteorology. Journal of the Air Waste Management Association, 47(3), 269-285

[2]Kavouras, I. G., Etyemezian, V., DuBois, D. W., Xu, J., Pitchford, M. (2009). Source reconciliation of atmospheric dust causing visibility impairment in Class I areas of the western United States. Journal of Geophysical Research: Atmospheres (1984Ű2012), 114(D2)

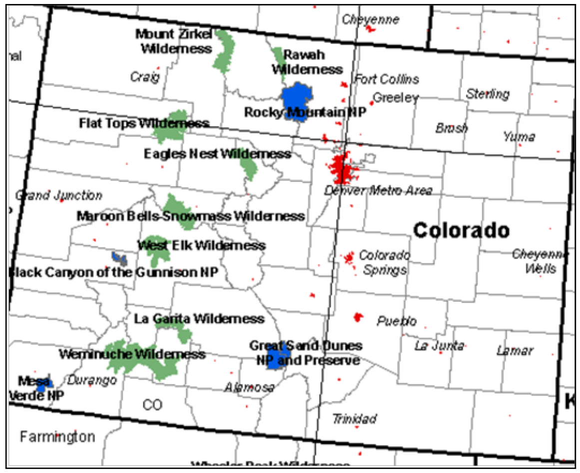


Figure 3.1: Class I areas in Colorado. Red indicates a populated region, blue indicates a National Park or Preserve, and green indicates a federally-protected wilderness area.

The APCD developed a Regional Haze State Implementation Plan (SIP) in 2010 illustrating how Colorado intends to meet the requirements of EPA's Regional rules for the period ending in 2018 (the first planning period in the rule), while also establishing enforceable controls that will help address the long term national visibility goals targeted to be achieved by the year 2064.

Colorado's Regional Haze SIP was approved by the Colorado Air Quality Control Commission on January 7, 2011. This plan will lead to less haze and improved visibility in some of Colorado's most treasured and scenic areas, including Rocky Mountain National Park, Mesa Verde, Maroon Bells, and the Great Sand Dunes. By 2018, the plan will result in more than 70,000 tons of pollutant reductions annually, including 35,000 tons of nitrogen oxides, which leads to ground-level ozone formation. In total, the plan covers 30 industrial emitters at 16 facilities throughout Colorado, including coal-fired power plants and cement kilns.

3.1.5 Monitoring

There are several ways to measure visibility. The APCD uses camera systems to provide qualitative visual documentation of a view. Transmissometers and nephelometers are used to measure the atmosphere's ability to attenuate light quantitatively.

A visibility site was installed in Denver in late 1990 using a long-path transmissometer. Visibility in the downtown area is monitored using a receiver located near Cheesman Park at 1901 E. 13th Avenue and a transmitter located on the roof of the Federal Building at 1929 Stout Street (Figure 3.2). This instrument directly measures light extinction, which is proportional to the ability of atmospheric particles and gases to attenuate image-forming light as it travels from an object to an observer. The visibility standard is stated in units of atmospheric extinction. Days when the visibility is affected by rain, snow, or relative humidity above 70% are termed "excluded" and are not counted as violations of the visibility standard.

In September 1993, a transmissometer and nephelometer were purchased by the City of Fort Collins to monitor visibility in that community. Elsewhere in Colorado, several agencies of the federal government, in cooperation with regional and nationwide state air pollution organizations, also monitor visibility in a number of national parks and wilderness Class I areas, either individually or jointly through the Interagency Monitoring of Protected Visual Environments (IMPROVE) program. The goals of the monitoring programs are to establish background visibility levels, identify trends of deterioration or improvement, identify suspected sources of visibility impairment, and to track regional haze. Visibility and the atmospheric constituents that cause visibility degradation are characterized with camera systems, transmissometers, and extensive fine particle chemical composition measurements by the monitoring network. There are currently IMPROVE monitoring sites in Rocky Mountain National Park, Mesa Verde National

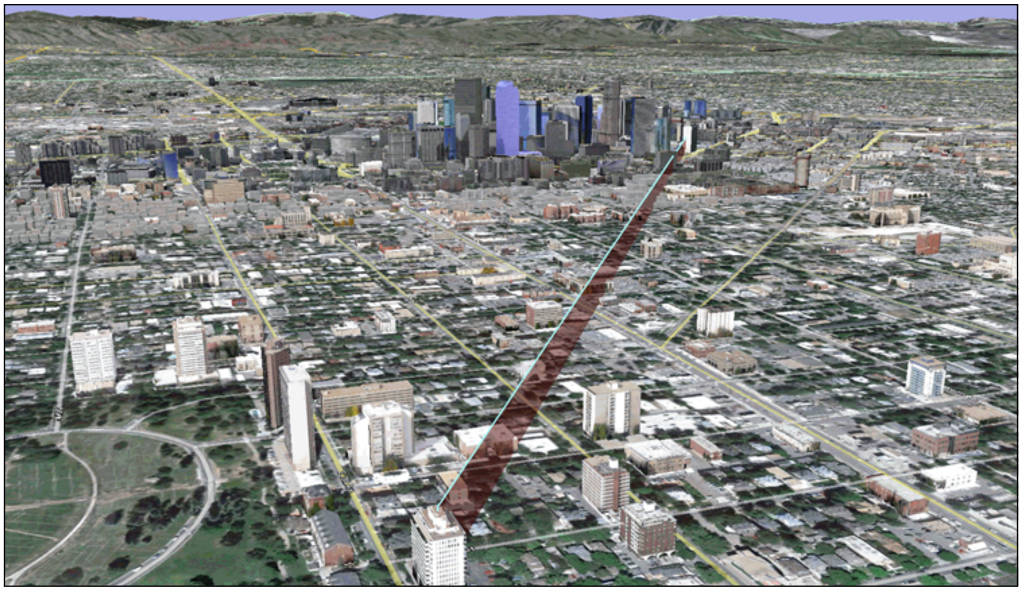


Figure 3.2: Denver transmissometer path (for illustration purposes only).

Park, Weminuche Wilderness, Mount Zirkel Wilderness, Great Sand Dunes National Monument, White River National Forest, and Flattops Wilderness. These data are not contained in this report, but are available at `http://vista.cira.colostate.edu/improve/`.

3.1.6 Denver Camera

The APCD operates a web-based camera that can be viewed on the Live Image of Denver icon on the bottom left side of the screen at the APCD web site `http://www.colorado.gov/airquality`. There is a great deal of other information available from this site in addition to the image from the visibility camera, including the Front Range Air Quality Forecast, Air Quality Advisory, Monitoring Reports, this report, and Open Burning Forecast.

The images in Figure 3.3 show the visibility on one of the best and worst days for the year. One of the best visibility days was March 9, 2014. One of the worst visibility days was February 10, 2014.

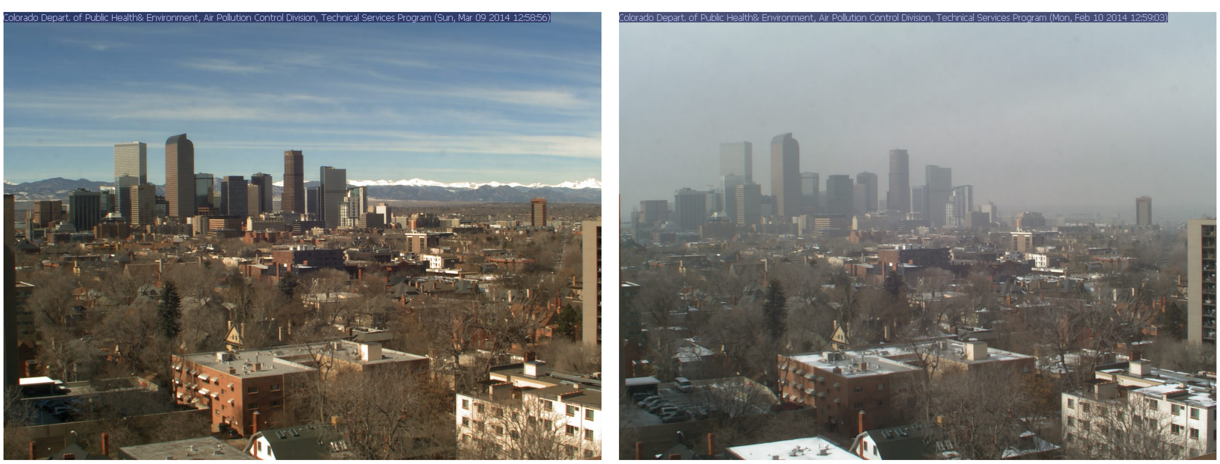


Figure 3.3: Denver Camera images of the best (left) and worst (right) visibility days in Denver during 2014.

These two pictures are images made by the web camera at the visibility monitor located at 1901 E. 13$^{\text{th}}$ Avenue in Denver, and are centered on the Federal Building at 1929 Stout Street (see Figure 3.2, the camera follows the transmissometer path). The difference in these two pictures is not just the brightness but the detail that can be seen between the two images. On the best day, buildings can be clearly resolved, and the Front Range is visible. On the worst day, however, contrast between buildings is lower, and the Front Range is obscured. The beta extinction values for March 9, 2014 (best day) and February 10, 2013 (worst day) were 0.026 and 0.367 inverse kilometers, respectively.

3.2 Nitric Oxide

Nitric oxide (NO) is the most abundant of the oxides of nitrogen emitted from combustion sources. There are no known adverse health effects at normal ambient concentrations. However, NO is a precursor to nitrogen dioxide, nitric acid, particulate nitrates, and ozone, all of which have demonstrated adverse health effects. There are no federal or state standards for nitric oxide.

Nitric oxide was measured simultaneously with NO_2 at the Welby, CAMP, La Casa, and I-25 Denver sites. Table 3.1 shows the maximum and average NO concentrations measured in Colorado in 2014. Without national standards with which to compare these numbers, they are presented here for informational purposes only, and are considered by the APCD to be consistent with recent historical nitric oxide concentrations (the I-25 site does not have long-term historical data to compare, as it was installed in June of 2013).

Table 3.1: Summary of nitric oxide values measured at APCD monitoring sites in 2014.

Site Name	County	NO (ppb)	
		Annual Average	Maximum Value
Welby	Adams	17.6	458
CAMP	Denver	21.6	453
La Casa	Denver	17.2	418
I-25 Denver	Denver	40.0	486

3.3 Total Suspended Particulates

Total suspended particulates (TSP) were first monitored in Colorado in 1960 at 414 14th Street in Denver. This location monitored TSP until 1988. The Adams City and Gates TSP monitors began operation in 1964 and the Denver CAMP monitor at 2105 Broadway began operating in 1965. Either the EPA or the City of Denver operated these monitors until the mid-1970s, when daily operation was taken over by the Colorado Department of Public Health and Environment. The APCD only monitors for TSP at the La Casa site today.

Particulate monitoring expanded to more than 70 locations throughout the state by the early 1980s. The primary standards for total suspended particulates were 260 $\mu g\ m^{-3}$ as a 24-hour sample and 75 $\mu g\ m^{-3}$ as an annual geometric mean. On July 1, 1987, with the promulgation of PM_{10} standards, the old TSP standards were eliminated. Until December 2006 the Division operated six TSP samplers to measure lead. On January 1, 2007 the number of lead monitoring sites was reduced to one location, at the Denver Municipal Animal Shelter located at 678 S. Jason Street. The reason for the change in the number of TSP monitors is that the ambient concentrations of lead have been reduced dramatically. The DMAS site was shut down and relocated due to site inaccessibility, to the La Casa NCore monitoring site at 4545 Navajo Street in late 2012. While TSP was discontinued at both sites, APCD began sending low-volume PM_{10} filters for lead analysis by XRF to Chester Lab, with the first sample being analyzed January 3, 2013.

In October of 2008 the lead standard changed. With this change, a TSP sampler was installed near the Centennial Airport in Arapahoe County. The location was selected to more closely monitor lead from small aircraft that still use leaded fuel. The maximum TSP concentration recorded in 2013 at the Centennial Airport was 52 $\mu g\ m^{-3}$. A more detailed explanation of the lead standard and measurements can be found in subsection 2.2.6.

3.4 Air Toxics

Toxic air pollutants, or air toxics, are those pollutants that cause or may cause cancer or other serious health effects, such as reproductive effects or birth defects. Air toxics may also cause adverse environmental and ecological effects. EPA is required to reduce air emissions of 188 air toxics listed in the Clean Air Act. Examples of air toxics include benzene (found in gasoline), perchloroethylene (emitted from some dry cleaning facilities), and methylene chloride (used as a solvent by a number of industries). Most air toxics originate from man-made sources, including mobile sources like cars, trucks, and construction equipment, and stationary sources like factories, refineries, and power plants, as well as indoor sources (some building materials and cleaning solvents). Some air toxics are also released from natural sources such as volcanic eruptions and forest fires (United States Environmental Protection Agency 2009).

People exposed to air toxics at sufficient concentrations may experience various health effects including cancer and damage to the immune system, as well as neurological, reproductive (including reduced fertility), developmental, respiratory, and other health problems. In addition to exposure from breathing air toxics, risks are also associated with the deposition of toxic pollutants onto soils or surface waters, where they are taken up by plants and ingested by animals and eventually magnified up through the food chain. Like humans, animals may experience health problems due to air toxics exposure.

The APCD currently monitors for air toxics in Grand Junction as part of EPA's National Air Toxics Trend Stations project. Monitoring for ozone precursors, which are a subset of air toxics, also began at CAMP and Platteville in December of 2011. The data from the Grand Junction study and the Ozone Precursor study are available in separate reports, available at `http://www.colorado.gov/airquality/tech.aspx#misc`.

3.5 Meteorology

The APCD takes a limited set of meteorological measurements at 17 locations around the state. These measurements include wind speed, wind direction, temperature, standard deviation of horizontal wind direction, and select monitoring of relative humidity. Relative humidity measurements are also taken in conjunction with the two visibility monitors. The humidity data are not summarized in this report since they are used primarily to validate the visibility measurements taken at the specific locations. The Division does not collect precipitation measurements. The wind speed, wind direction, and temperature measurements are collected primarily for air quality forecasting and air quality modeling. These instruments are installed on ten-meter towers and the data are collected as hourly averages and sent along with other air quality data to be stored on the EPA's Air Quality Systems database. The wind speed and wind direction data are shown as wind roses at the end of each monitoring area in chapter 4 below.

The wind roses displayed in this report (see chapter 4) are based on the direction that the wind is blowing from. Another way of visualizing a wind rose is to picture yourself standing in the center of the plot and facing into the wind. The wind direction is divided into 12 cardinal directions (ESE, for example). The wind speed is divided into six ranges. The roses in Section 4 below use 1-5 mph, 5-8 mph, 8-13 mph, 13-20 mph, 20-24 mph, and greater than 25 mph. The length of each arm of the wind rose represents the percentage of time the wind was blowing from that direction at that speed. The longer the arm, the greater the percentage of time the wind is blowing from that direction.

3.6 Chemical Speciation of $PM_{2.5}$

Numerous health effects studies have correlated negative health effects to the total mass concentration of $PM_{2.5}$ in ambient air. However, it has not yet been completely determined if the health correlation is to total mass concentration, or to concentrations of specific chemical species in the $PM_{2.5}$ mix. When the EPA promulgated the NAAQS for $PM_{2.5}$ in 1997, a compliance monitoring network based on total $PM_{2.5}$ mass was established. Mass concentrations from the compliance network are used to determine attainment of the NAAQS. EPA soon supplemented the $PM_{2.5}$ network with the Speciation Trends Network (STN) monitoring to provide information on the chemical composition of $PM_{2.5}$. The main purpose of the STN is to identify sources, develop implementation plans to reduce $PM_{2.5}$ pollution, and support health effects research.

Colorado began chemical speciation monitoring at the Commerce City site in February 2001. Four other chemical speciation sites were established in 2001 in Colorado Springs, Durango, Grand Junction, and Platteville. The Durango site was closed in September 2003. The Colorado Springs site was closed in December 2006. These sites were eliminated when concentrations were found to trend low and when funding was reduced for the project. The Grand Junction site was closed in December 2009 and moved to DMAS NCore where it began sampling in January of 2010 to comply with the requirement from EPA to monitor $PM_{2.5}$ speciation at NCore sites. The DMAS NCore site was shut down due to site inaccessibility and moved to the La Casa NCore monitoring site at 4545 Navajo Street in late 2012. APCD is currently monitoring for $PM_{2.5}$ speciation at the LaCasa, Platteville and Commerce City monitoring sites.

If $PM_{2.5}$ pollution is to be controlled, it is important to know the composition of $PM_{2.5}$ particles so that the appropriate sources can be targeted for reductions (see subsubsection 2.2.5.3 above for more information on $PM_{2.5}$ sources). Therefore, chemical speciation monitoring is conducted for 47 elemental metals, five ionic species, and elemental and organic carbon. Selected filters can also be analyzed for semi-volatile organics and microscopic analyses. The results of these samples can be obtained from the APCD upon request. Some of these chemical species and compounds can cause serious health effects, premature death, visibility degradation, and regional haze. The chemical speciation data for $PM_{2.5}$ is used in many ways, such as to determine which general source categories are likely responsible for the $PM_{2.5}$ pollution at a given monitoring site on a given day, and how much pollution comes from each source category. There are two broad categories of $PM_{2.5}$ - primary and secondary particles. Primary $PM_{2.5}$ particles include those emitted directly to the air. Primary particles include carbonaceous particles from incomplete combustion in internal combustion engines, wood burning appliances, waste burning, and crushed geologic materials. Secondary $PM_{2.5}$ is formed from gases that combine in the atmosphere through chemical processes and form liquid aerosol droplets. Ammonium nitrates and ammonium sulfates are generally the two largest types of secondary $PM_{2.5}$ in Colorado.

4

Spatial Variability of Air Quality

In this section, concentration data covering the last decade are summarized for each air quality monitor in the APCD network, which are grouped below by monitoring region and pollutant. The box plots presented in this section show the maximum, minimum, median, and interquartile range of values measured during each year. Where appropriate, the annual design value (e.g., the 98^{th} percentile of 24-hour $PM_{2.5}$ concentrations) is shown as a green point and the NAAQS level is shown as a dotted red line.

Please refer to subsection 1.1.2 for a brief description of the monitoring regions discussed below.

4.1 Central Mountains Region

4.1.1 Particulate Matter

The data below may include exceptional events. See subsubsection 2.2.5.4.

Table 4.1: Summary of PM_{10} values recorded at monitoring stations in the Central Mountains region during 2014.

Site Name	County	PM_{10} (µg m^{-3})		
		Annual Average	24-Hr Max	3-Year Exceedances
Cañon City	Fremont	18.1	55	0
Crested Butte	Gunnison	21.6	116	0
Mt.Crested Butte	Gunnison	14.8	74	0.7
Aspen	Pitkin	15.7	38	0
Steamboat Springs	Routt	19.6	84	0

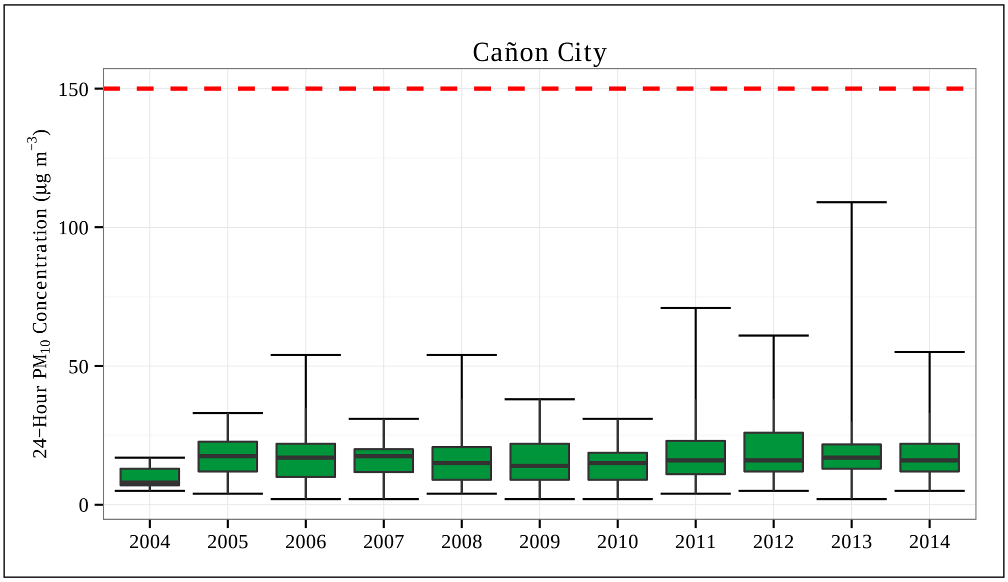


Figure 4.1: 24-hr PM_{10} concentrations at the Cañon City station. The 24-hour standard (150 μg m^{-3}) is shown as a dashed red line.

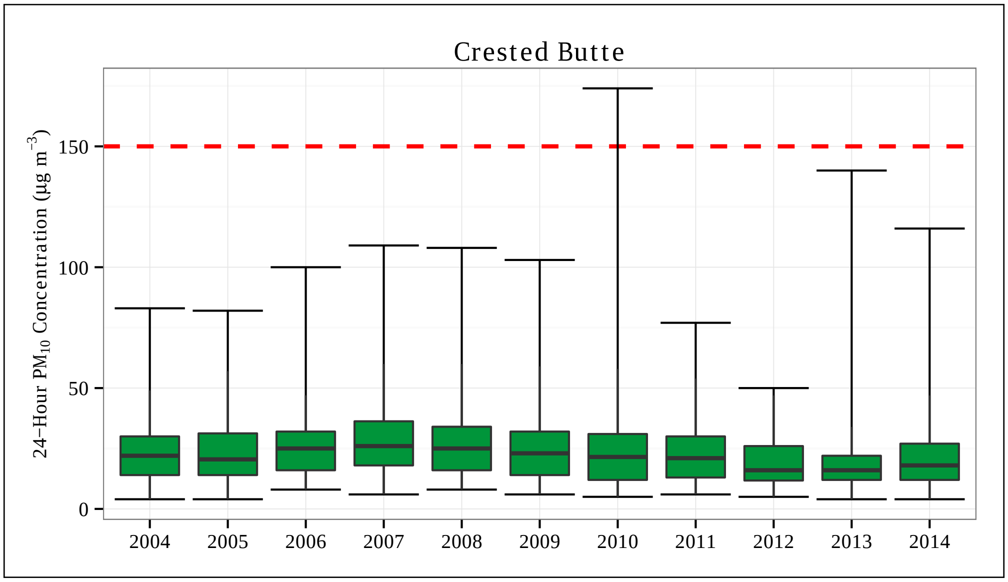


Figure 4.2: 24-hr PM_{10} concentrations at the Crested Butte station. The 24-hour standard (150 μg m^{-3}) is shown as a dashed red line.

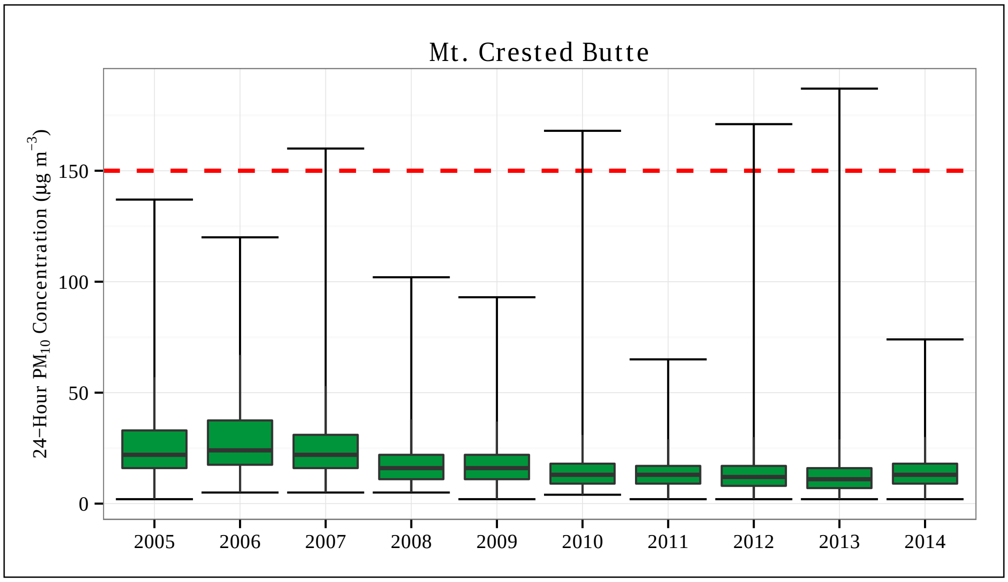


Figure 4.3: 24-hr PM_{10} concentrations at the Mt. Crested Butte station. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

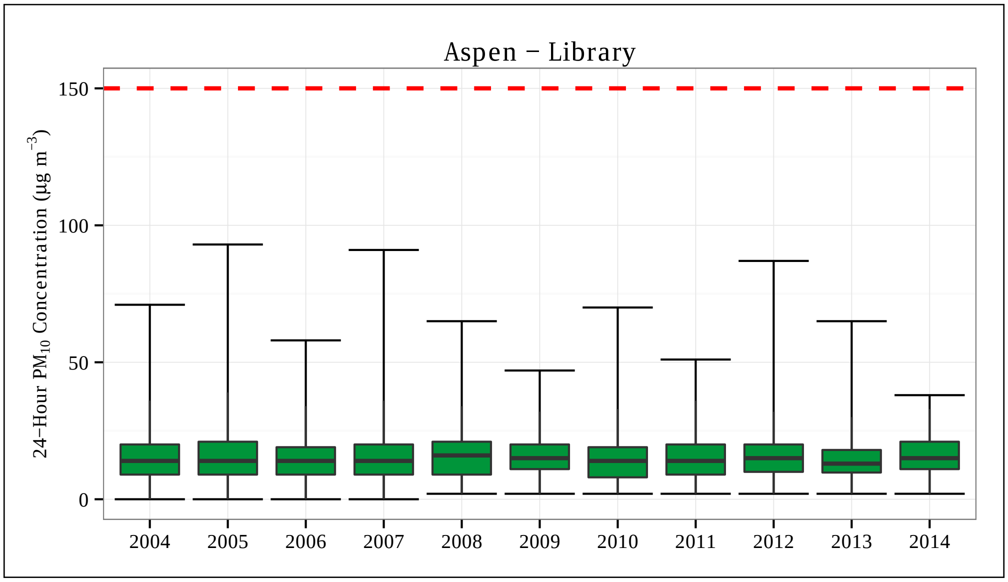


Figure 4.4: 24-hr PM_{10} concentrations at the Aspen - Library station. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

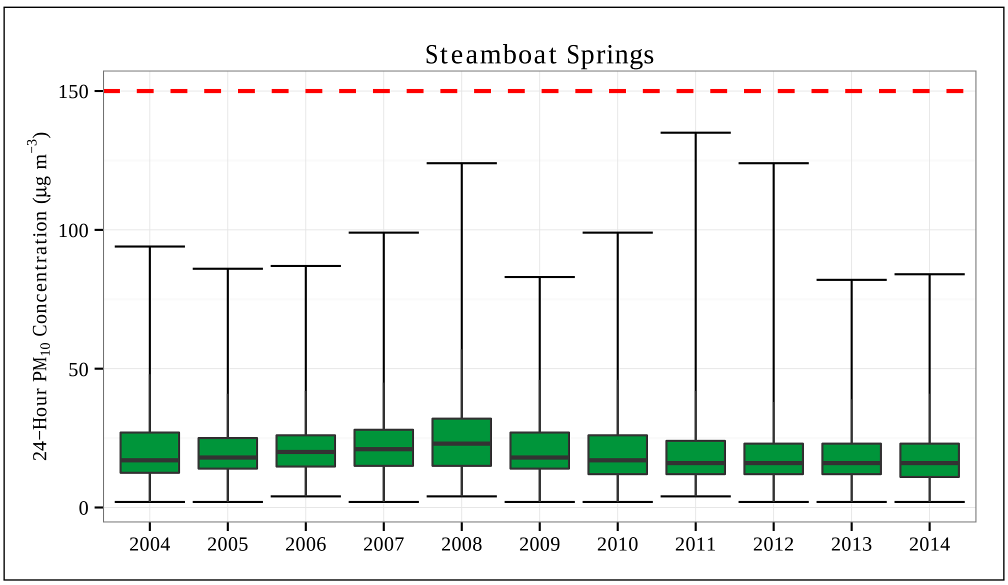


Figure 4.5: 24-hr PM_{10} concentrations at the Steamboat Springs station. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

4.2 Denver Metro / North Front Range Region

4.2.1 Particulate Matter

Table 4.2 shows that there were no violations of the PM_{10} or $PM_{2.5}$ NAAQS in the Denver Metro / Northern Front Range counties in 2014. Data below may include exceptional events (see subsubsection 2.2.5.4).

Table 4.2: Summary of PM_{10} and $PM_{2.5}$ values recorded at monitoring stations in the Denver Metro / Northern Front Range region during 2014.

Site Name	County	PM_{10} ($\mu g\ m^{-3}$)			$PM_{2.5}$ ($\mu g\ m^{-3}$)	
		Annual Average	24-Hr Max	3-Year Exceedances	Annual Average	98^{th} Percentile
Alsup	Adams	28.6	117	0	9.1	27.1
Welby	Adams	14.7	93	0		
Arapaho Comm. College	Arapahoe				6.0	16.8
Longmont	Boulder	23.3	61	0	7.5	23.9
Boulder Chamber of Comm.	Boulder	23.7	56	0	6.1	15.4
CAMP	Denver	30.9	129	0	7.6	27.3
Denver Visitor Center	Denver	23.6	72	0		
La Casa	Denver	20.2	69	0	8.0	24.4
I-25 Denver	Denver					
Chatfield State Park	Douglas				5.6	13.0
Ft. Collins - CSU	Larimer	17.1	150	0	6.4	19.4
Greeley - Hospital	Weld	21.5	71	0	7.5	25.4
Platteville	Weld				8.1	30.5

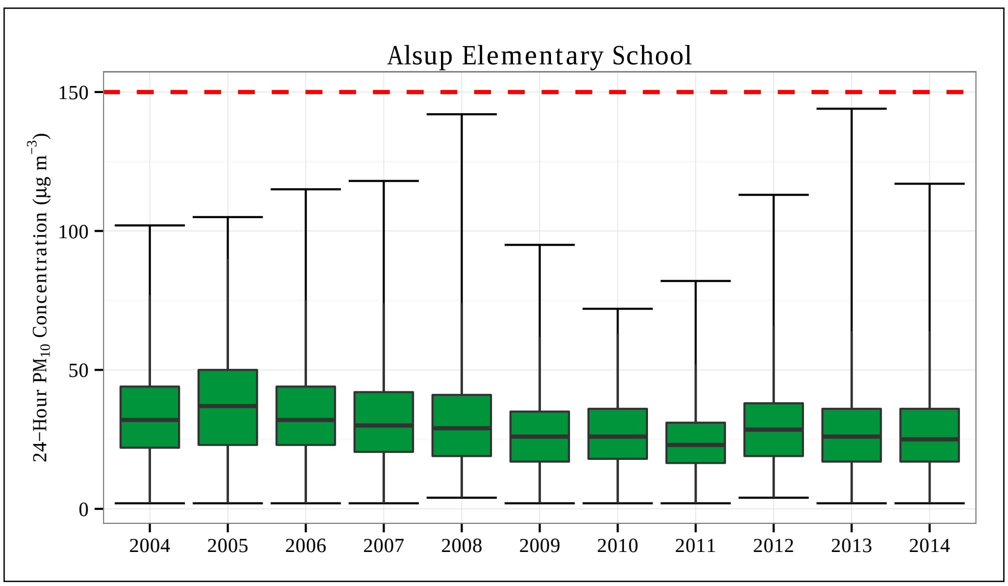


Figure 4.6: 24-hr PM_{10} concentrations at the Alsup station. The 24-hour standard (150 $\mu g\ m^{-3}$) is shown as a dashed red line.

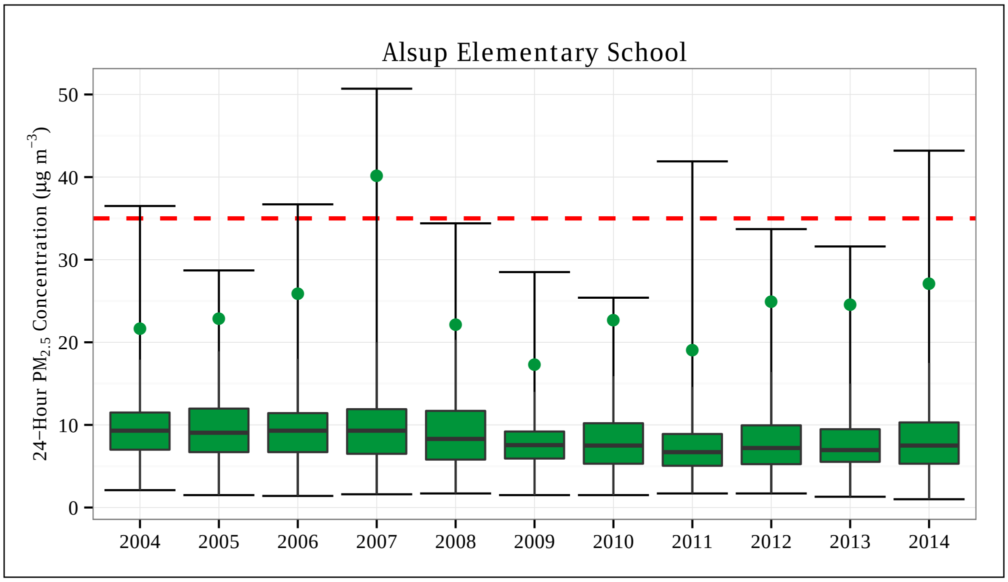


Figure 4.7: 24-hr $PM_{2.5}$ concentrations at the Alsup station. The 24-hour standard (35 µg m^{-3}) is shown as a dashed red line. The annual design value (98^{th} percentile of values measured throughout the year) is shown for each year as a green point.

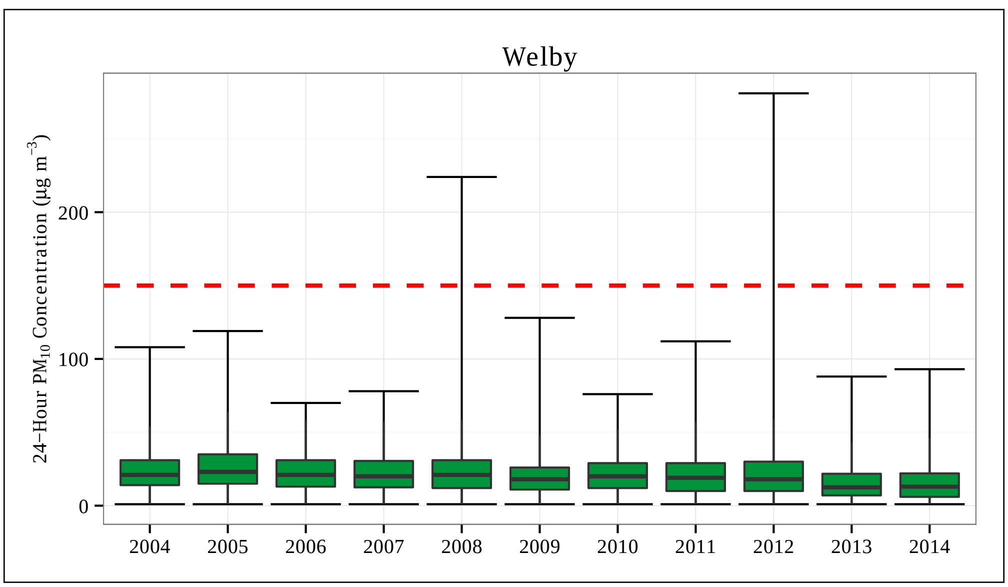


Figure 4.8: 24-hr PM_{10} concentrations at the Welby station. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

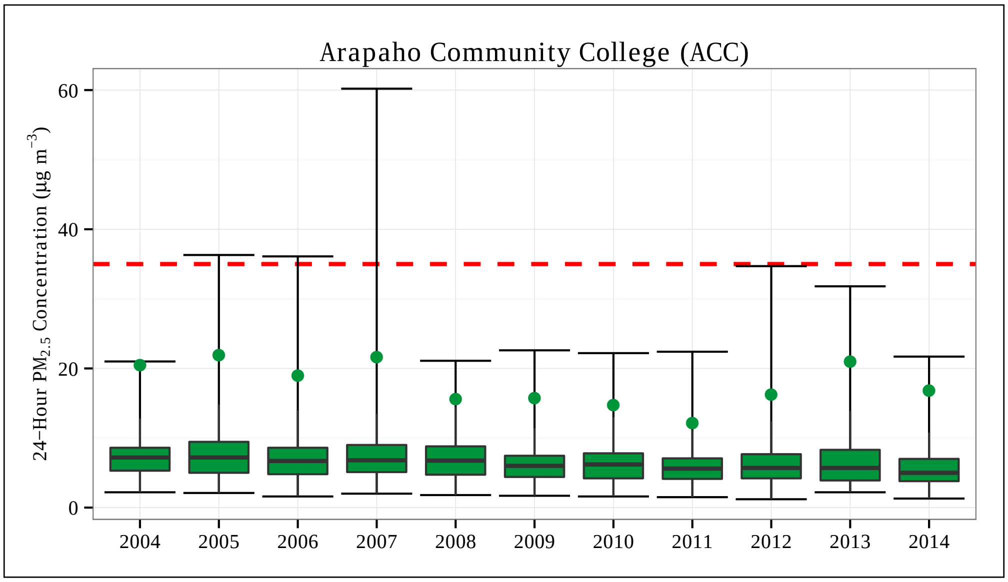


Figure 4.9: 24-hr $PM_{2.5}$ concentrations at the Arapaho Community College station. The 24-hour standard (35 µg m^{-3}) is shown as a dashed red line. The annual design value (98th percentile of values measured throughout the year) is shown for each year as a green point.

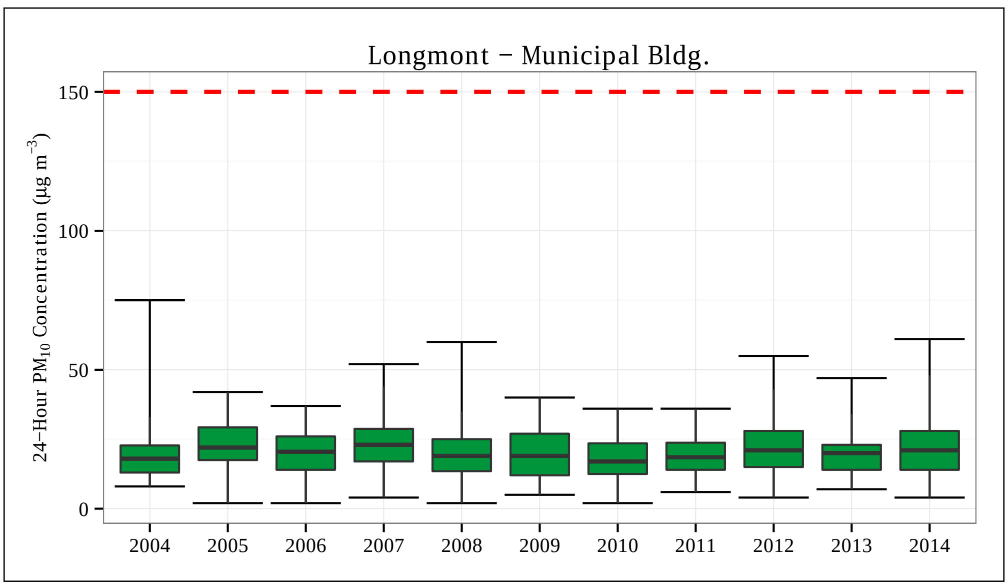


Figure 4.10: 24-hr PM_{10} concentrations at the Longmont station. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

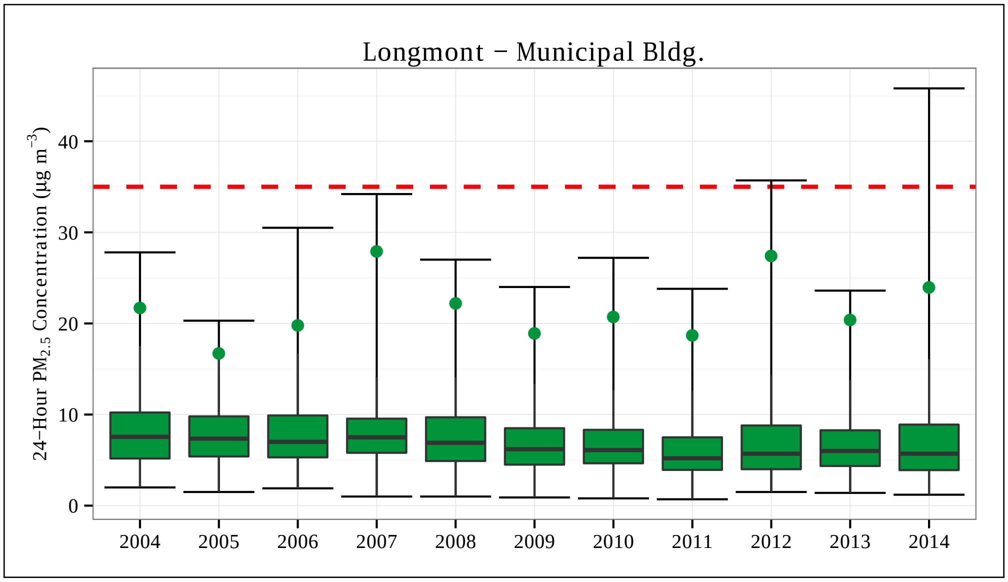


Figure 4.11: 24-hr $PM_{2.5}$ concentrations at the Longmont - Municpal Bldg. station. The 24-hour standard (35 µg m^{-3}) is shown as a dashed red line. The annual design value (98^{th} percentile of values measured throughout the year) is shown for each year as a green point.

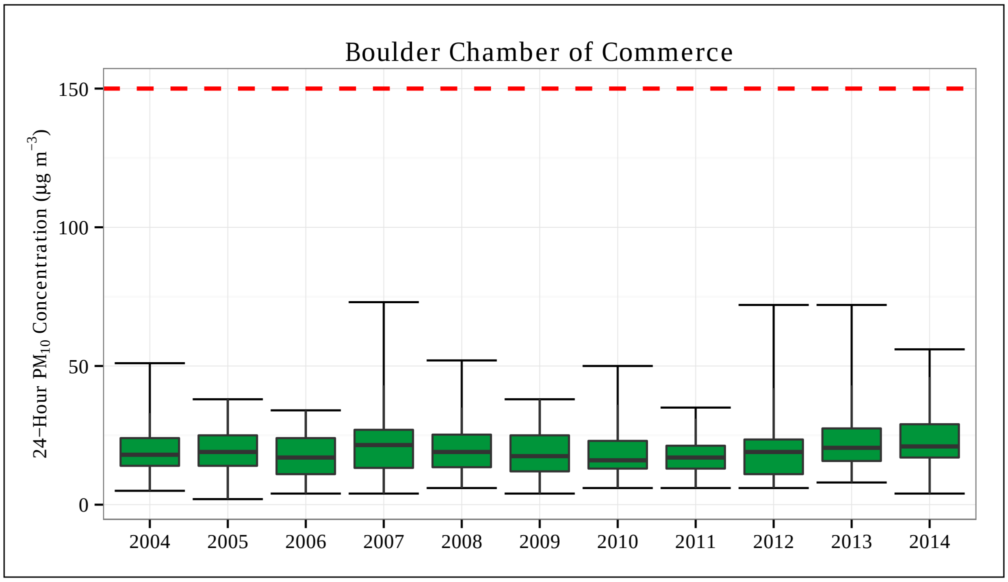


Figure 4.12: 24-hr PM_{10} concentrations at the Boulder Chamber of Commerce station. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

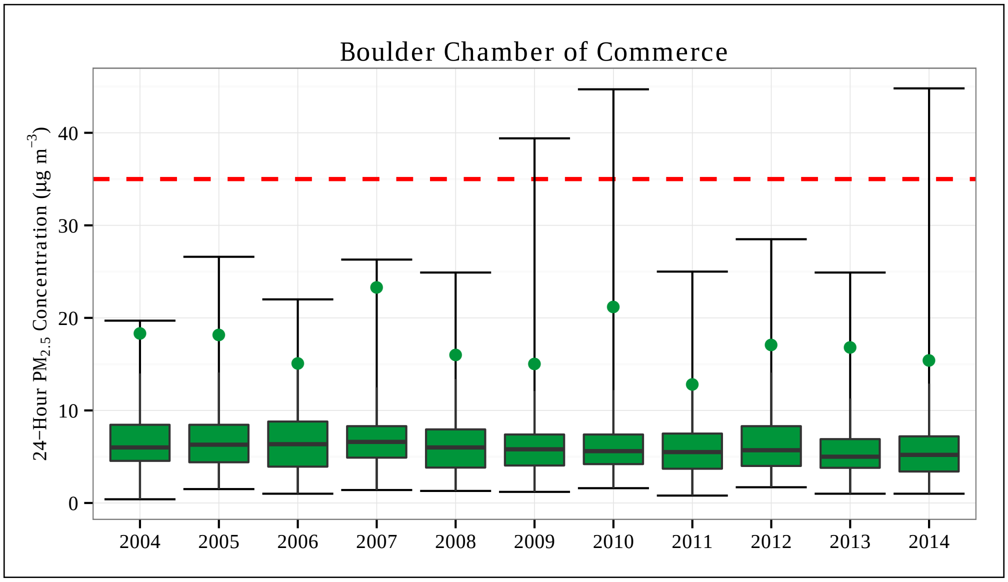


Figure 4.13: 24-hr $PM_{2.5}$ concentrations at the Boulder Chamber of Commerce station. The 24-hour standard (35 µg m^{-3}) is shown as a dashed red line. The annual design value (98^{th} percentile of values measured throughout the year) is shown for each year as a green point.

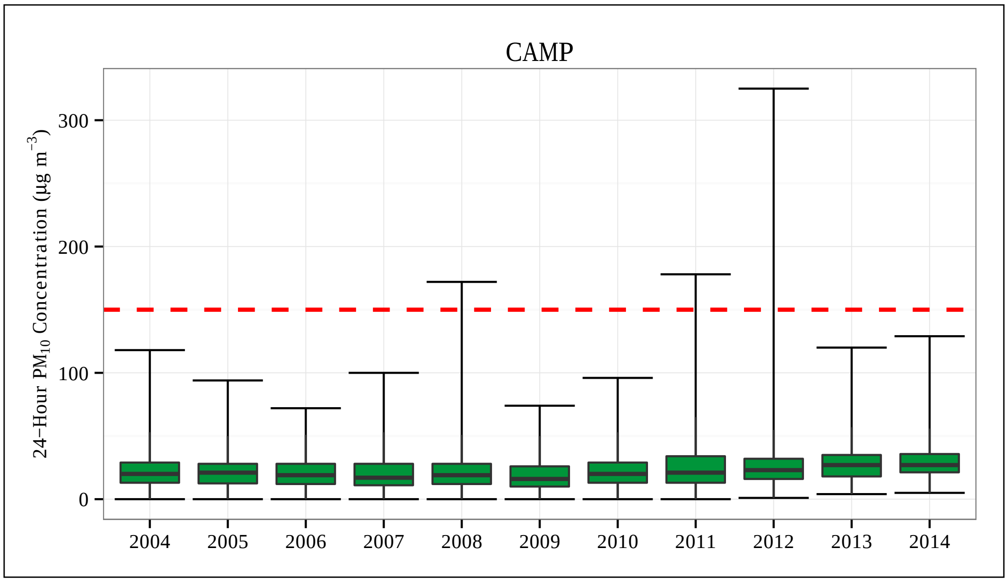


Figure 4.14: 24-hr PM_{10} concentrations at the CAMP station. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

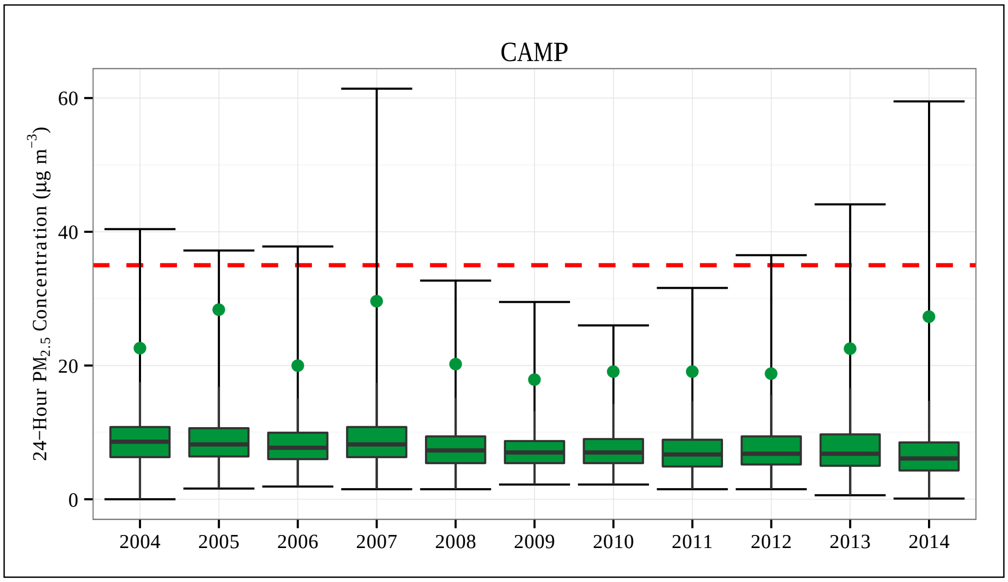


Figure 4.15: 24-hr $PM_{2.5}$ concentrations at the CAMP station. The 24-hour standard (35 $\mu g\ m^{-3}$) is shown as a dashed red line. The annual design value (98th percentile of values measured throughout the year) is shown for each year as a green point.

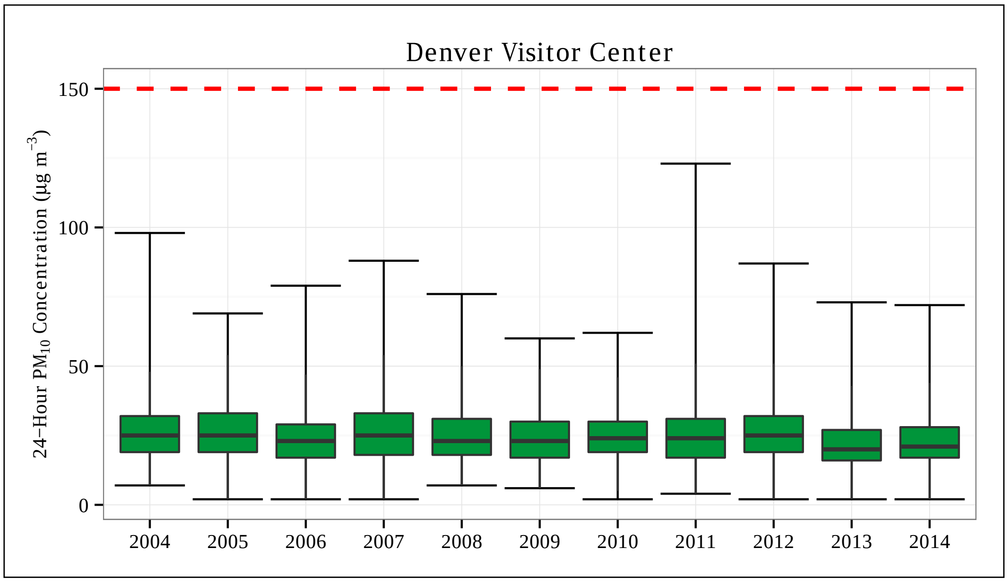


Figure 4.16: 24-hr PM_{10} concentrations at the Denver Visitor Center station. The 24-hour standard (150 $\mu g\ m^{-3}$) is shown as a dashed red line.

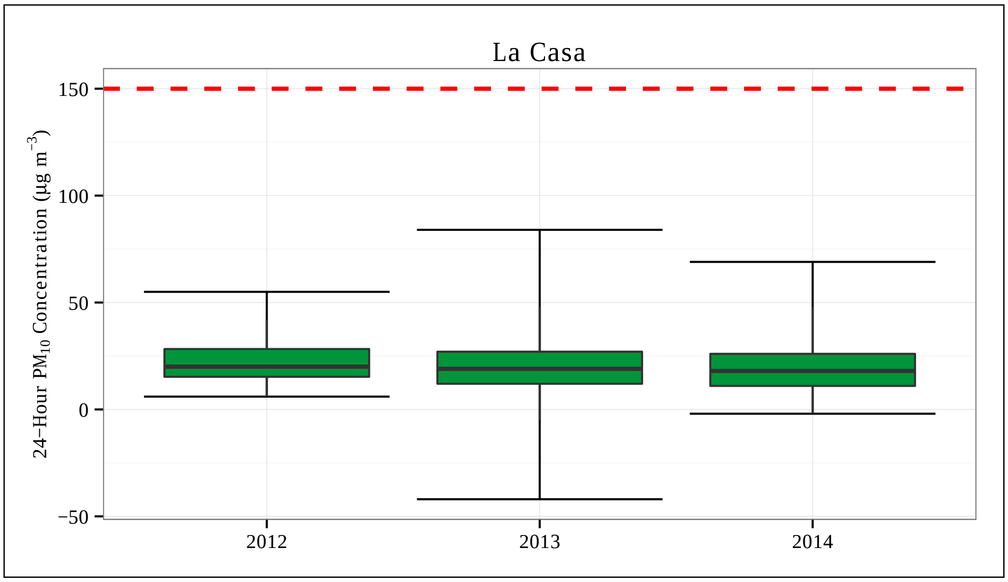


Figure 4.17: 24-hr PM_{10} concentrations at the La Casa station. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

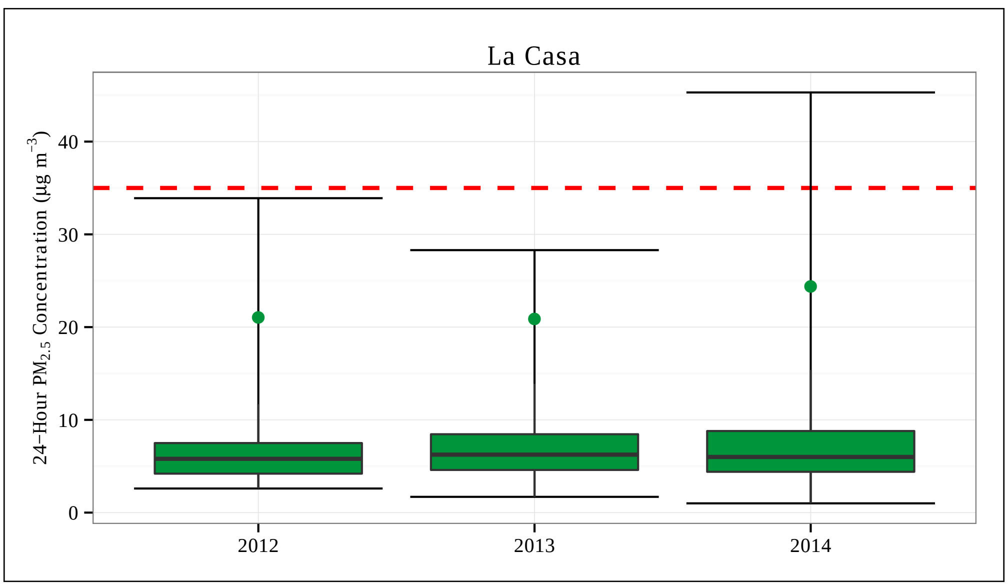


Figure 4.18: 24-hr $PM_{2.5}$ concentrations at the La Casa station. The 24-hour standard (35 µg m^{-3}) is shown as a dashed red line. The annual design value (98th percentile of values measured throughout the year) is shown for each year as a green point.

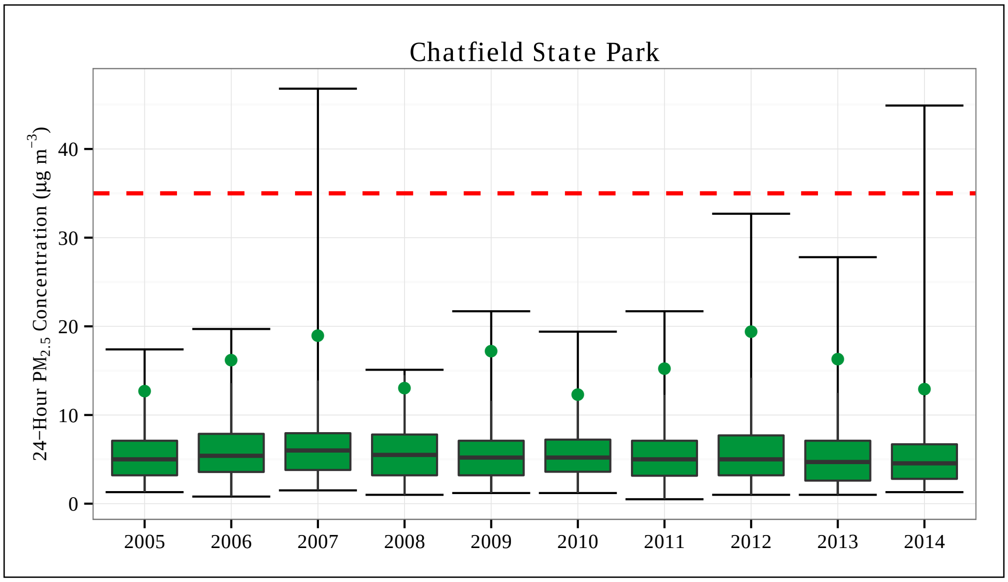


Figure 4.19: 24-hr $PM_{2.5}$ concentrations at the Chatfield station. The 24-hour standard (35 µg m^{-3}) is shown as a dashed red line. The annual design value (98^{th} percentile of values measured throughout the year) is shown for each year as a green point.

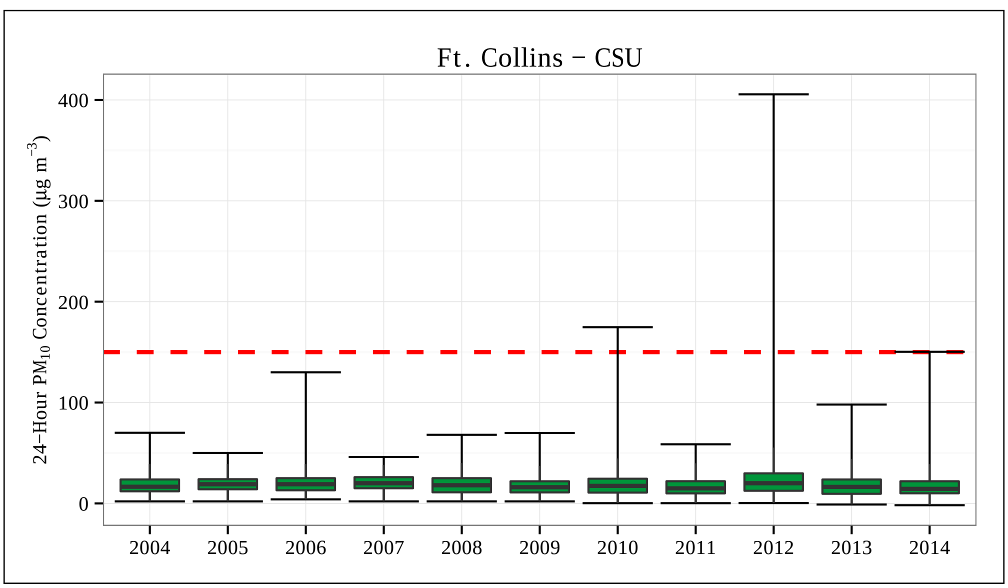


Figure 4.20: 24-hr PM_{10} concentrations at the Ft. Collins - CSU station. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

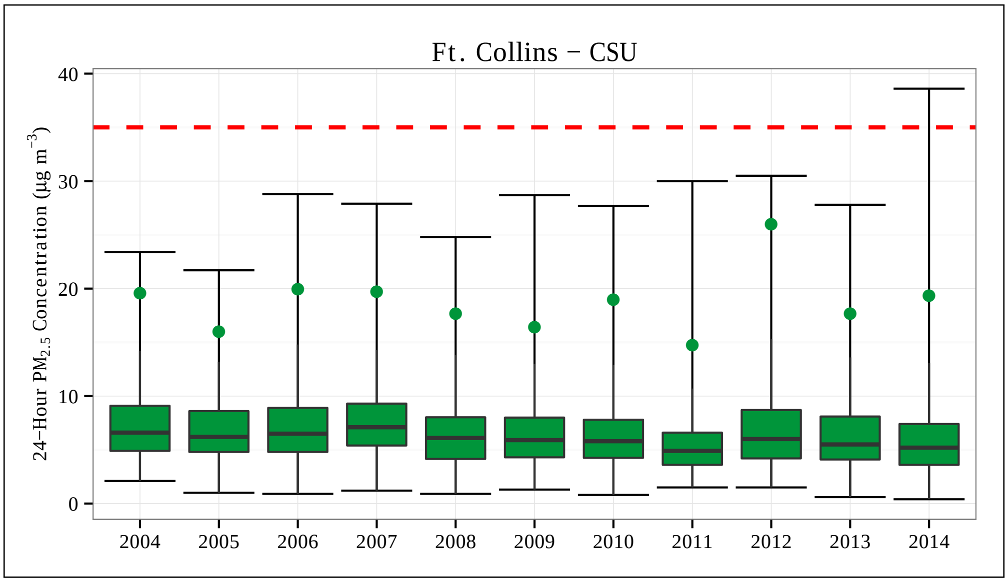


Figure 4.21: 24-hr $PM_{2.5}$ concentrations at the Ft. Collins - CSU station. The 24-hour standard (35 µg m^{-3}) is shown as a dashed red line. The annual design value (98^{th} percentile of values measured throughout the year) is shown for each year as a green point.

Figure 4.22: 24-hr PM_{10} concentrations at the Greeley - Hospital station. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

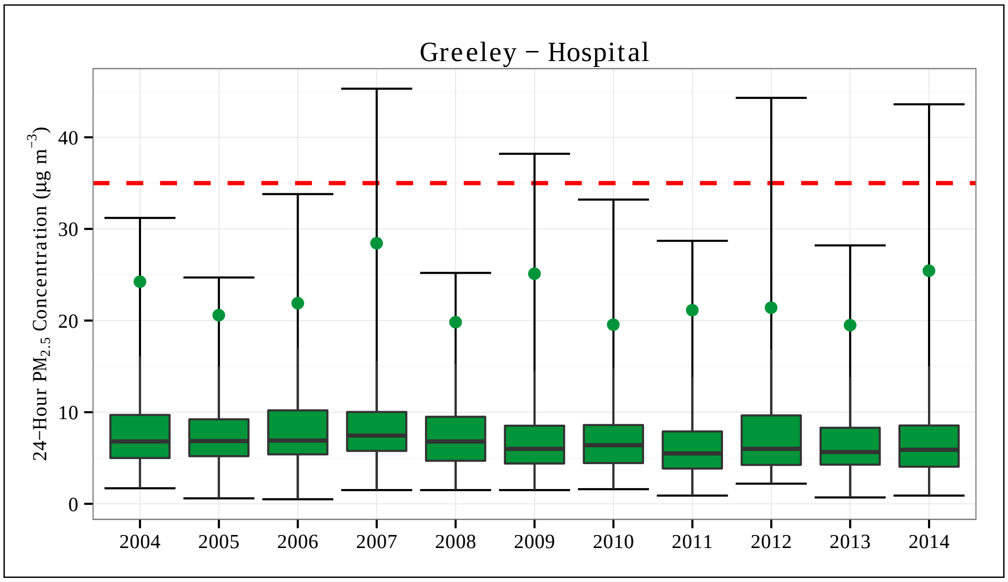


Figure 4.23: 24-hr $PM_{2.5}$ concentrations at the Greeley - Hospital station. The 24-hour standard (35 µg m^{-3}) is shown as a dashed red line. The annual design value (98^{th} percentile of values measured throughout the year) is shown for each year as a green point.

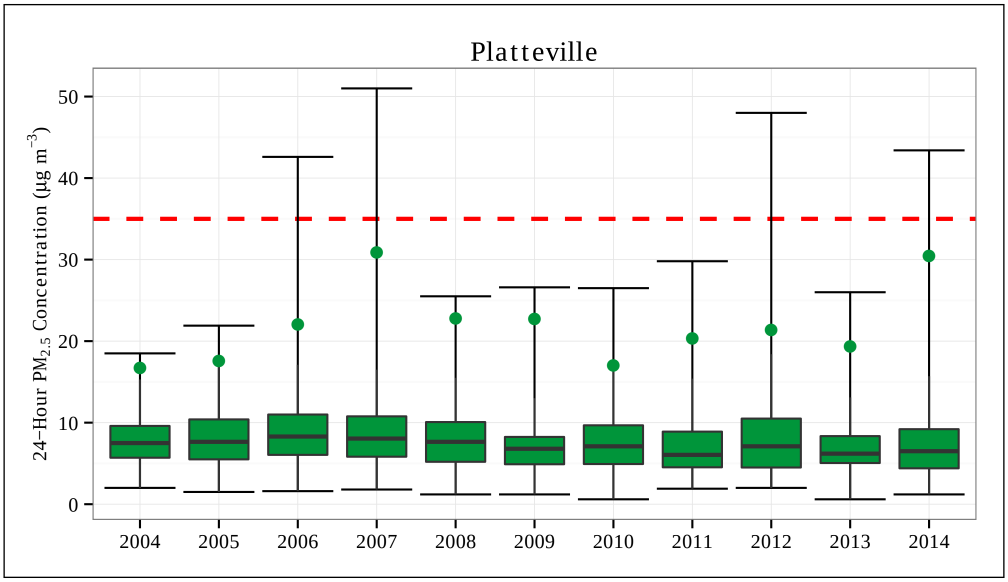


Figure 4.24: 24-hr $PM_{2.5}$ concentrations at the Platteville station. The 24-hour standard (35 µg m^{-3}) is shown as a dashed red line. The annual design value (98^{th} percentile of values measured throughout the year) is shown for each year as a green point.

4.2.2 Carbon Monoxide

Table 4.3: Summary of CO values recorded at monitoring stations in the Denver Metro / Northern Front Range region during 2014.

Site Name	County	CO 1-Hour Average (ppm)		CO 8-Hour Average (ppm)	
		1st Max.	2nd Max.	1st Max.	2nd Max.
Welby	Adams	3.5	2.4	1.6	1.4
CAMP	Denver	3.1	3.0	1.8	0.7
La Casa	Denver	2.9	2.7	2.3	1.8
I-25 Denver	Denver	3.3	3.2	2.6	1.1
Ft. Collins - Mason	Larimer	2.7	2.6	1.0	1.0
Greeley - West Annex	Weld	2.7	2.7	1.4	1.1

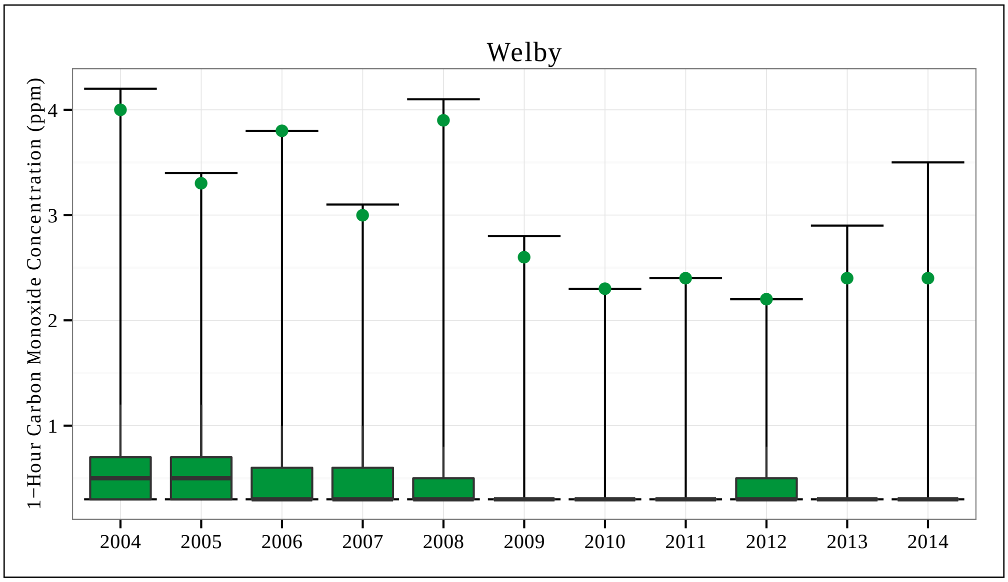


Figure 4.25: 1-hour average CO concentrations at the Welby station. The annual design value (2nd highest 1-hour value) is shown for each year as a green point.

Note: 8-hour average CO concentrations are not shown in this section. The one-hour graphs show that values are well below the 1-hour standard of 35 ppm and also indicate that the 8-hour averages are well below the 8-hour standard of 9 ppm.

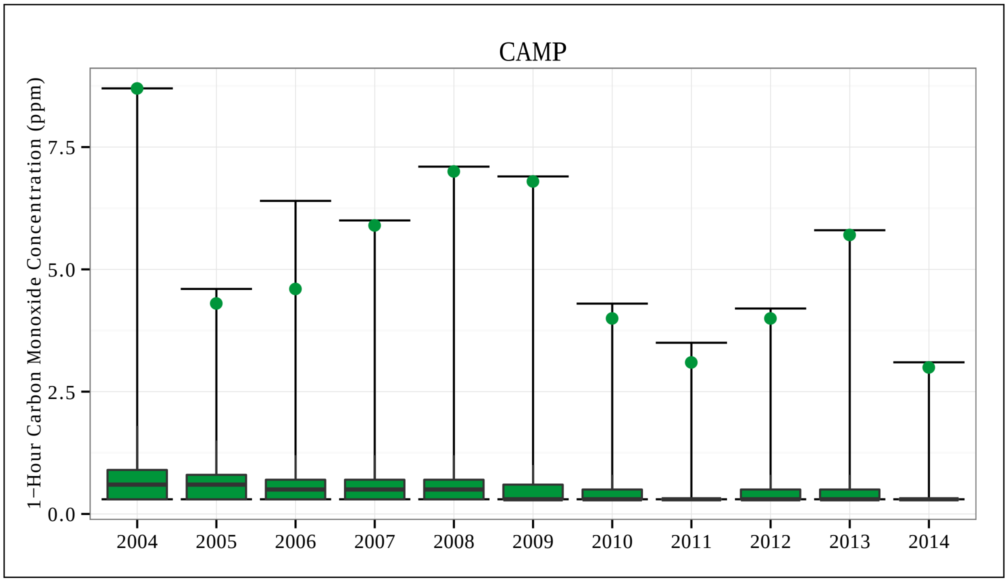


Figure 4.26: 1-hour average CO concentrations at the CAMP station. The annual design value (2^{nd} highest 1-hour value) is shown for each year as a green point.

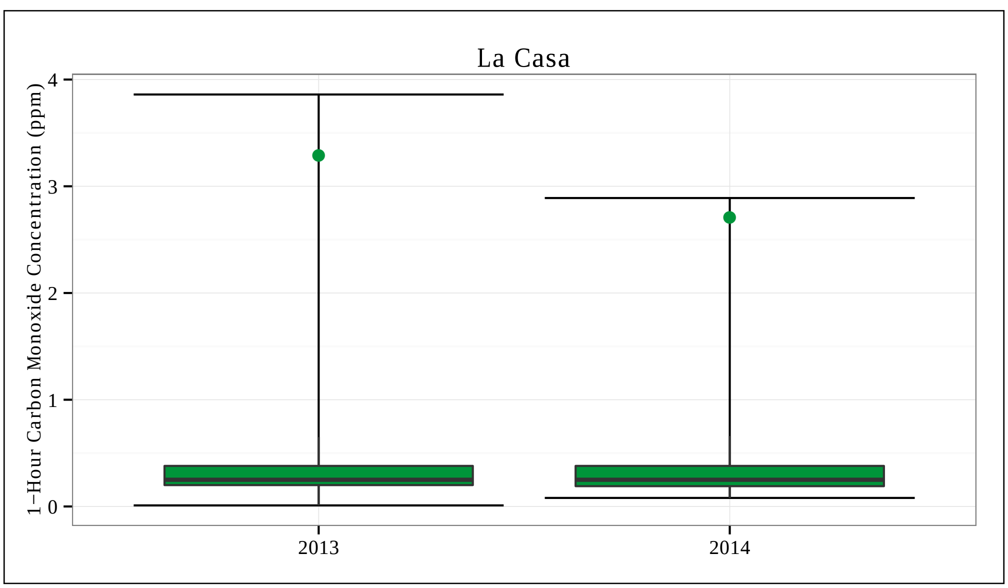


Figure 4.27: 1-hour average CO concentrations at the La Casa station. The annual design value (2^{nd} highest 1-hour value) is shown for each year as a green point.

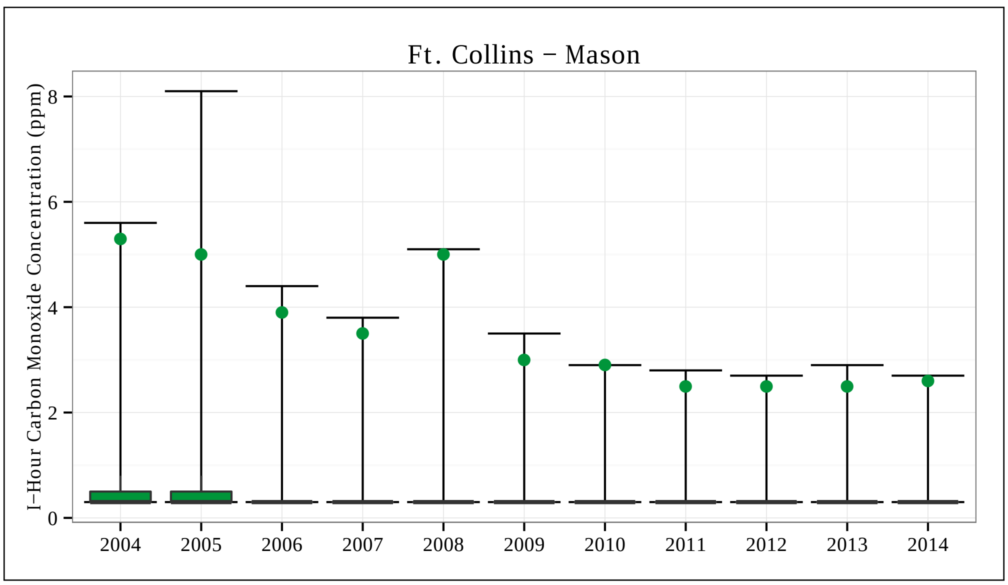


Figure 4.28: 1-hour average CO concentrations at the Ft. Collins - Mason station. The annual design value (2nd highest 1-hour value) is shown for each year as a green point.

4.2.3 Ozone

Table 4.4: Summary of O_3 values recorded at monitoring stations in the Denver Metro / Northern Front Range region during 2014.

Site Name	County	Ozone 8-Hour Average (ppm)		
		1^{st} Max.	4^{th} Max.	3-Year Ave. of 4^{th} Max.
Welby	Adams	0.074	0.067	0.073
Aurora East	Arapahoe	0.078	0.067	0.071
South Boulder Creek	Boulder	0.076	0.070	0.075
CAMP	Denver	0.068	0.061	0.065
La Casa	Denver	0.070	0.066	0.068
Chatfield State Park	Douglas	0.077	0.074	0.081
Welch	Jefferson	0.071	0.066	0.075
Rocky Flats - N.	Jefferson	0.082	0.077	0.082
NREL	Jefferson	0.079	0.076	0.080
Aspen Park	Jefferson	0.074	0.065	0.073
Ft. Collins - West	Larimer	0.083	0.074	0.078
Ft. Collins - Mason	Larimer	0.075	0.072	0.073
Greeley - County Tower	Weld	0.079	0.070	0.074

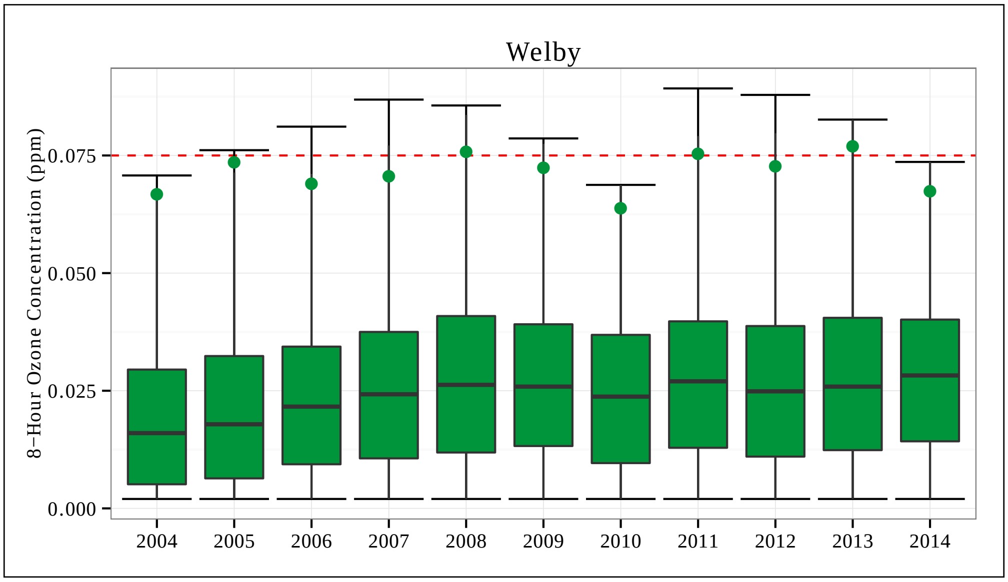


Figure 4.29: 8-hour average O_3 concentrations at the Welby station. The 8-hour standard (0.075 ppm) is shown as a dashed red line. The annual design value (4^{th} highest daily maximum 8-hour average value) is shown for each year as a green point.

Figure 4.30: 8-hour average O_3 concentrations at the Aurora - East station. The 8-hour standard (0.075 ppm) is shown as a dashed red line. The annual design value (4^{th} highest daily maximum 8-hour average value) is shown for each year as a green point.

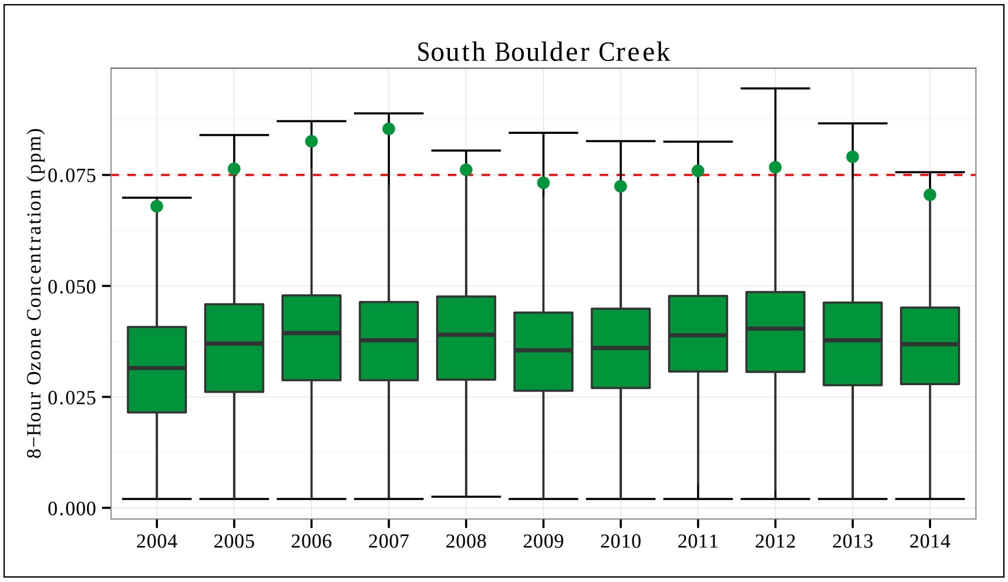


Figure 4.31: 8-hour average O_3 concentrations at the South Boulder Creek station. The 8-hour standard (0.075 ppm) is shown as a dashed red line. The annual design value (4^{th} highest daily maximum 8-hour average value) is shown for each year as a green point.

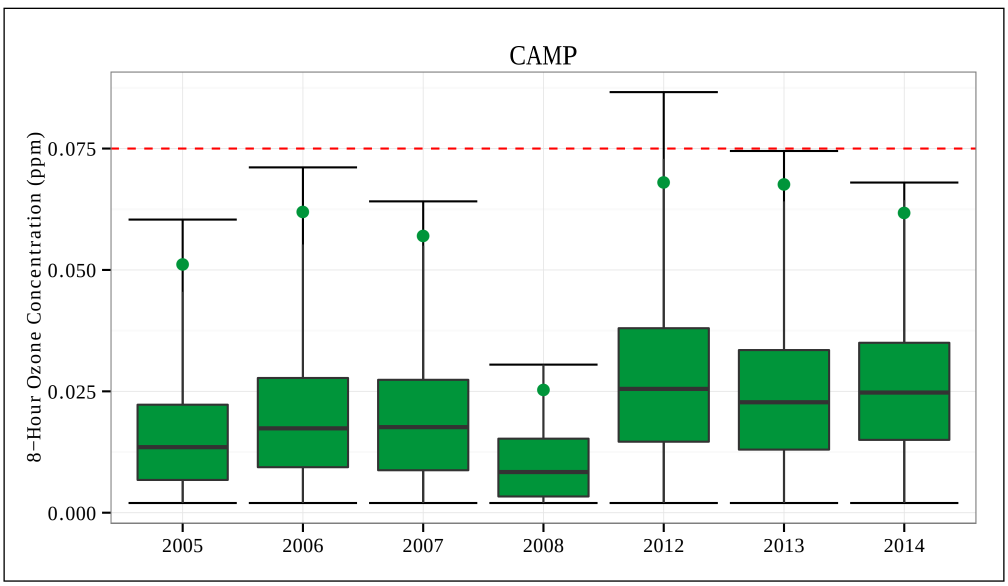


Figure 4.32: 8-hour average O_3 concentrations at the CAMP station. The 8-hour standard (0.075 ppm) is shown as a dashed red line. The annual design value 4^{th} highest daily maximum 8-hour average value) is shown for each year as a green point.

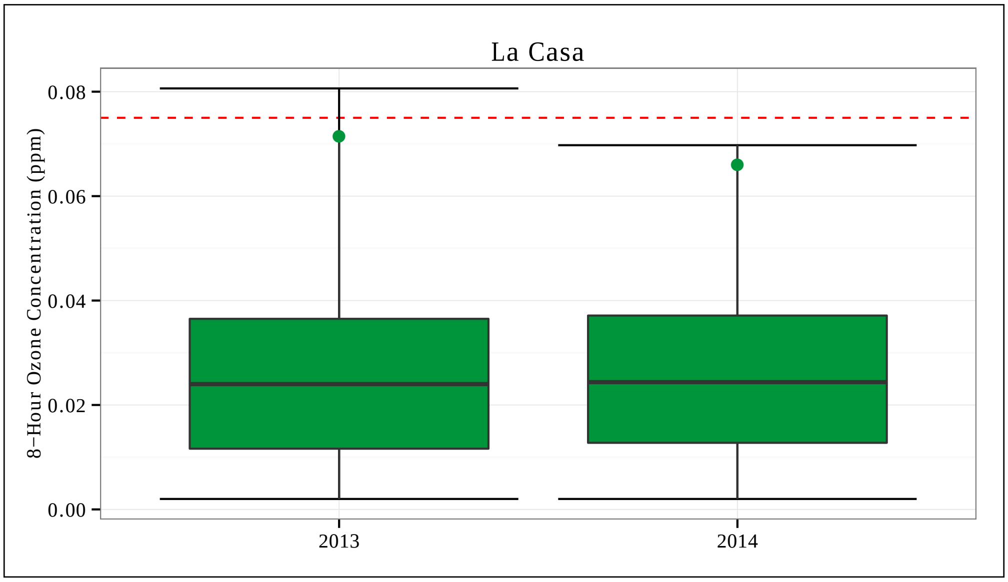


Figure 4.33: 8-hour average O_3 concentrations at the La Casa station. The 8-hour standard (0.075 ppm) is shown as a dashed red line. The annual design value (4^{th} highest daily maximum 8-hour average value) is shown for each year as a green point.

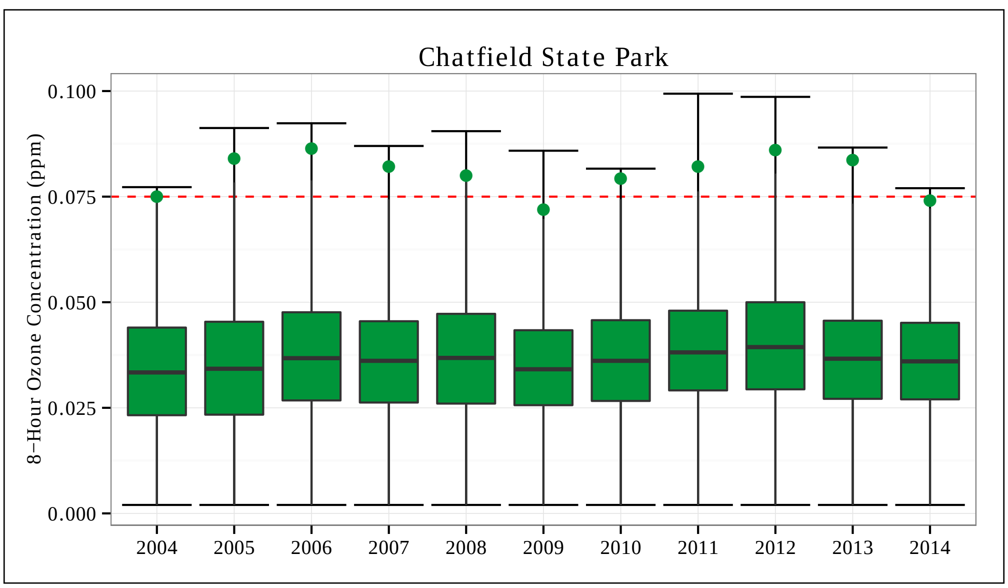


Figure 4.34: 8-hour average O_3 concentrations at the Chatfield State Park station. The 8-hour standard (0.075 ppm) is shown as a dashed red line. The annual design value (4^{th} highest daily maximum 8-hour average value) is shown for each year as a green point.

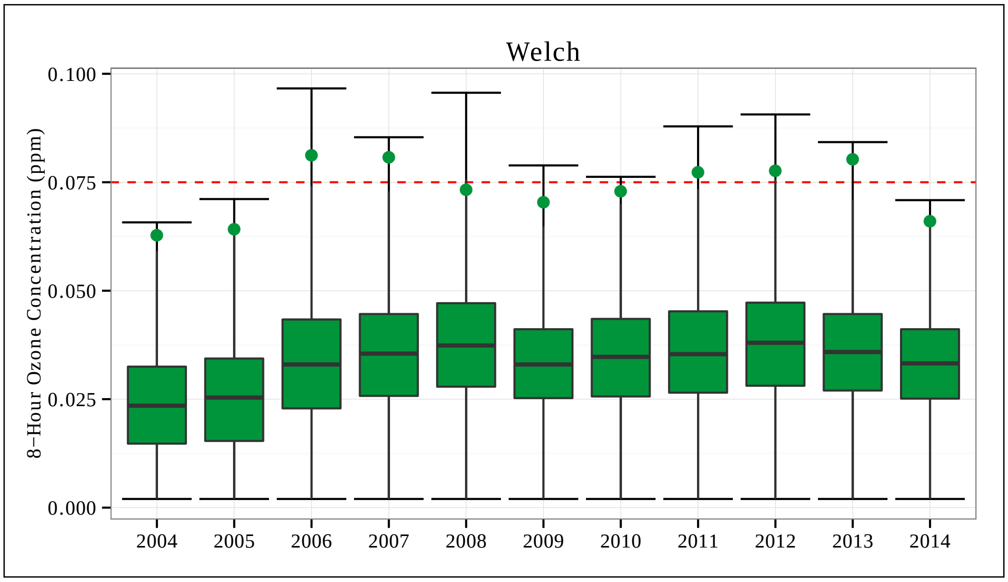


Figure 4.35: 8-hour average O_3 concentrations at the Welch station. The 8-hour standard (0.075 ppm) is shown as a dashed red line. The annual design value (4^{th} highest daily maximum 8-hour average value) is shown for each year as a green point.

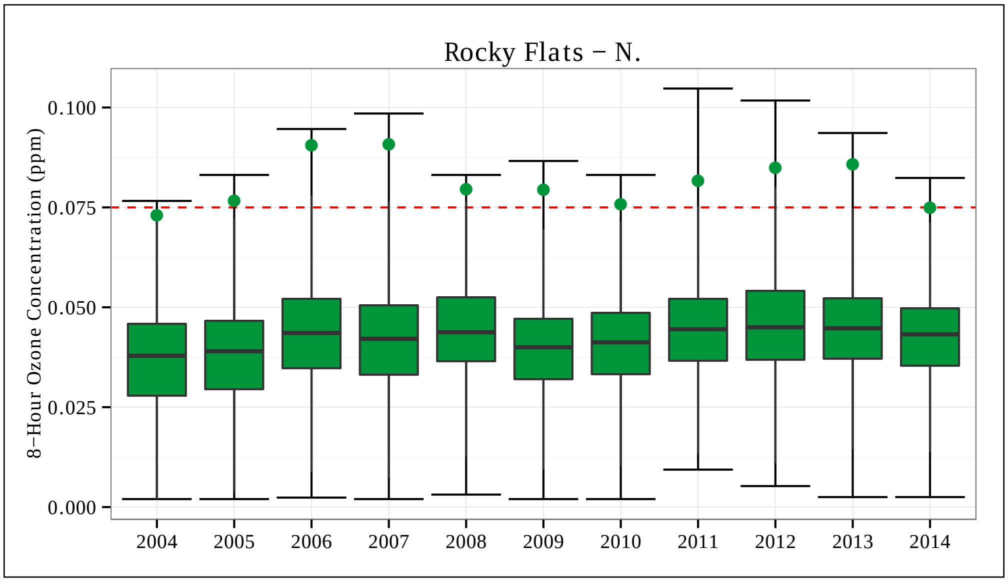


Figure 4.36: 8-hour average O_3 concentrations at the Rocky Flats - N. station. The 8-hour standard (0.075 ppm) is shown as a dashed red line. The annual design value (4^{th} highest daily maximum 8-hour average value) is shown for each year as a green point.

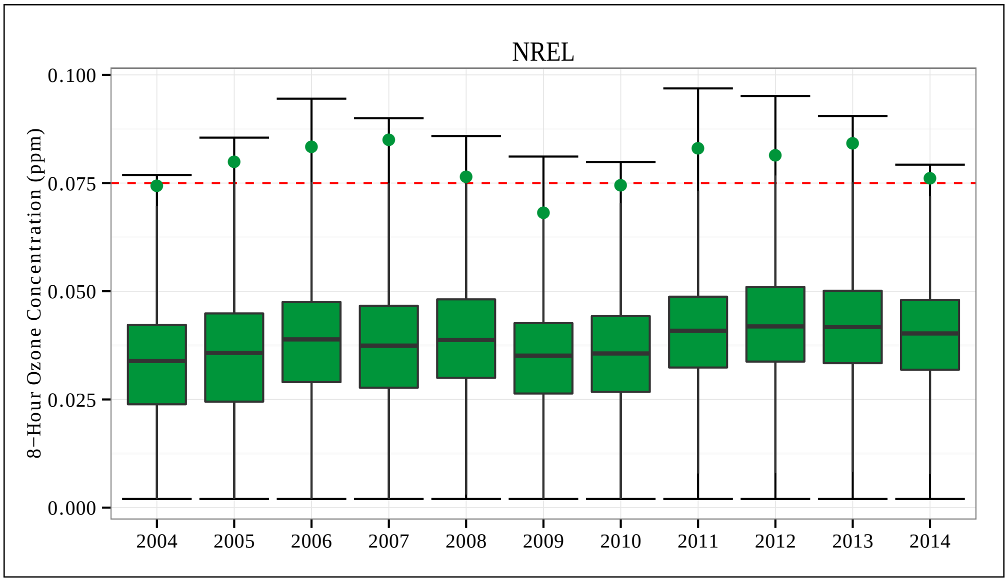


Figure 4.37: 8-hour average O_3 concentrations at the NREL station. The 8-hour standard (0.075 ppm) is shown as a dashed red line. The annual design value (4th highest daily maximum 8-hour average value) is shown for each year as a green point.

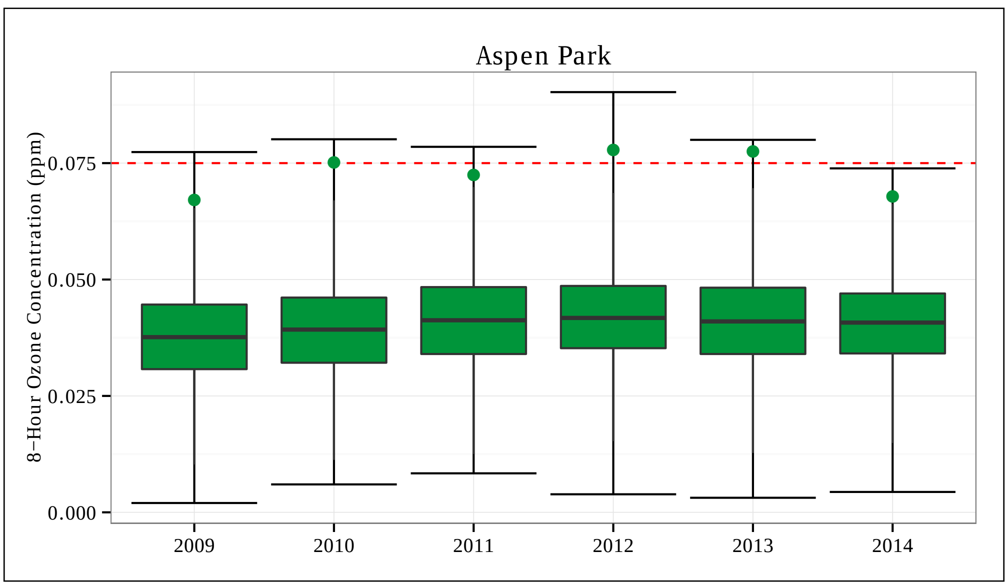


Figure 4.38: 8-hour average O_3 concentrations at the Aspen Park station. The 8-hour standard (0.075 ppm) is shown as a dashed red line. The annual design value (4th highest daily maximum 8-hour average value) is shown for each year as a green point.

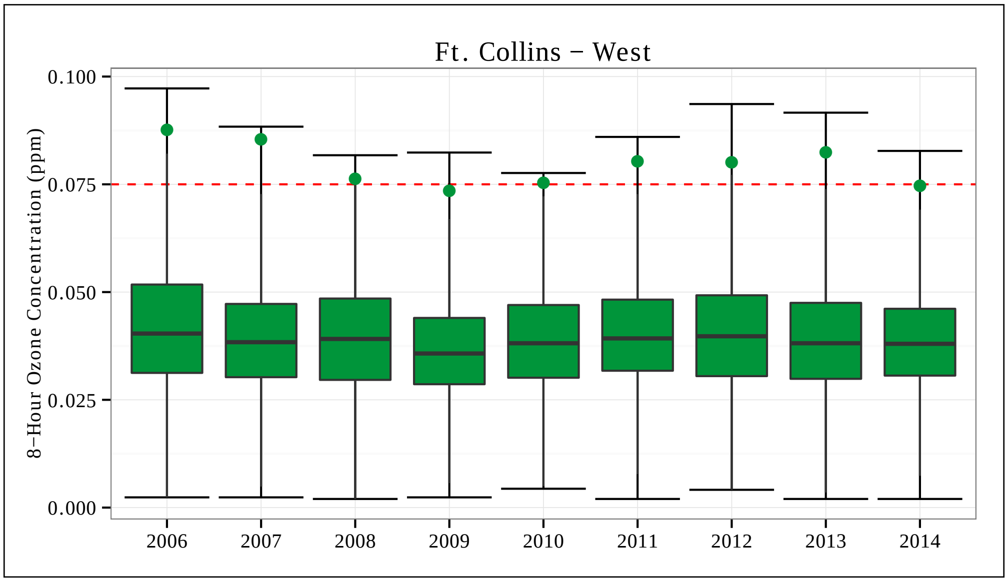


Figure 4.39: 8-hour average O_3 concentrations at the Ft. Collins - West station. The 8-hour standard (0.075 ppm) is shown as a dashed red line. The annual design value (4^{th} highest daily maximum 8-hour average value) is shown for each year as a green point.

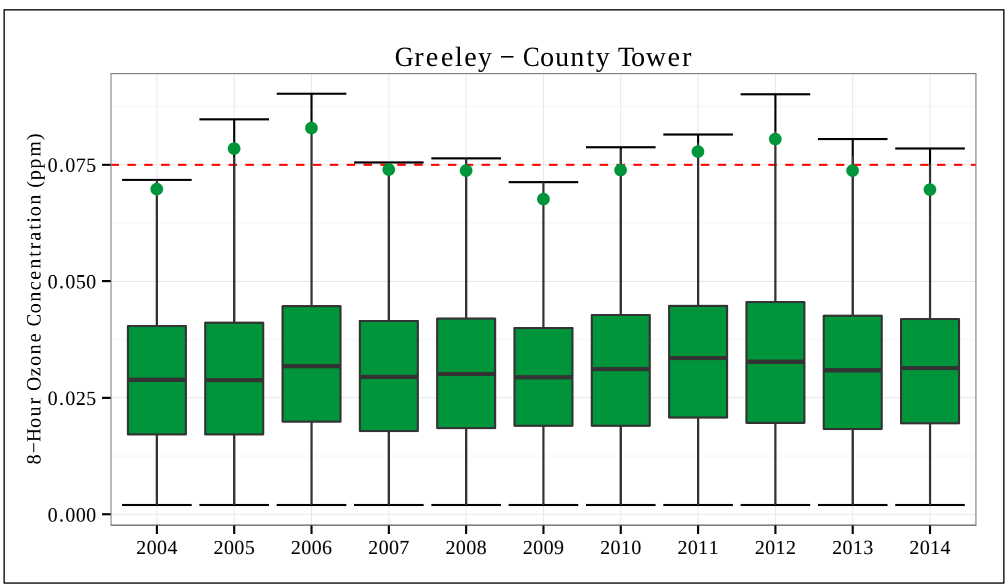


Figure 4.41: 8-hour average O_3 concentrations at the Greeley - County Tower station. The 8-hour standard (0.075 ppm) is shown as a dashed red line. The annual design value (4^{th} highest daily maximum 8-hour average value) is shown for each year as a green point.

4.2.4 Nitrogen Dioxide

Table 4.5: Summary of NO_2 values recorded at monitoring stations in the Denver Metro / Northern Front Range region during 2014. 3-year averages are not available for the La Casa and I-25 Denver sites, as these are relatively new stations.

Site Name	County	NO_2 (ppb)		
		Annual Mean	98th Percentile	3-Year Ave. of 98th Percentile
Welby	Adams	18.4	66.0	63.0
CAMP	Denver	22.7	76.6	72.0
La Casa	Denver	21.2	63.5	
I-25 Denver	Denver	25.4	69.6	

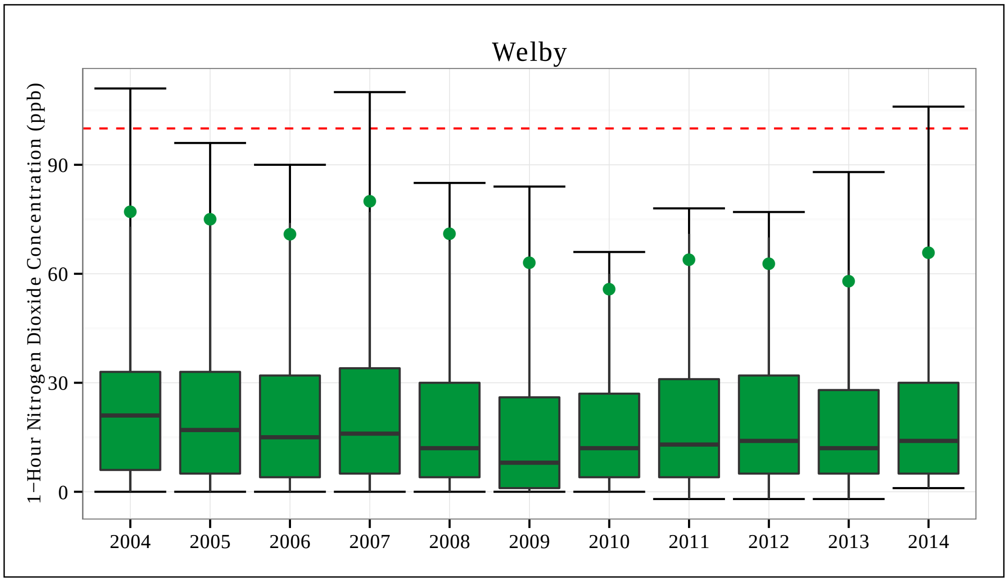


Figure 4.42: 1-hour average NO_2 concentrations at the Welby station. The annual design value (98th percentile of daily maximum 1-hour values) is shown for each year as a green point.

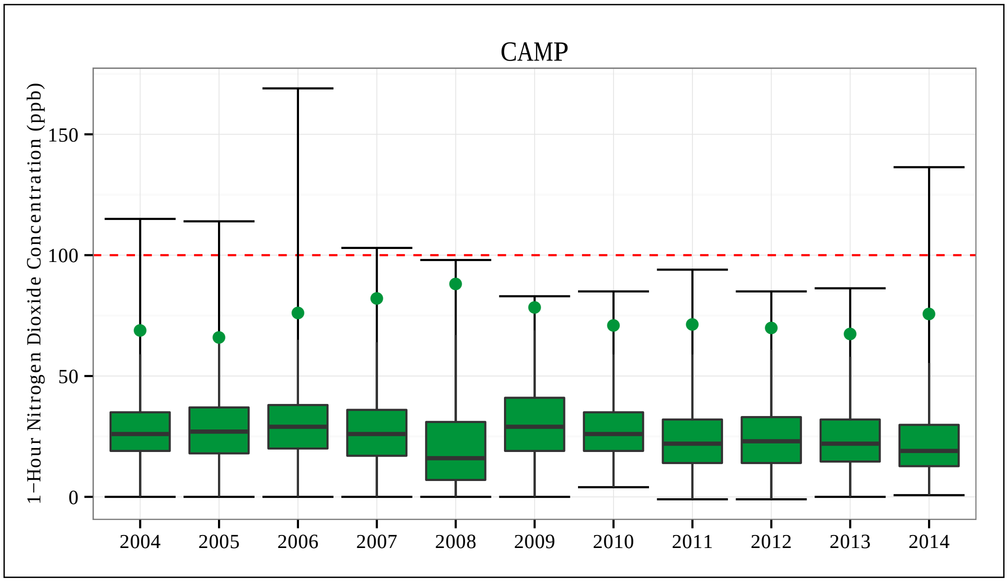


Figure 4.43: 1-hour average NO_2 concentrations at the CAMP station. The annual design value (98^{th} percentile of daily maximum 1-hour values) is shown for each year as a green point.

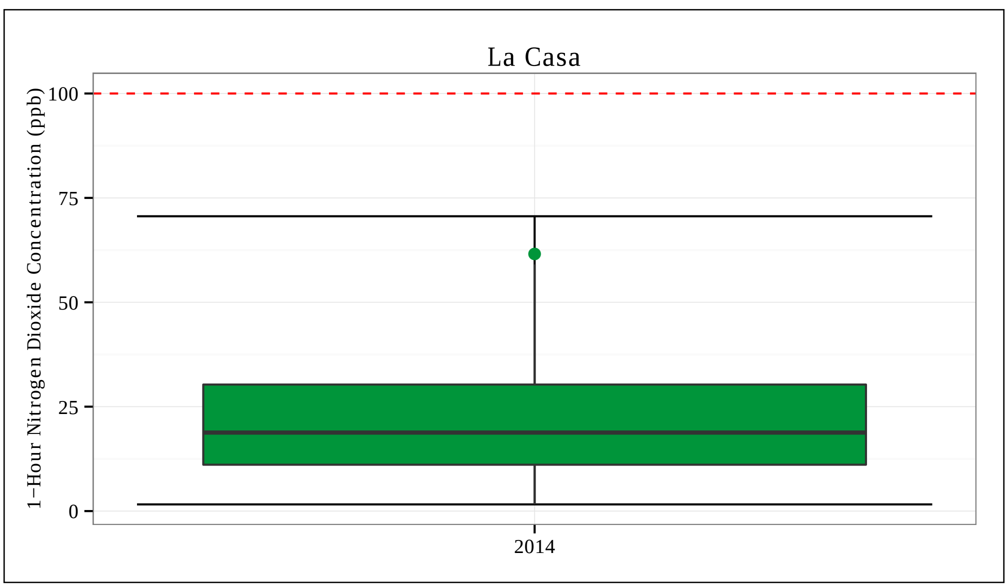


Figure 4.44: 1-hour average NO_2 concentrations at the La Casa station. The annual design value (98^{th} percentile of daily maximum 1-hour values) is shown for each year as a green point.

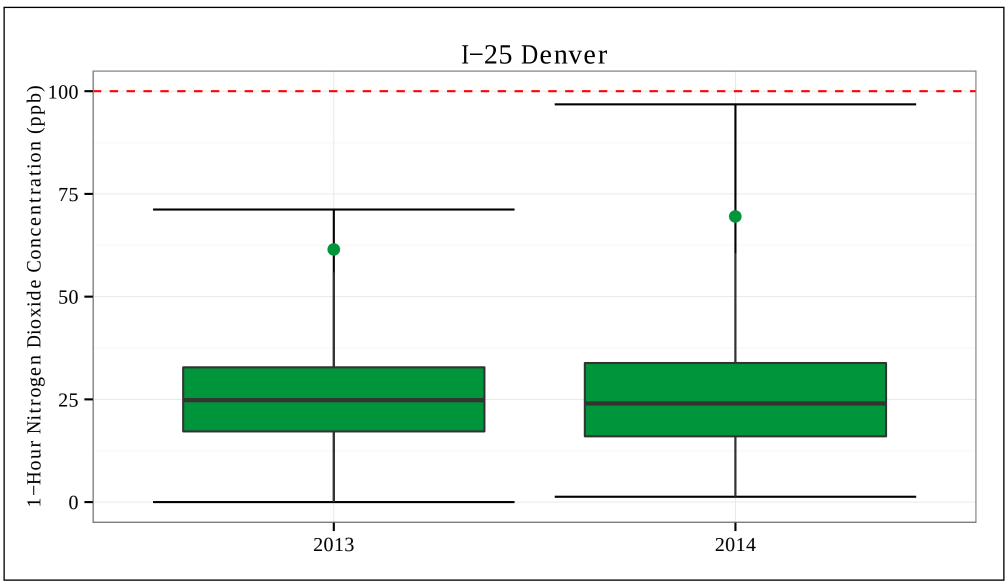


Figure 4.45: 1-hour average NO_2 concentrations at the I-25 Denver station. The annual design value (98^{th} percentile of daily maximum 1-hour values) is shown for each year as a green point.

4.2.5 Sulfur Dioxide

Table 4.6: Summary of SO_2 values recorded at monitoring stations in the Denver Metro / Northern Front Range region.

Site Name	County	SO_2 (ppb)		
		Annual Mean	99^{th} Percentile	3-Year Ave. of 99th Percentile
Welby	Adams	1.2	18	25
CAMP	Denver	1.0	14	30
La Casa	Denver	1.3	15	26

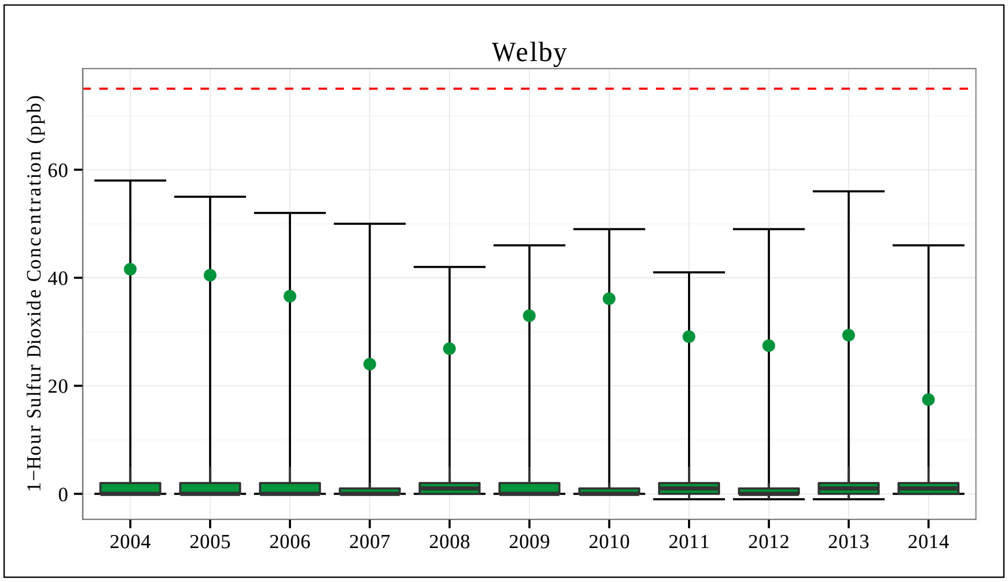


Figure 4.46: 1-hour average SO_2 concentrations at the Welby station. The annual design value (99^{th} percentile of daily maximum 1-hour values) is shown for each year as a green point.

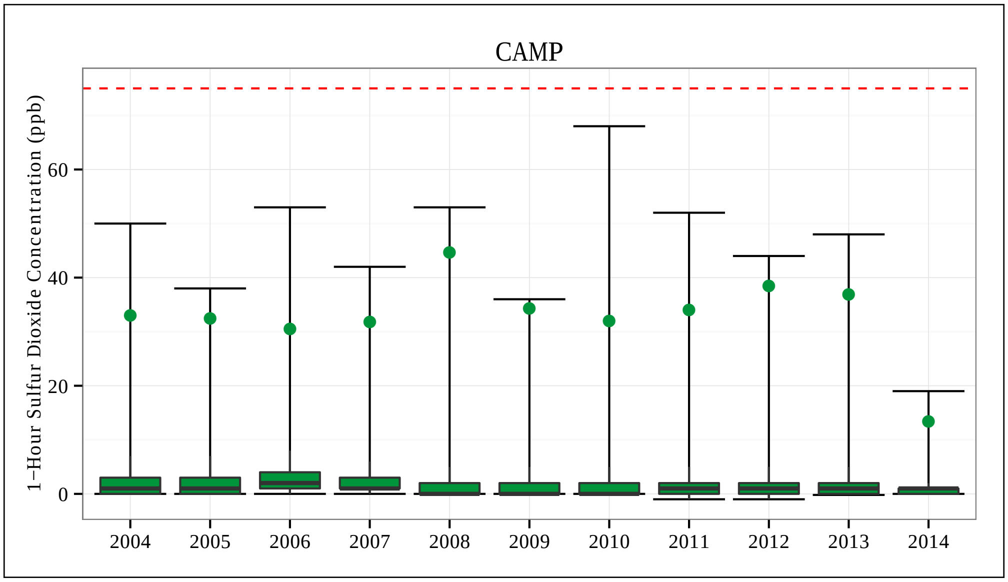


Figure 4.47: 1-hour average SO_2 concentrations at the CAMP station. The annual design value (99^{th} percentile of daily maximum 1-hour values) is shown for each year as a green point.

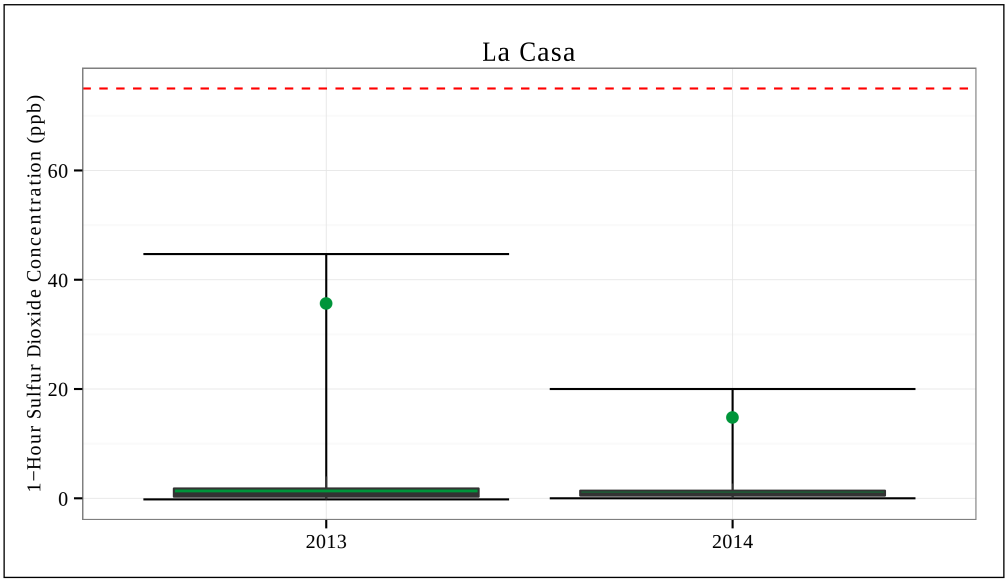


Figure 4.48: 1-hour average SO_2 concentrations at the La Casa station. The annual design value (99^{th} percentile of daily maximum 1-hour values) is shown for each year as a green point.

4.2.6 Visibility

Visibility data for the Denver and Ft. Collins sites are summarized below. Days where the visibility standard was exceeded are classified as “poor” or “extremely poor,” while other days are classified as “moderate” or “good.” Considering only days with valid data, the standard was exceeded 15% and 14% of the year in Denver and Ft. Collins, respectively.

Table 4.7: Summary of Denver visibility data showing the number of days with extremely poor, poor, moderate, and good visibility, as well as the number of days with missing data and the number of days that were excluded due to high (> 70%) relative humidity.

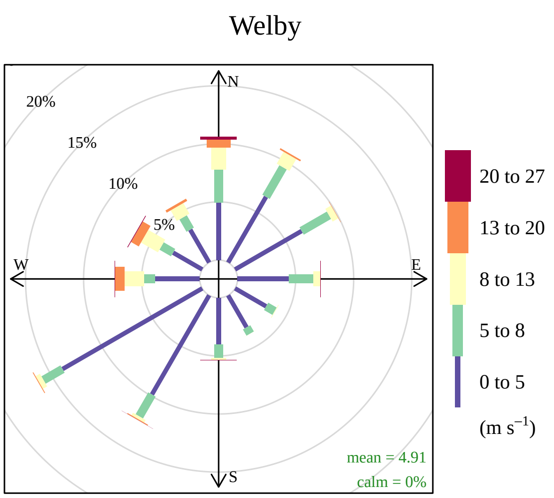
Month	Extremely Poor	Poor	Moderate	Good	Missing	>70% RH
January	1	6	12	7	0	5
February	2	3	13	3	1	6
March	0	1	12	13	0	5
April	0	1	11	17	0	1
May	0	6	14	10	0	1
June	0	1	16	12	0	1
July	1	6	16	5	1	2
August	0	0	23	8	0	0
September	1	1	12	6	8	2
October	0	1	0	1	29	0
November	1	3	8	12	4	2
December	4	6	10	6	5	0
Sum	10	35	147	100	48	25

Table 4.8: Summary of Ft. Collins visibility data showing the number of days with extremely poor, poor, moderate, and good visibility, as well as the number of days with missing data and the number of days that were excluded due to high (> 70%) relative humidity.

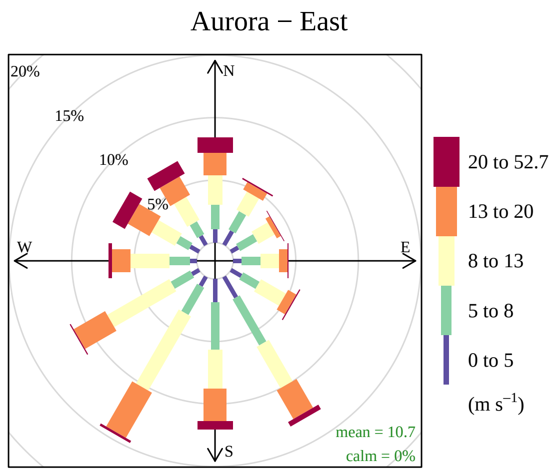
Month	Extremely Poor	Poor	Moderate	Good	Missing	>70% RH
January	0	0	6	13	7	5
February	0	1	0	11	8	8
March	0	2	2	21	1	5
April	0	1	5	22	1	1
May	0	5	8	14	2	2
June	0	4	11	12	1	2
July	0	10	9	1	11	0
August	0	3	9	6	13	0
September	0	4	15	6	5	0
October	0	2	9	9	8	3
November	0	1	4	7	17	1
December	0	2	4	4	17	4
Sum	0	35	82	126	91	31

4.2.7 Meteorology

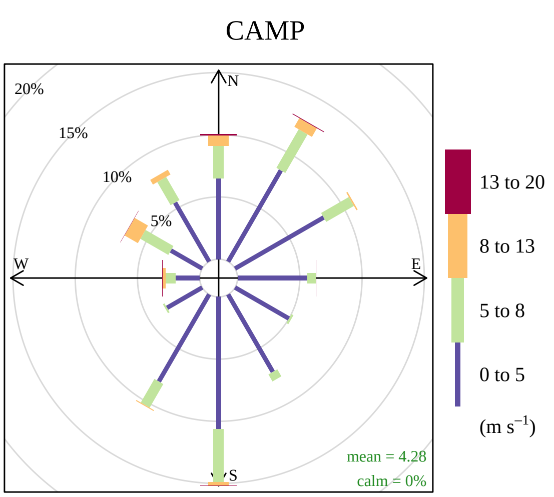
Wind roses for meteorological stations in the Denver Metro / North Front Range region are shown below. Wind roses are plotted based on the direction that the wind is blowing from. Another way of visualizing a wind rose is to picture yourself standing in the center of the plot and facing into the wind. The wind direction is divided into 12 cardinal directions. The wind speed is divided into five ranges. The roses below use 0-5 mph, 5-8 mph, 8-13 mph, 13-20 mph, 20-24 mph, and greater than 24 mph. The length of each arm of the wind rose represents the percentage of time the wind was blowing from that direction at that speed. The longer the arm, the greater the percentage of time the wind is blowing from that direction.



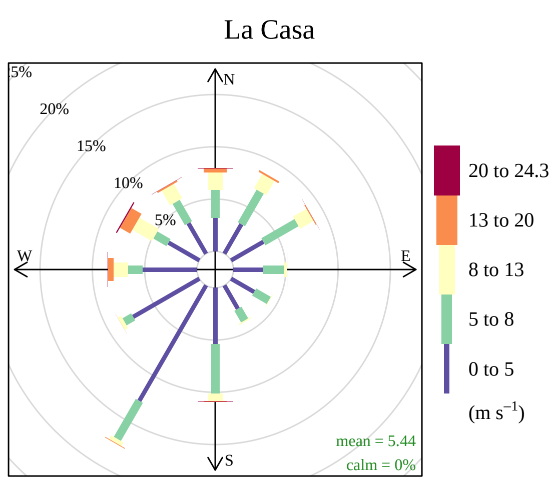
Frequency of counts by wind direction (%)



Frequency of counts by wind direction (%)

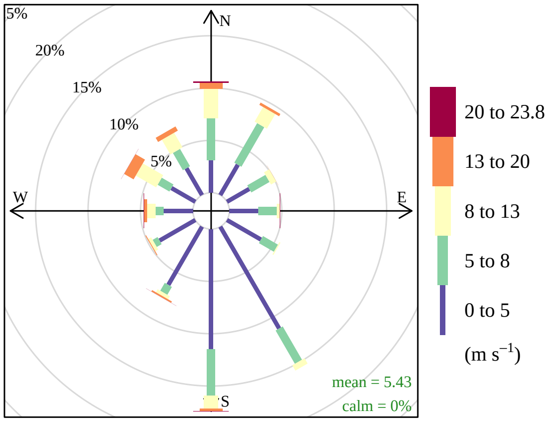


Frequency of counts by wind direction (%)



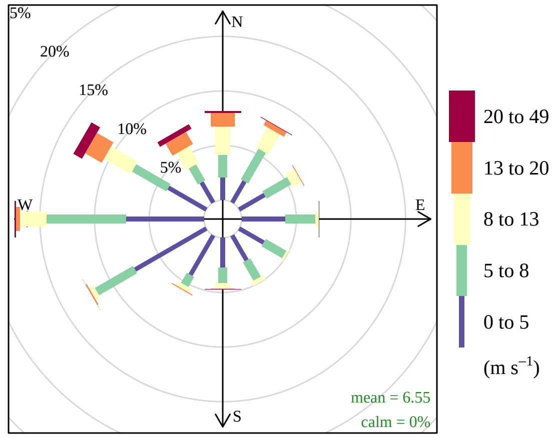
Frequency of counts by wind direction (%)

I−25 Denver



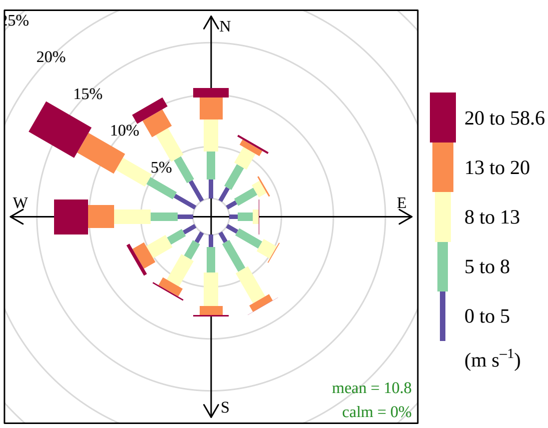
Frequency of counts by wind direction (%)

Welch



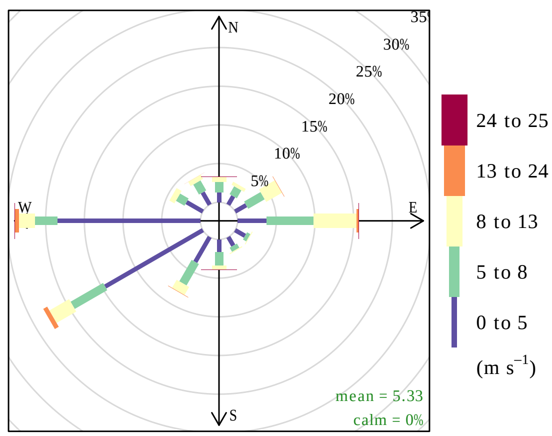
Frequency of counts by wind direction (%)

Rocky Flats − N.

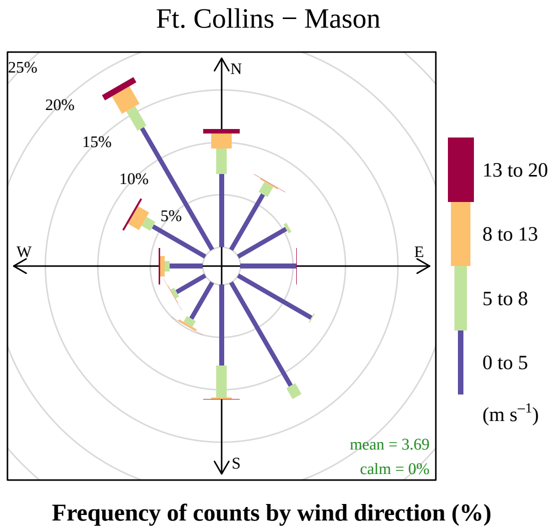


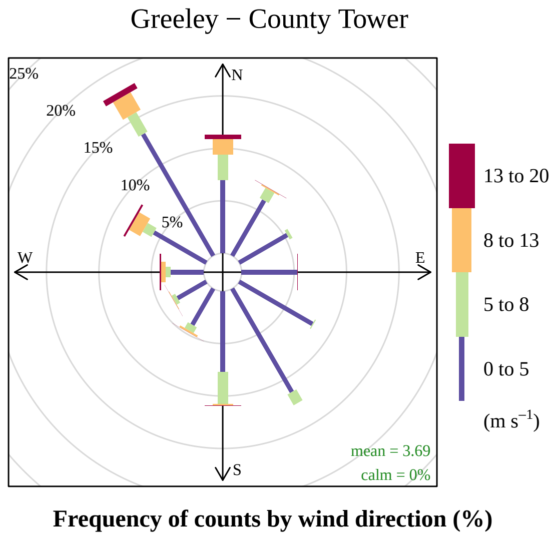
Frequency of counts by wind direction (%)

Aspen Park



Frequency of counts by wind direction (%)


Ft. Collins − Mason
25%
20%
15%
10%
5%
N
W
E
S
mean = 3.69
calm = 0%
13 to 20
8 to 13
5 to 8
0 to 5
(m s−1)
Frequency of counts by wind direction (%)


Greeley − County Tower
25%
20%
15%
10%
5%
N
W
E
S
mean = 3.69
calm = 0%
13 to 20
8 to 13
5 to 8
0 to 5
(m s−1)
Frequency of counts by wind direction (%)

4.3 Eastern High Plains Region

4.3.1 Particulate Matter

The Lamar - Municipal Bldg. station has had an average of 3 exceedances per year over a 3 year period, which is in violation of the annual average primary standard, if exceptional events are not excluded. For an explanation of “exceptional events”, see subsubsection 2.2.5.4. The former Lamar Power Plant site was inappropriately sited and did not represent ambient air exposure. It was located on the roof of the old power plant near an obstructing wall which may have biased the results. APCD sent a request to EPA that the site be closed. That request was approved and APCD stopped sampling at the site in late 2013.

Table 4.9: Summary of PM_{10} values recorded at monitoring stations in the Eastern High Plains region during 2014.

Site Name	County	PM_{10} (µg m^{-3})		
		Annual Average	24-Hr Max	3-Year Exceedances
Lamar - Mun. Bldg.	Prowers	31.4	387	3

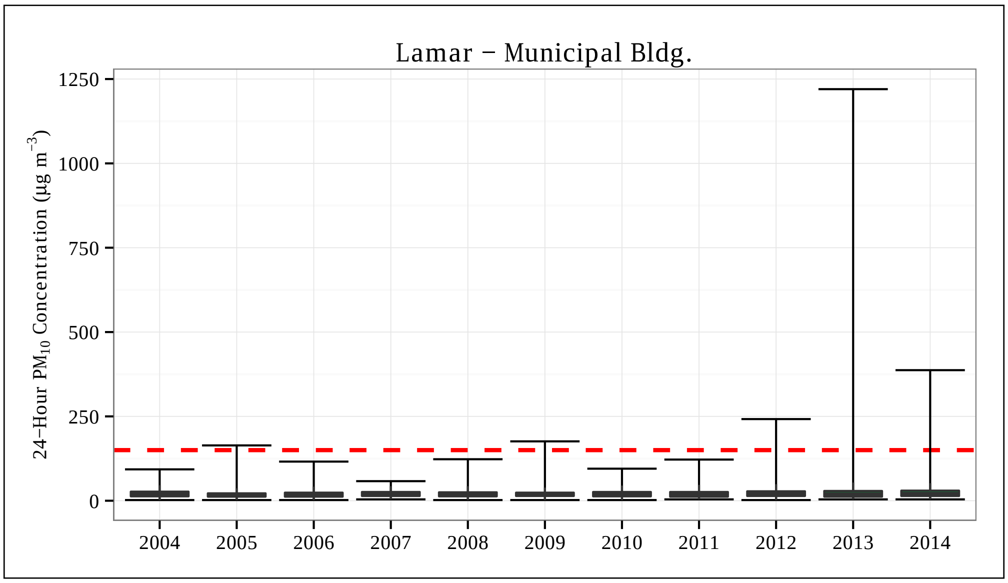


Figure 4.49: 24-hour average PM_{10} concentrations at the Lamar - Municipal Bldg. station. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

4.3.2 Meteorology

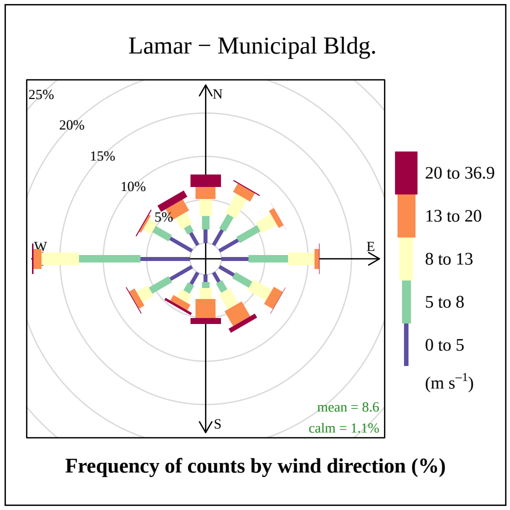


Figure 4.50: Wind rose from the Lamar - Port of Entry meteorological station.

4.4 Pikes Peak Region

4.4.1 Particulate Matter

Table 4.10: Summary of PM_{10} and $PM_{2.5}$ values recorded at the Colorado College station during 2014.

Site Name	County	PM_{10} (µg m^{-3})			$PM_{2.5}$ (µg m^{-3})	
		Annual Average	24-Hr Max	3-Year Exceedances	Annual Average	98th Percentile
Colorado College	El Paso	19.5	41	0	5.8	13.2

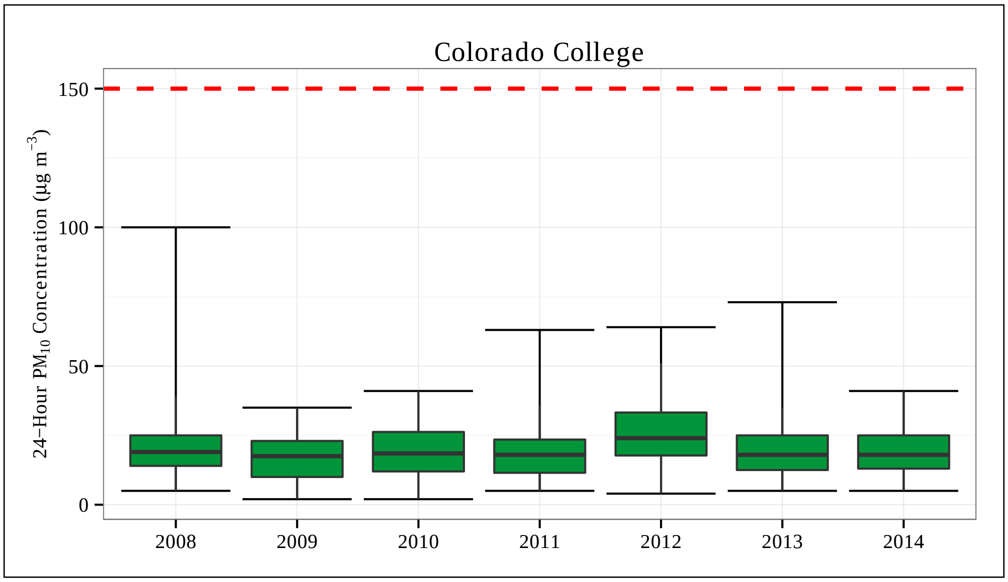


Figure 4.51: 24-hour average PM_{10} concentrations at the Colorado College station. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

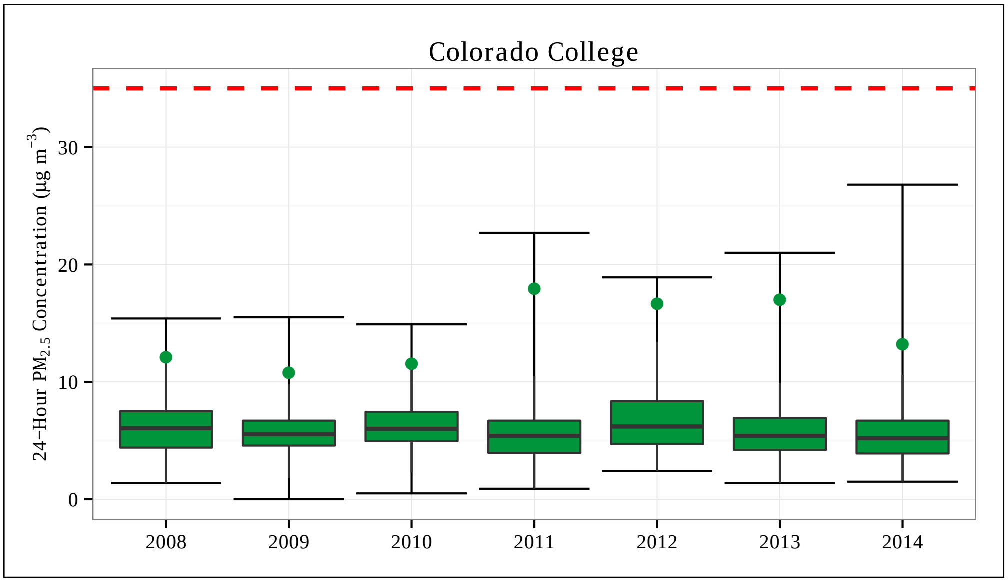


Figure 4.52: 24-hr $PM_{2.5}$ concentrations at the Colorado College station. The 24-hour standard (35 µg m^{-3}) is shown as a dashed red line. The annual design value (98^{th} percentile of values measured throughout the year) is shown for each year as a green point.

4.4.2 Carbon Monoxide

Table 4.11: Summary of CO values recorded at the Highway 24 (Colorado Springs) station during 2014.

Site Name	County	CO 1-Hour Average (ppm)		CO 8-Hour Average (ppm)	
		1st Max.	2nd Max.	1st Max.	2nd Max.
Highway 24	El Paso	3.5	3.4	3.4	1.7

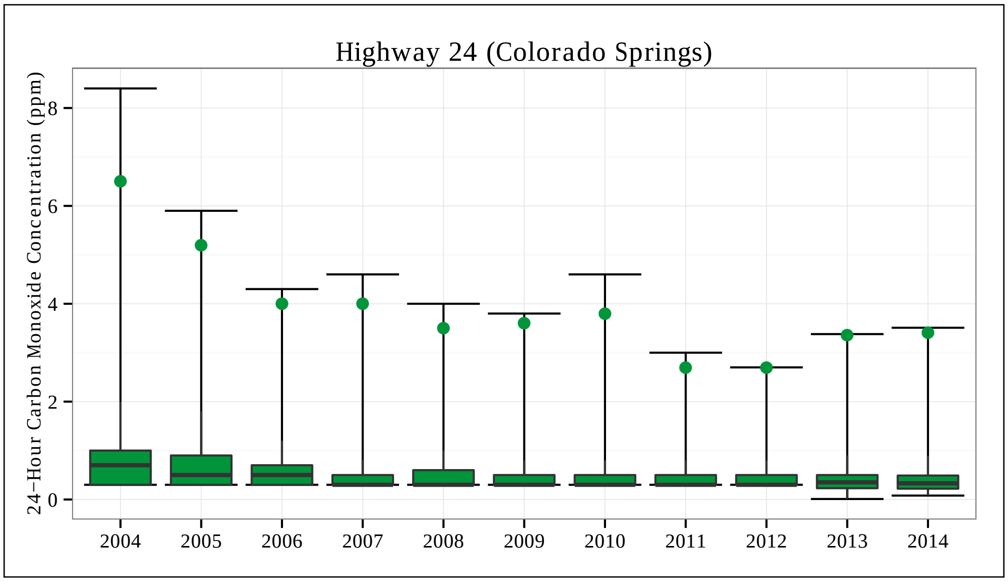


Figure 4.53: 1-hour average CO concentrations at the Highway 24 station. The annual design value (2nd highest 1-hour value) is shown for each year as a green point.

4.4.3 Ozone

Table 4.12: Summary of O_3 values recorded at monitoring stations in the Pikes Peak region during 2014.

Site Name	County	Ozone 8-Hour Average (ppm)		
		1^{st} Max.	4^{th} Max.	3-Year Ave. of 4^{th} Max.
U.S. Air Force Academy	El Paso	0.067	0.064	0.071
Manitou Springs	El Paso	0.064	0.062	0.069

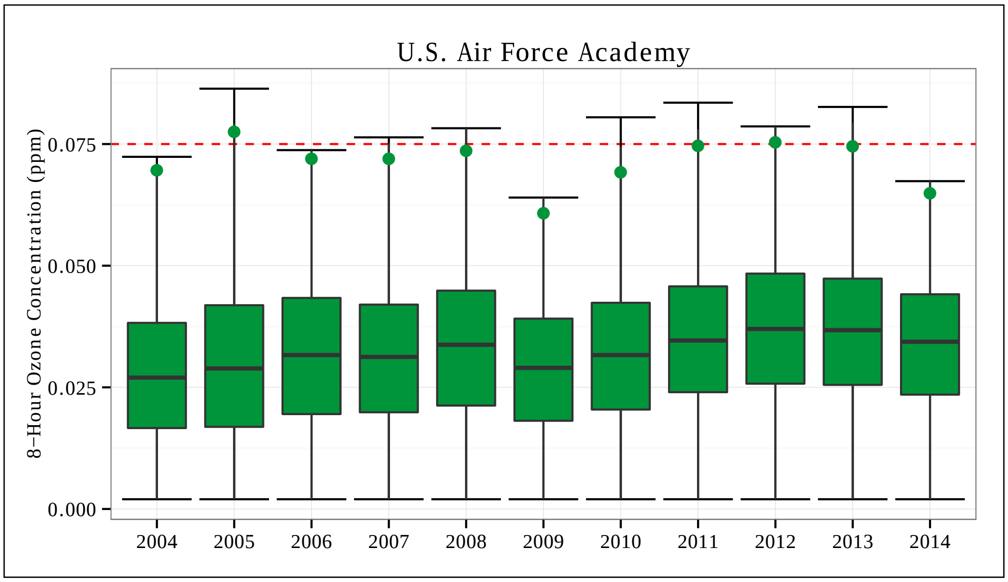


Figure 4.54: 8-hour average O_3 concentrations at the U.S. Air Force Academy station. The 8-hour standard (0.075 ppm) is shown as a dashed red line. The annual design value (4^{th} highest daily maximum 8-hour average value) is shown for each year as a green point.

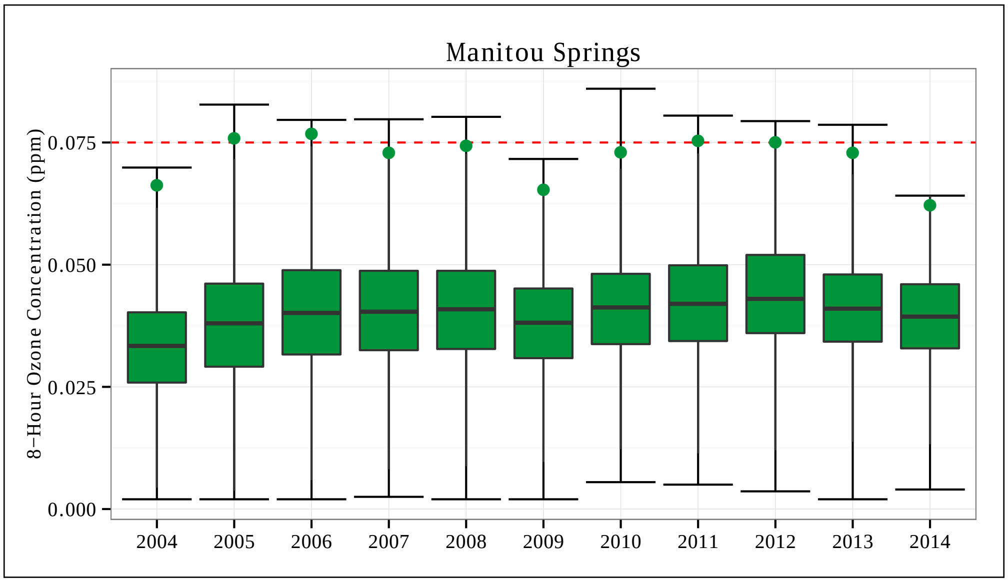


Figure 4.55: 8-hour average O_3 concentrations at the Manitou Springs station. The 8-hour standard (0.075 ppm) is shown as a dashed red line. The annual design value (4^{th} highest daily maximum 8-hour average value) is shown for each year as a green point.

4.4.4 Sulfur Dioxide

Table 4.13: Summary of SO_2 values recorded at the Highway 24 monitoring site in Colorado Springs.

Site Name	County	SO_2 (ppb)		
		Annual Mean	99^{th} Percentile	3-Year Ave. of 99^{th} Percentile
Highway 24	El Paso	3.1	57.0	

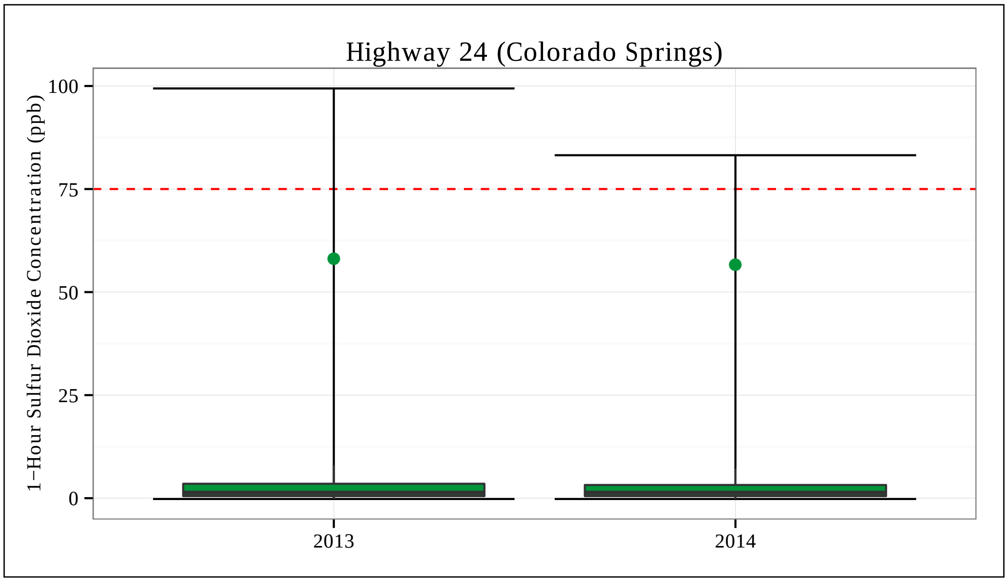


Figure 4.56: 1-hour average SO_2 concentrations at the Highway 24 station. The annual design value (99^{th} percentile of daily maximum 1-hour values) is shown for each year as a green point.

Note: Due to occasional values above the 75 ppb level, the area near the Highway 24 site is being studied in an effort to determine potential sources of SO_2. The Colorado Springs Department of Utilities is monitoring meteorology at its Martin Drake Power Plant in order to better characterize local conditions.

4.5 San Luis Valley Region

The San Luis Valley is somewhat unique in Colorado in that there isn't a predominant wind direction. While a majority of the winds in the area come from the south they are generally calmer, and dispersed between all southerly directions. Synoptic dust transportation may come from northwestern New Mexico or northeastern Arizona. Local particulate matter comes from farming activity and arid land. The Alamosa Municipal station has had an average of 4 exceedances over the last 3 years, and the ASC (Adams State College) site had an average of 3.1 exceedances, which is in violation of the annual average primary standard. Not including exceptional events awaiting EPA concurrence, neither site is in violation of this standard.

4.5.1 Particulate Matter

Table 4.14: Summary of PM_{10} values recorded at monitoring stations in the San Luis Valley region during 2014.

Site Name	County	PM_{10} ($\mu g\ m^{-3}$)		
		Annual Average	24-Hr Max	3-Year Exceedances
Alamosa - ASC	Alamosa	20.8	172	3.1
Alamosa - Mun. Bldg.	Alamosa	27.2	635	4

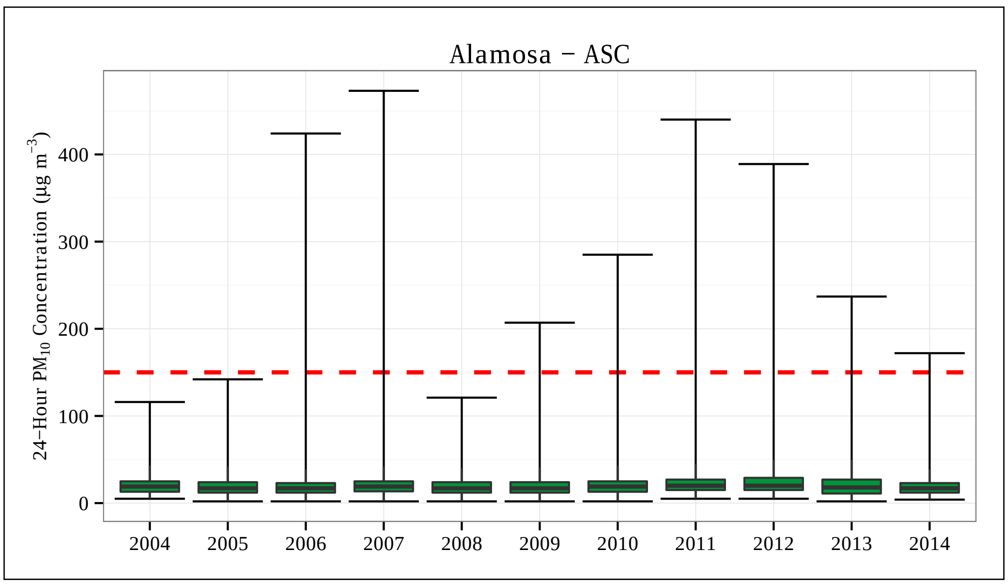


Figure 4.57: 24-hour average PM_{10} concentrations at the Alamosa - ASC station. The 24-hour standard (150 $\mu g\ m^{-3}$) is shown as a dashed red line.

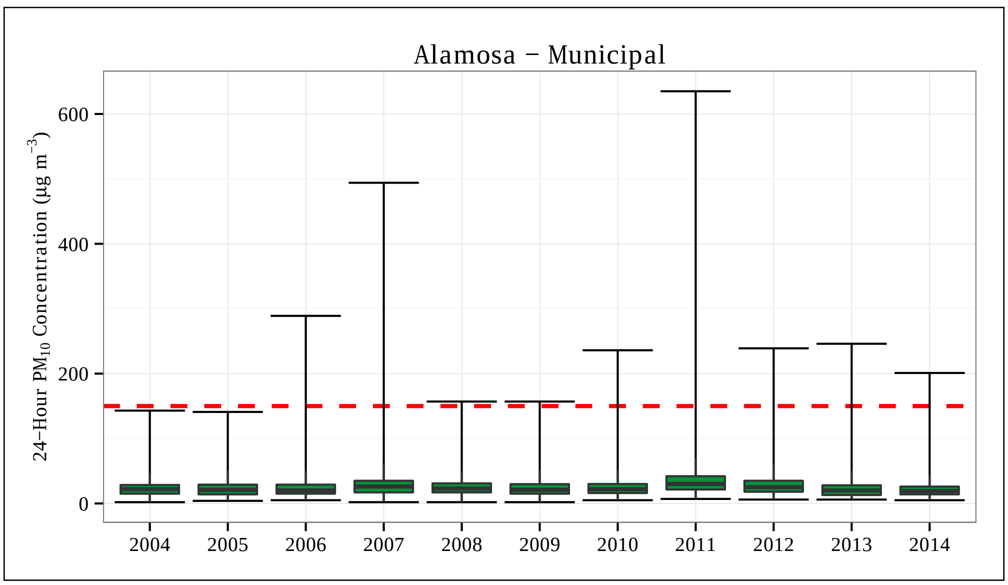


Figure 4.58: 24-hour average PM_{10} concentrations at the Alamosa - Municipal station. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

4.6 South Central Region

4.6.1 Particulate Matter

Table 4.15: Summary of PM_{10} and $PM_{2.5}$ values recorded at the Pueblo monitoring station during 2014.

Site Name	County	PM_{10} (µg m^{-3})			$PM_{2.5}$ (µg m^{-3})	
		Annual Average	24-Hr Max	3-Year Exceedances	Annual Average	98th Percentile
Pueblo	Pueblo	22.3	174	1	5.7	11.8

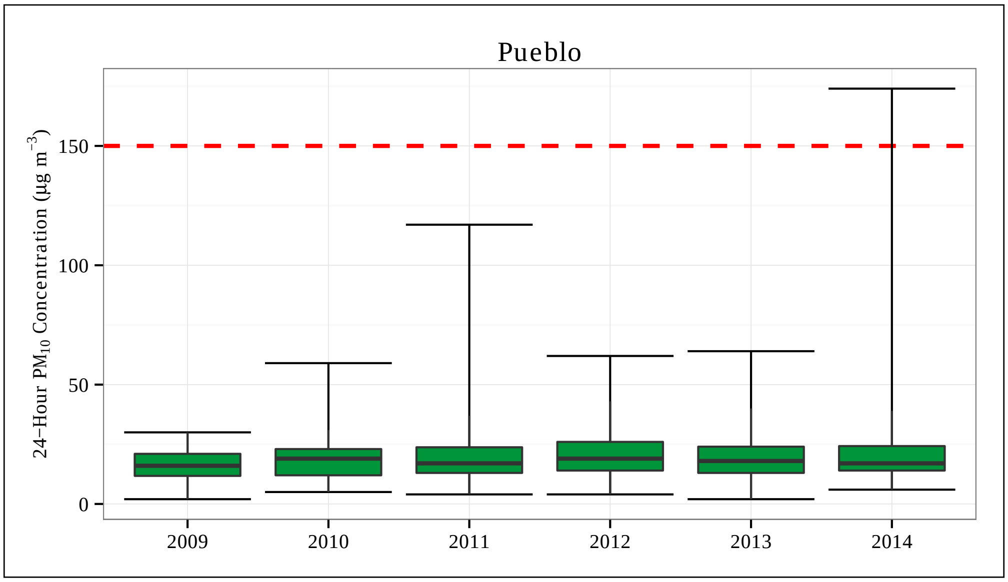


Figure 4.59: 24-hour average PM_{10} concentrations at the Pueblo station. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

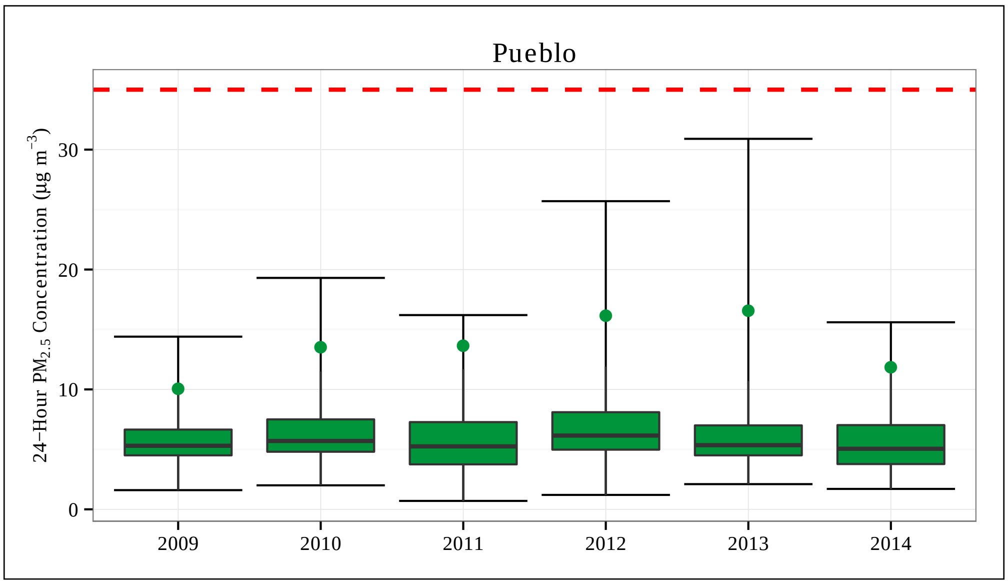


Figure 4.60: 24-hr $PM_{2.5}$ concentrations at the Pueblo station. The 24-hour standard (35 µg m^{-3}) is shown as a dashed red line. The annual design value (98th percentile of values measured throughout the year) is shown for each year as a green point.

4.7 Southwest Region

4.7.1 Particulate Matter

Table 4.16: Summary of PM_{10} and $PM_{2.5}$ values recorded at monitoring sites in the Southwest region during 2014.

Site Name	County	PM_{10} (µg m^{-3})			$PM_{2.5}$ (µg m^{-3})	
		Annual Average	24-Hr Max	3-Year Exceedances	Annual Average	98th Percentile
Pagosa Springs School	Archuleta	22.6	349	1		
Durango	La Plata	20.0	419	1		
Cortez - Health Dept.	Montezuma				5.2	8.9

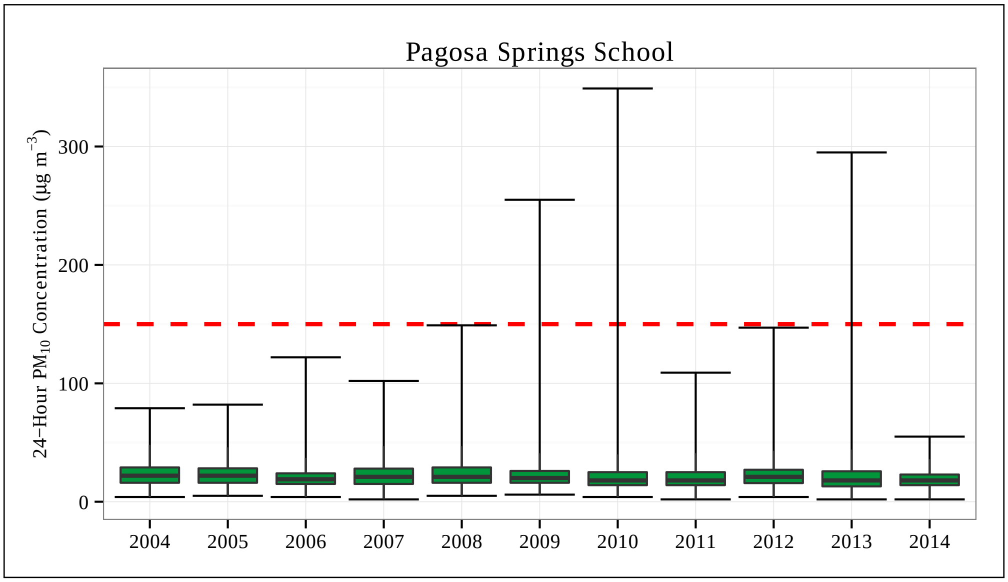


Figure 4.61: 24-hour average PM_{10} concentrations at the Pagosa Springs School station. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

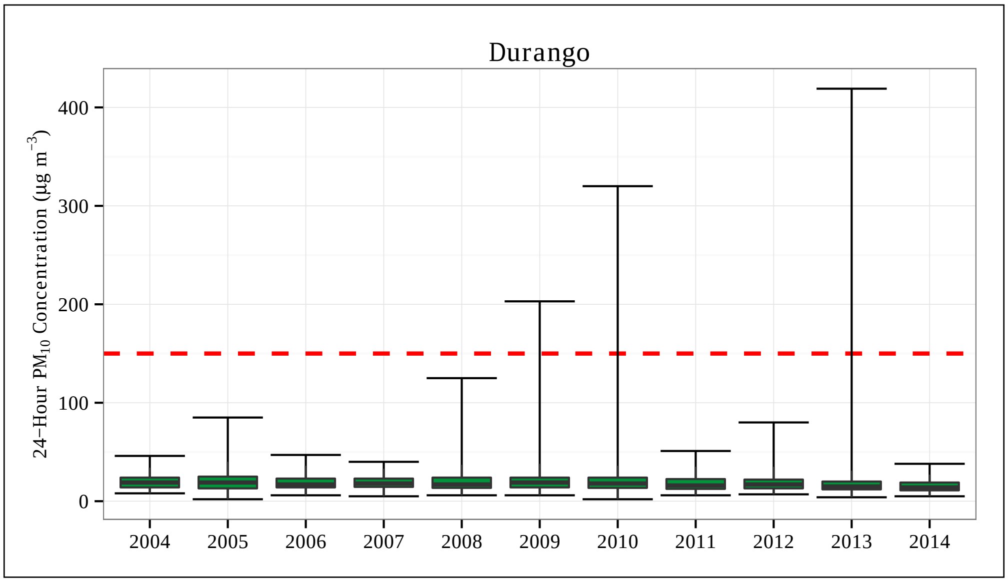


Figure 4.62: 24-hour average PM_{10} concentrations at the Durango station. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

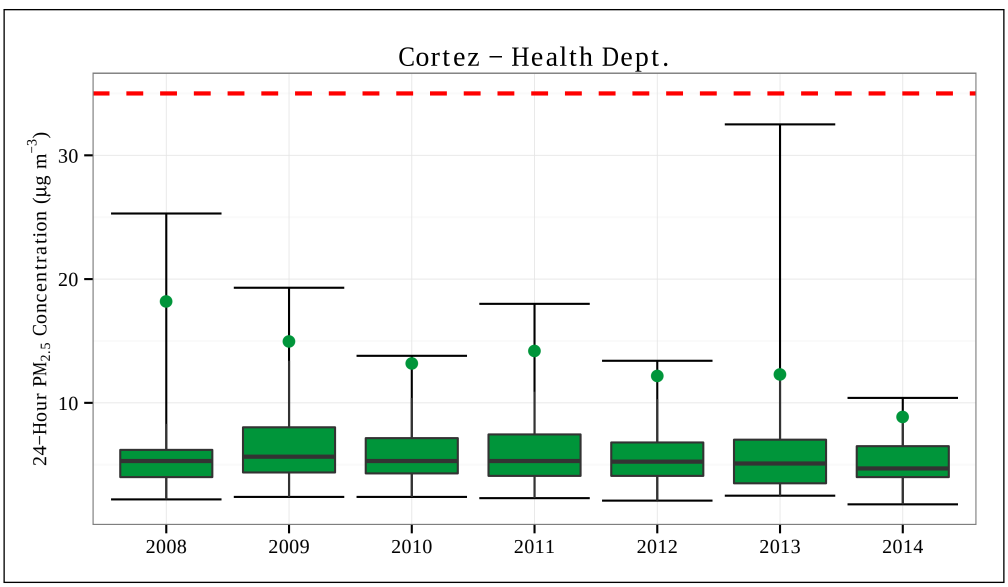


Figure 4.63: 24-hr $PM_{2.5}$ concentrations at the Cortez station. The 24-hour standard (35 µg m^{-3}) is shown as a dashed red line. The annual design value (98th percentile of values measured throughout the year) is shown for each year as a green point.

4.8 Western Slope Region

4.8.1 Particulate Matter

Table 4.17: Summary of PM_{10} and $PM_{2.5}$ values recorded at monitoring sites in the Western Slope region during 2014.

Site Name	County	PM_{10} (µg m^{-3})			$PM_{2.5}$ (µg m^{-3})	
		Annual Average	24-Hr Max	3-Year Exceedances	Annual Average	98th Percentile
Delta - Health Dept.	Delta	24.0	108	0		
Parachute	Garfield	16.3	39	0		
Rifle - Henry Bldg.	Garfield	18.0	47	0		
Carbondale	Garfield	12.3	46	0		
Grand Junction - Powell Bldg.	Mesa	18.6	46	0	8.2	29.3
Telluride	San Miguel	17.2	118	0		

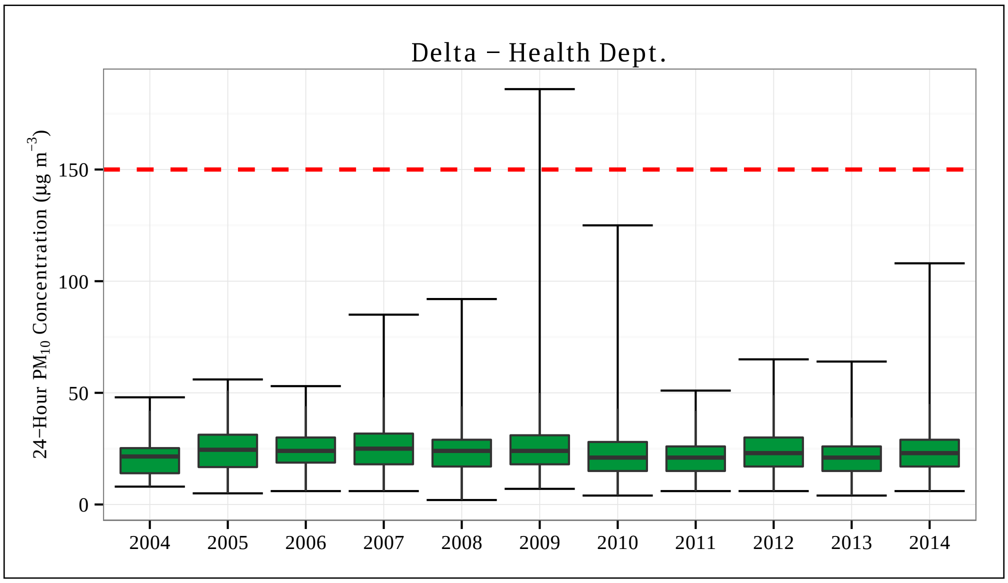


Figure 4.64: 24-hour average PM_{10} concentrations at the Delta - Health Dept. station. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

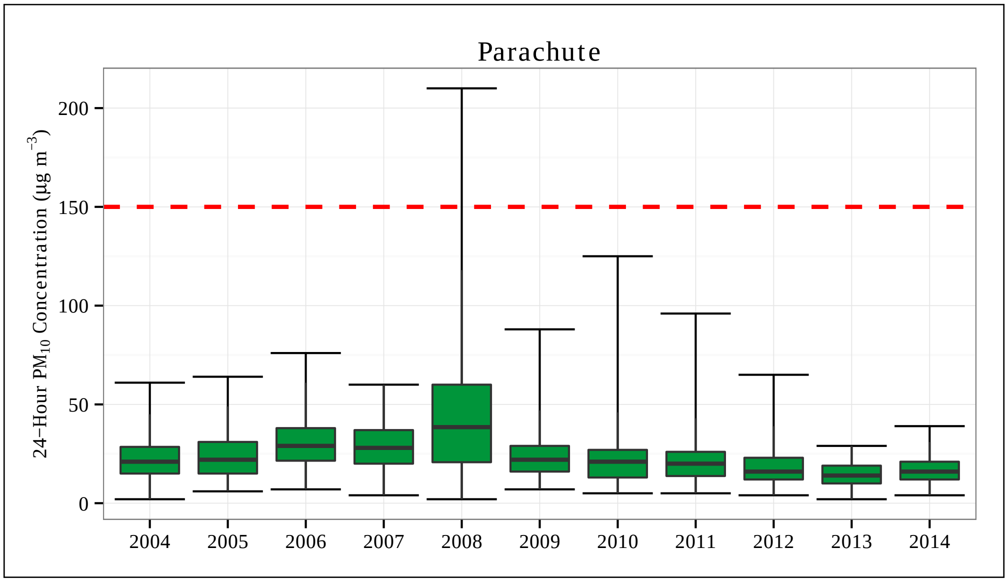


Figure 4.65: 24-hour average PM_{10} concentrations at the Parachute station. The 24-hour standard (150 μg m^{-3}) is shown as a dashed red line.

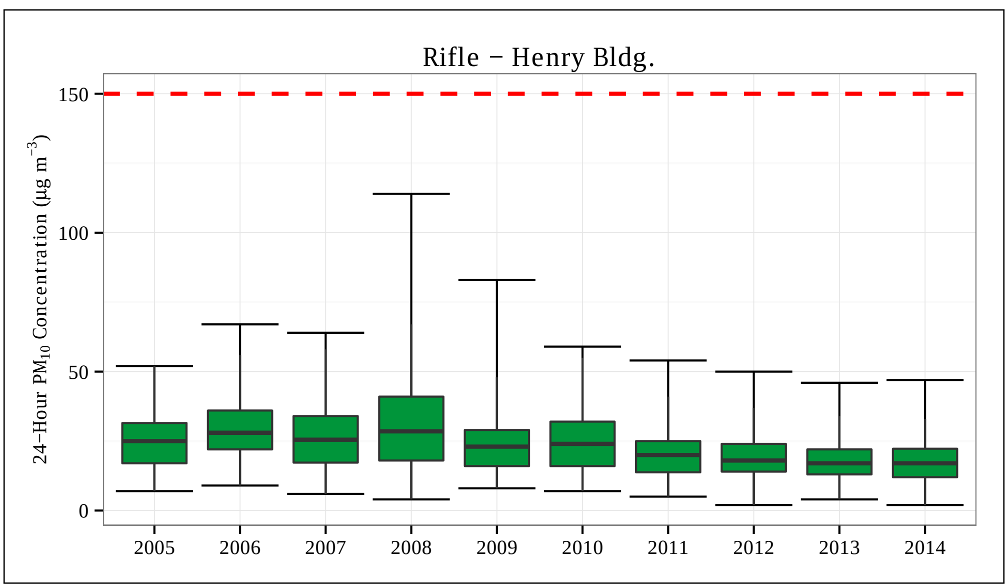


Figure 4.66: 24-hour average PM_{10} concentrations at the Rifle - Henry Bldg. station. The 24-hour standard (150 μg m^{-3}) is shown as a dashed red line.

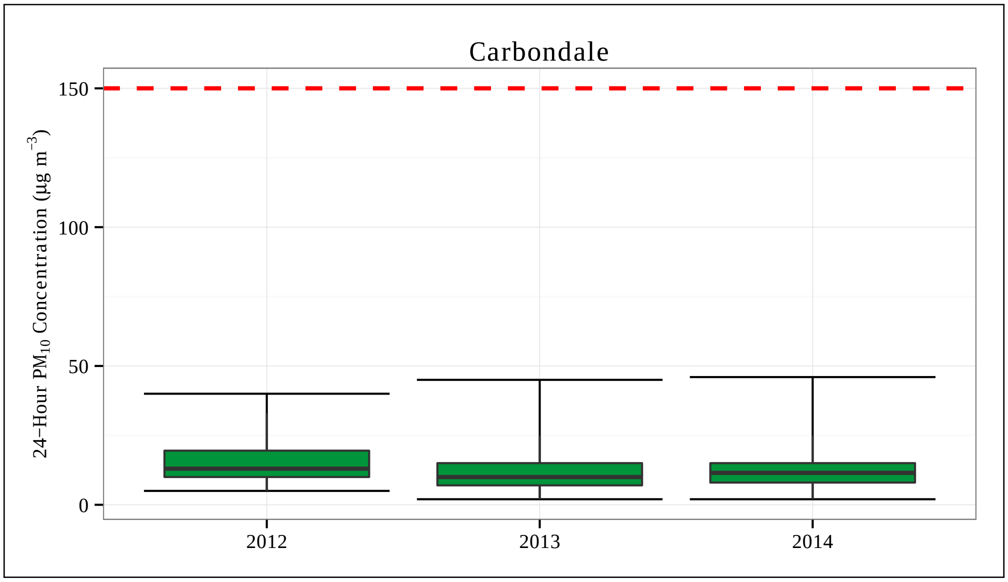


Figure 4.67: 24-hour average PM_{10} concentrations at the Carbondale station. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

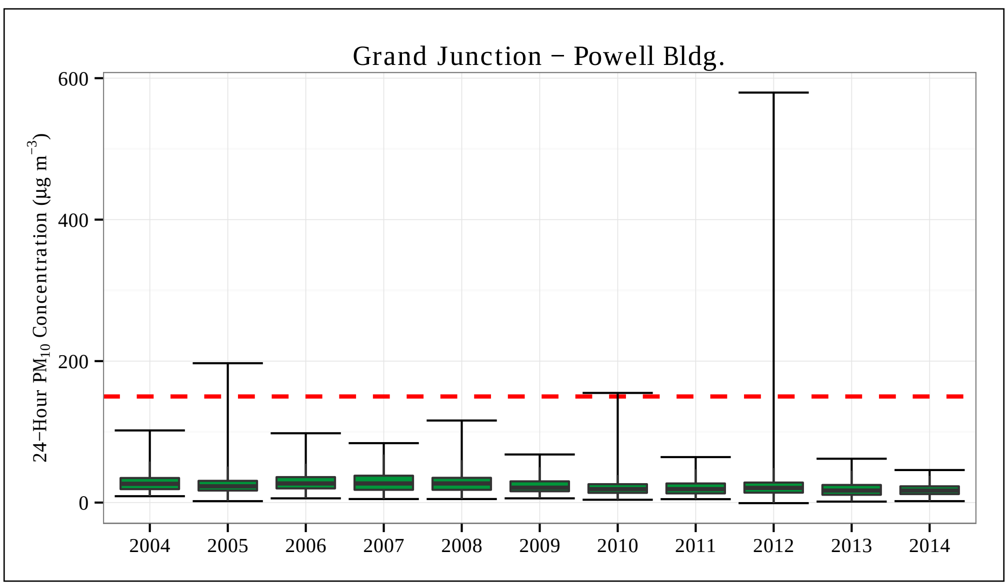


Figure 4.68: 24-hour average PM_{10} concentrations at the Grand Junction - Powell Bldg. station. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

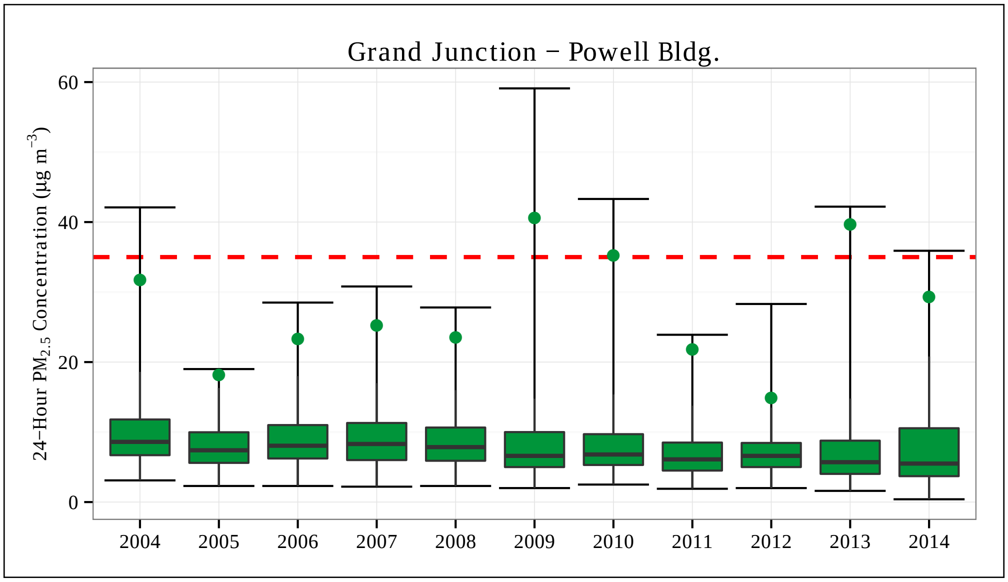


Figure 4.69: 24-hr $PM_{2.5}$ concentrations at the Grand Junction - Powell Bldg. station. The 24-hour standard (35 µg m^{-3}) is shown as a dashed red line. The annual design value (98^{th} percentile of values measured throughout the year) is shown for each year as a green point.

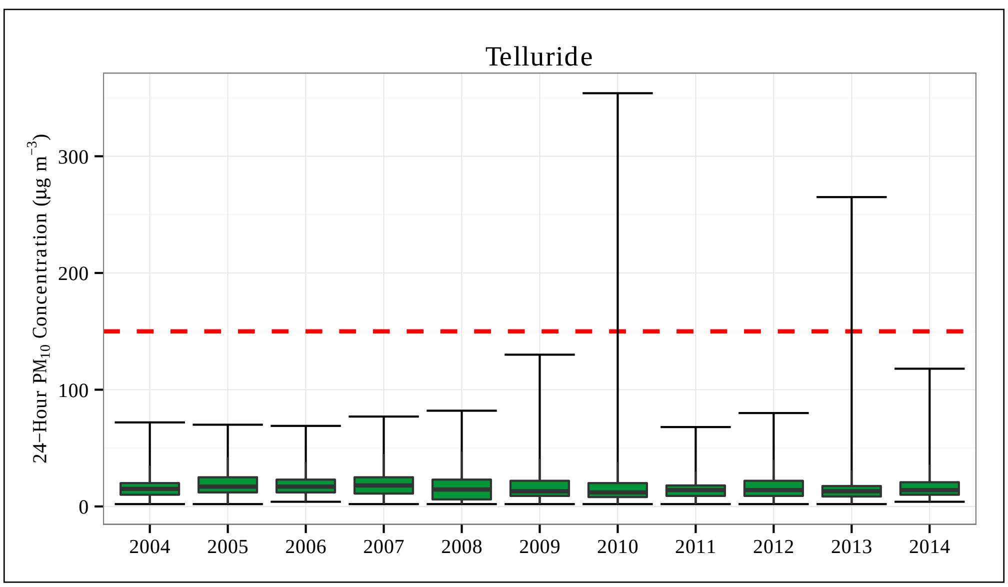


Figure 4.70: 24-hour average PM_{10} concentrations at the Telluride station. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

4.8.2 Carbon Monoxide

Table 4.18: Summary of CO values recorded at the Grand Junction - Pitkin station during 2014.

Site Name	County	CO 1-Hour Average (ppm)		CO 8-Hour Average (ppm)	
		1st Max.	2nd Max.	1st Max.	2nd Max.
Grand Junction - Pitkin	Mesa	1.9	1.7	0.9	0.8

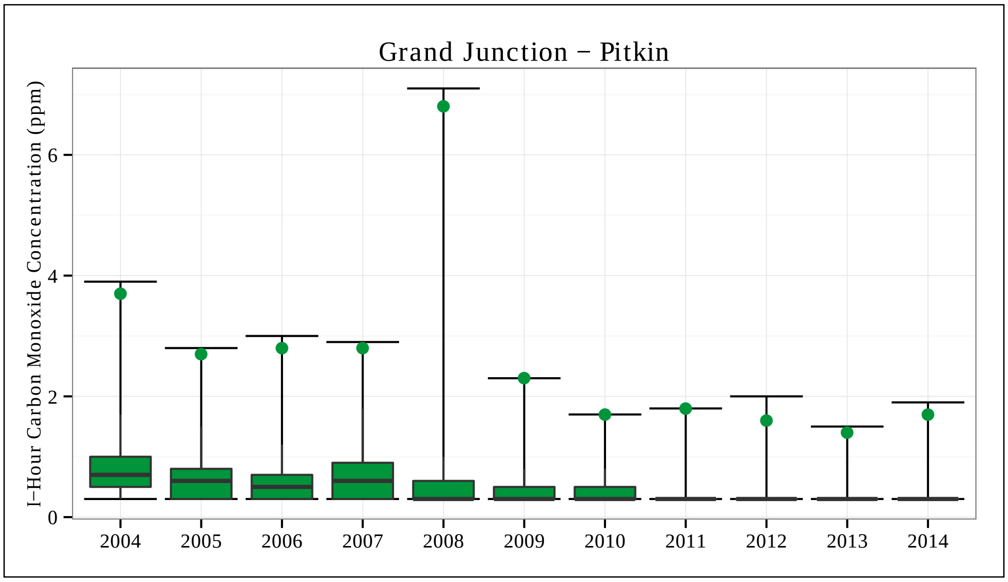


Figure 4.71: 1-hour average CO concentrations at the Grand Junction - Pitkin station. The annual design value (2nd highest 1-hour value) is shown for each year as a green point.

4.8.3 Ozone

Table 4.19: Summary of O_3 values recorded at monitoring stations in the Western Slope region during 2014.

Site Name	County	Ozone 8-Hour Average (ppm)		
		1^{st} Max.	4^{th} Max.	3-Year Ave. of 4^{th} Max.
Rifle - Health Dept.	Garfield	0.062	0.061	0.063
Palisade	Mesa	0.065	0.062	0.066
Lay Peak	Moffat	0.067	0.062	0.066

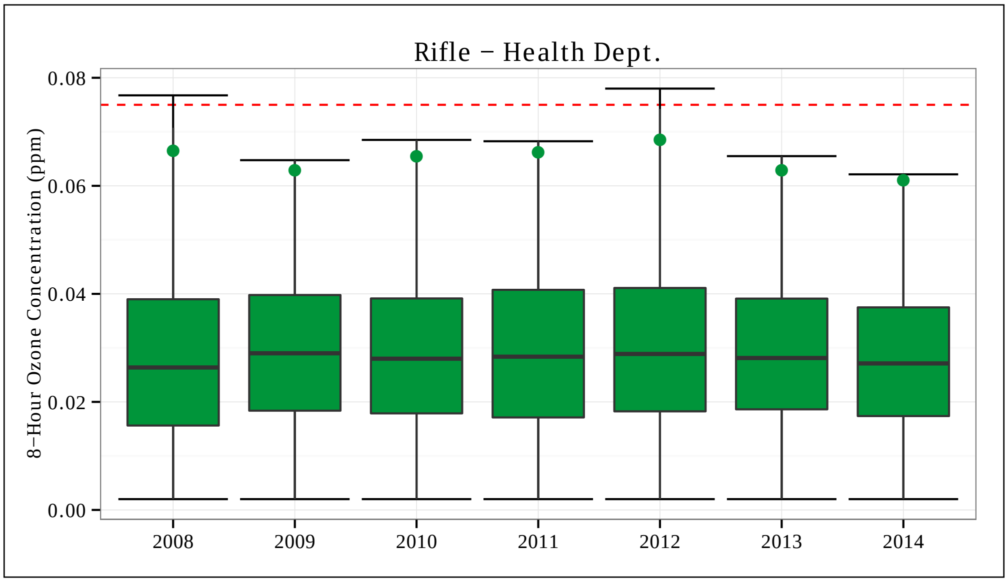


Figure 4.72: 8-hour average O_3 concentrations at the Rifle - Health Dept. station. The 8-hour standard (0.075 ppm) is shown as a dashed red line. The annual design value (4^{th} highest daily maximum 8-hour average value) is shown for each year as a green point.

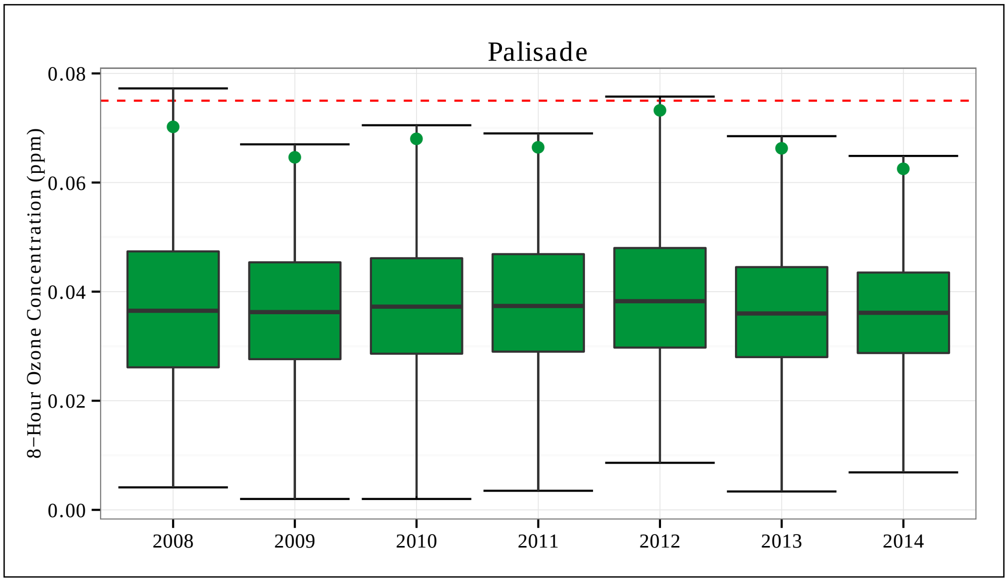


Figure 4.73: 8-hour average O_3 concentrations at the Palisade station. The 8-hour standard (0.075 ppm) is shown as a dashed red line. The annual design value (4^{th} highest daily maximum 8-hour average value) is shown for each year as a green point.

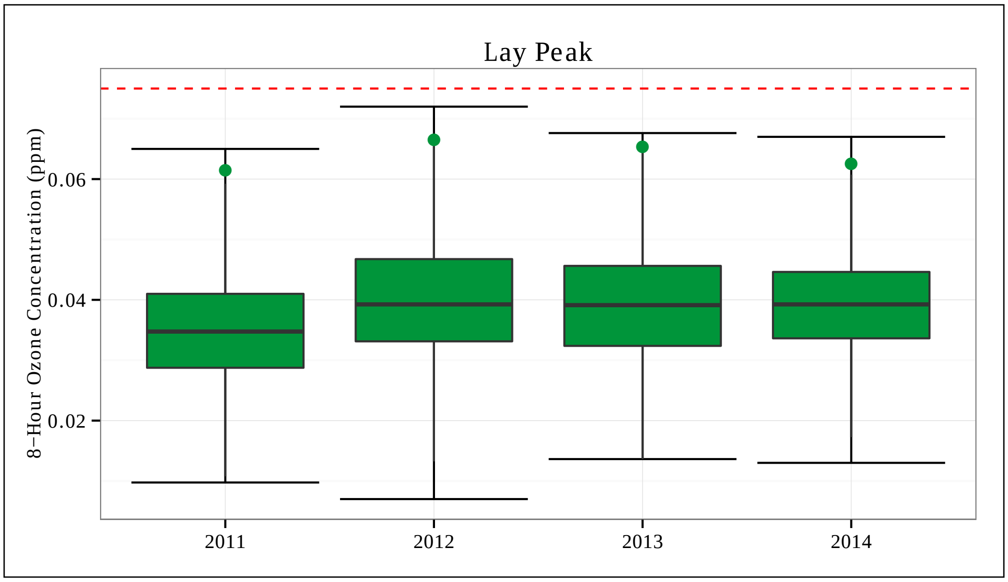
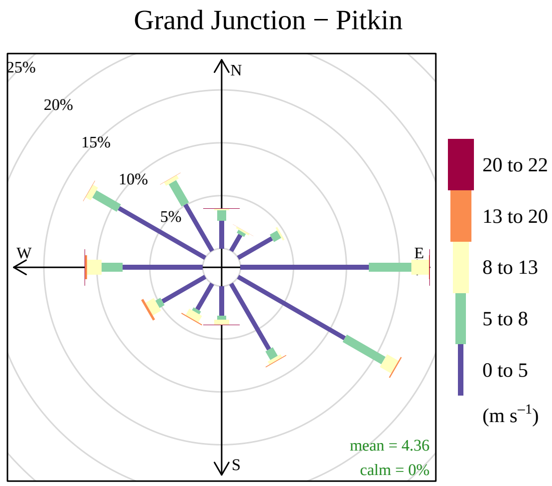
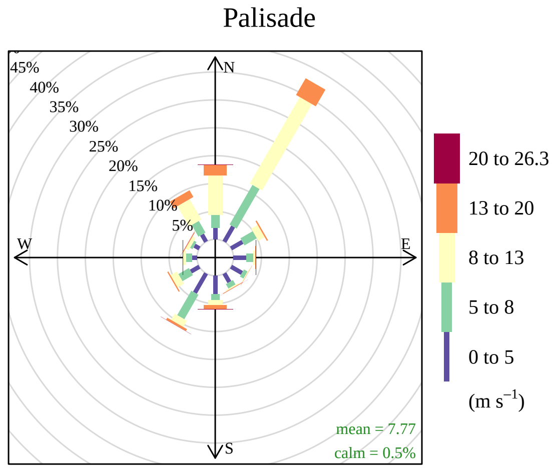


Figure 4.74: 8-hour average O_3 concentrations at the Lay Peak station. The 8-hour standard (0.075 ppm) is shown as a dashed red line. The annual design value (4^{th} highest daily maximum 8-hour average value) is shown for each year as a green point.

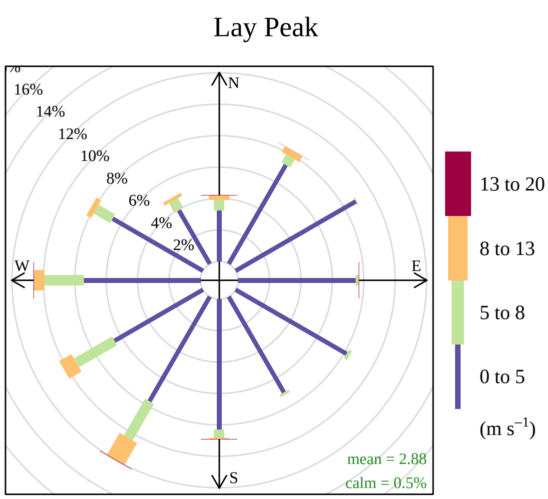
4.8.4 Meteorology



Frequency of counts by wind direction (%)



Frequency of counts by wind direction (%)



Frequency of counts by wind direction (%)

5

Seasonal Variability in Air Quality

Data has been presented in this report to give an overall picture of the progress of air quality through the years and to compare measured concentrations against the NAAQS. However, the APCD collects data as hourly averages (which are themselves the result of even more brief intervals being averaged together) for select criteria pollutants at each site. In this section, monthly averages will be presented for each site.

In some sense, there is little interpretation to be done concerning the air quality information presented in this section. It is not intended to compare Colorado's air quality against the standards, other states, or past air quality. This section is only to suggest a more detailed picture of the air quality in our state throughout the year.

5.1 Carbon Monoxide

CO can generally be considered an indicator of overall air quality. High CO concentrations indicate poor air quality, and low concentrations mean generally good air quality (except for O_3). CO is normally higher in the winter months and lower in the summer, for reasons discussed previously. This notion of low summer concentrations and higher winter concentrations holds true throughout Colorado.

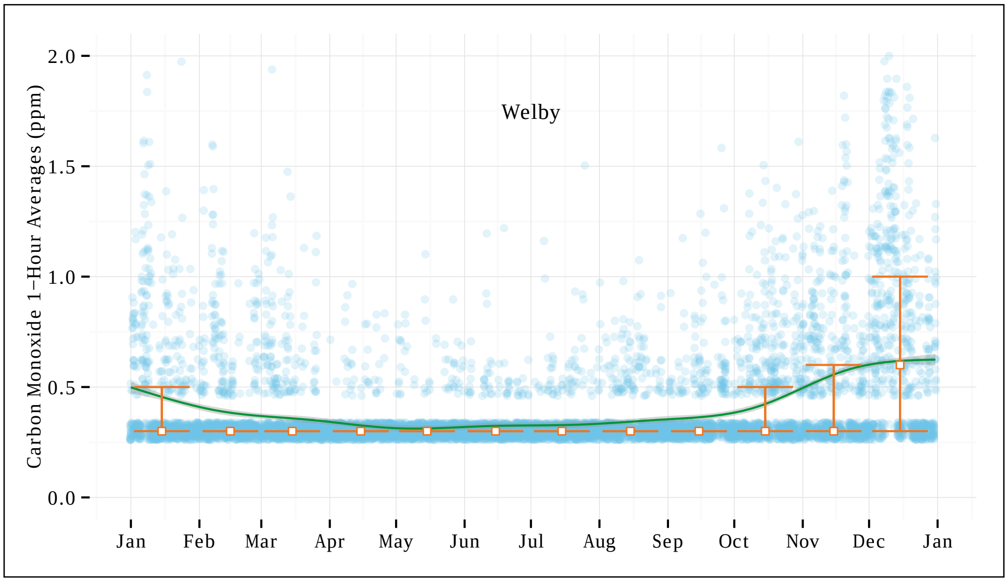


Figure 5.1: 1-hour average CO concentrations at the Welby station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

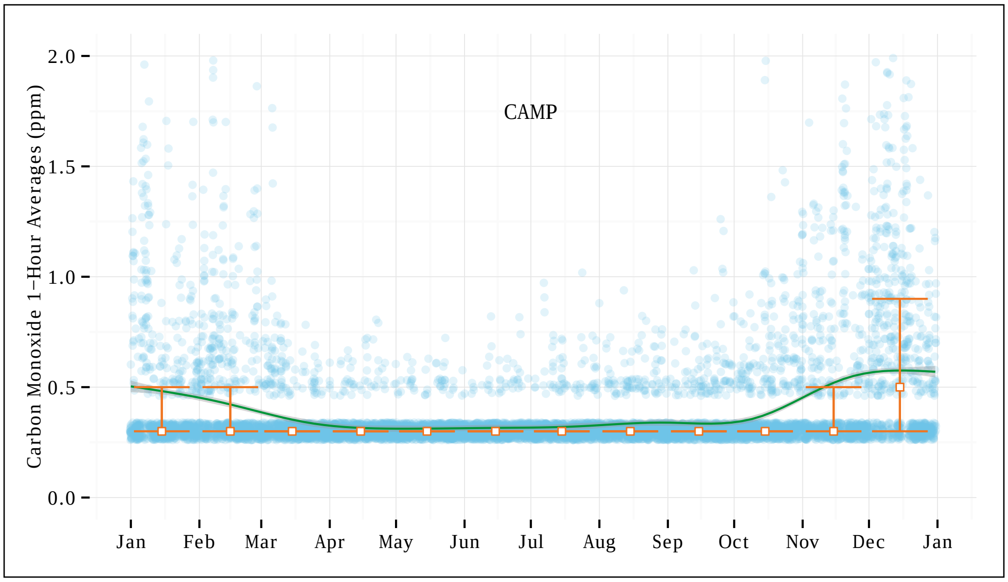


Figure 5.2: 1-hour average CO concentrations at the CAMP station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

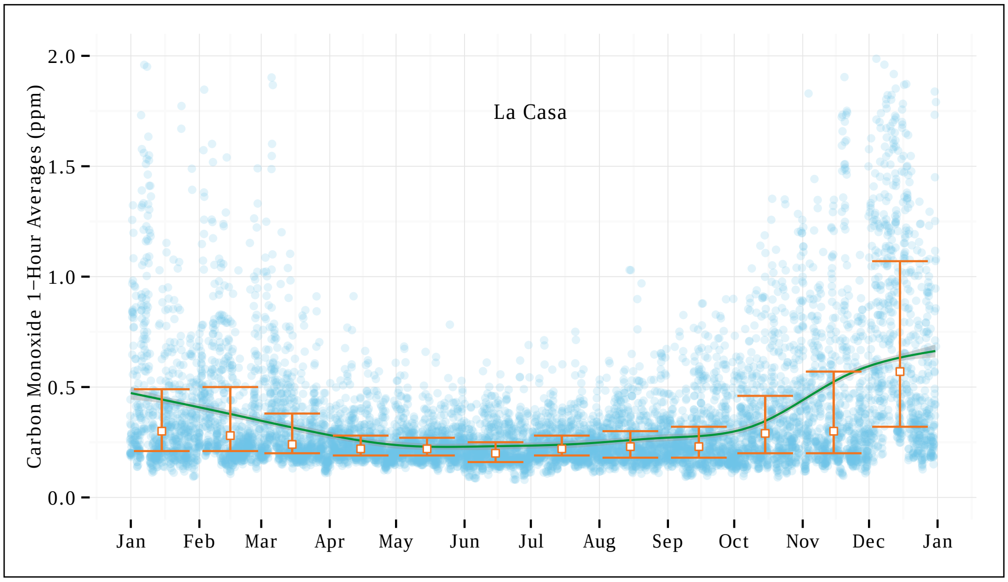


Figure 5.3: 1-hour average CO concentrations at the La Casa station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

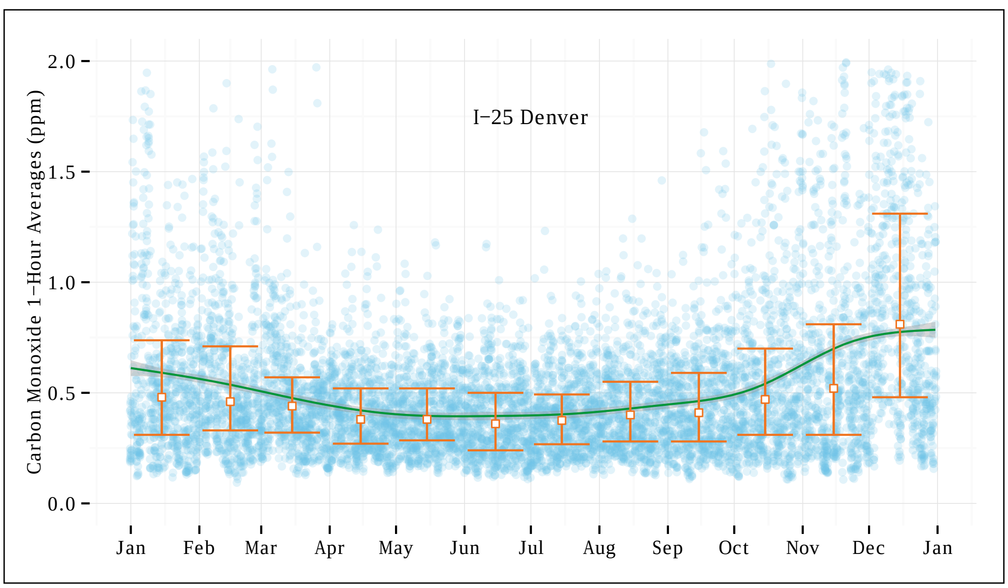


Figure 5.4: 1-hour average CO concentrations at the I-25 Denver station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

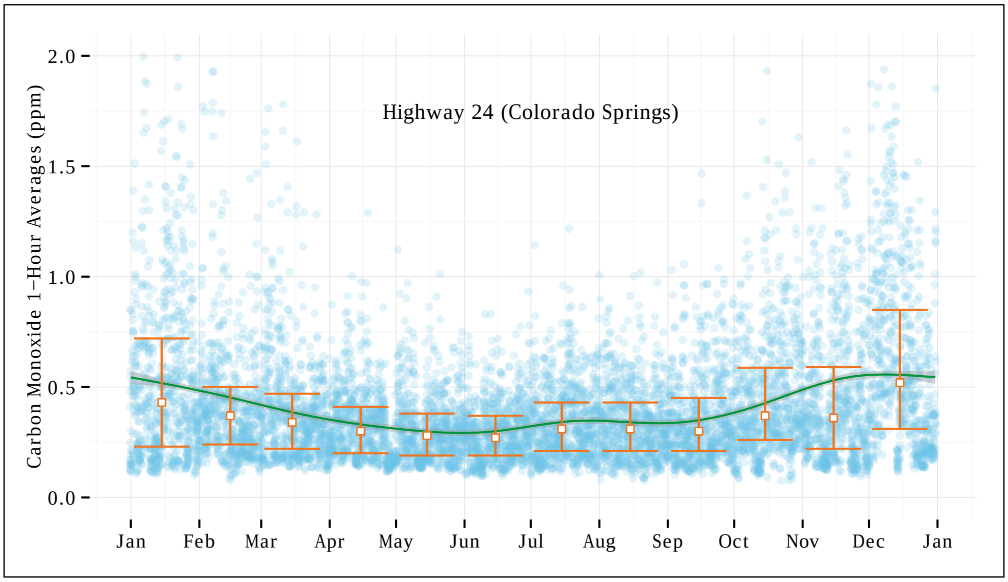


Figure 5.5: 1-hour average CO concentrations at the Highway 24 (Colorado Springs) station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

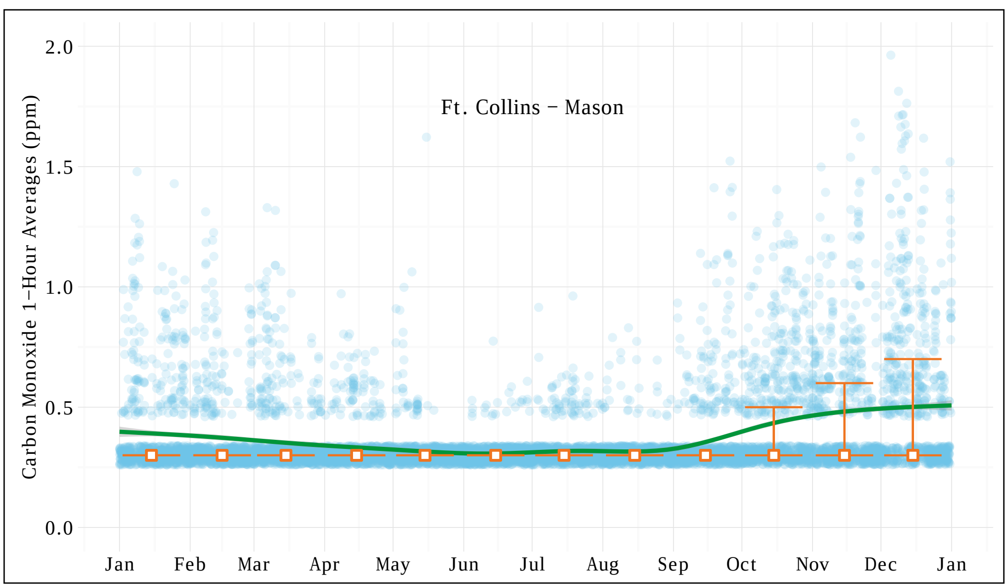


Figure 5.6: 1-hour average CO concentrations at the Ft. Collins - Mason station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

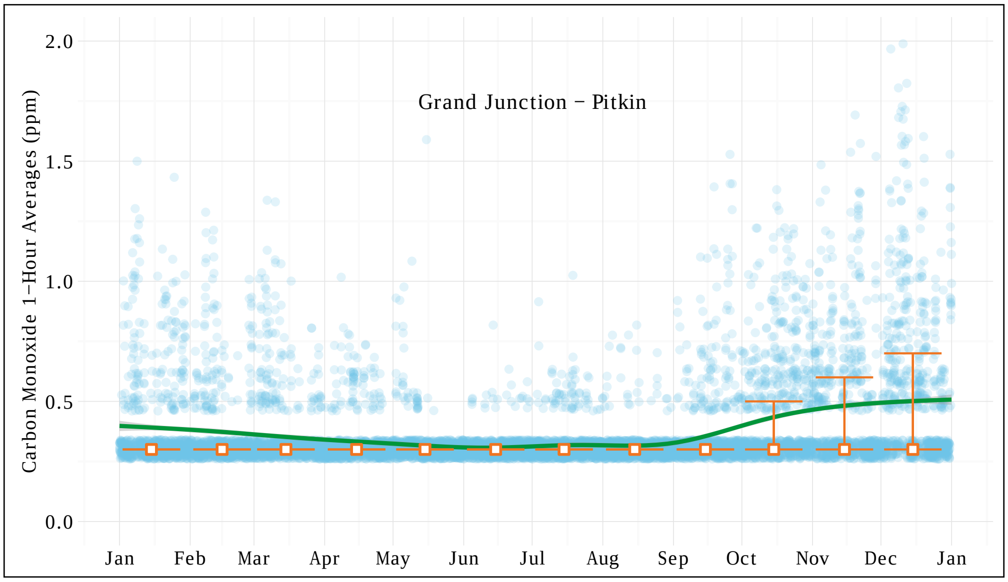


Figure 5.7: 1-hour average CO concentrations at the Grand Junction - Pitkin station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

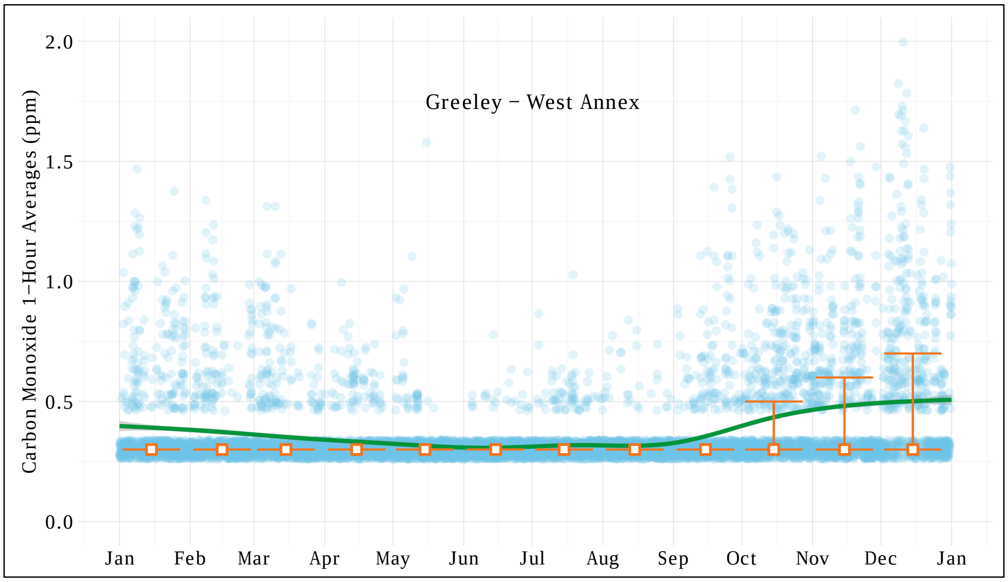


Figure 5.8: 1-hour average CO concentrations at the Greeley - West Annex station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

5.2 Sulfur Dioxide

Sulfur dioxide was measured at four stations during 2014 by APCD in Colorado: Welby, La Casa, CAMP, and Highway 24 (Colorado Springs).

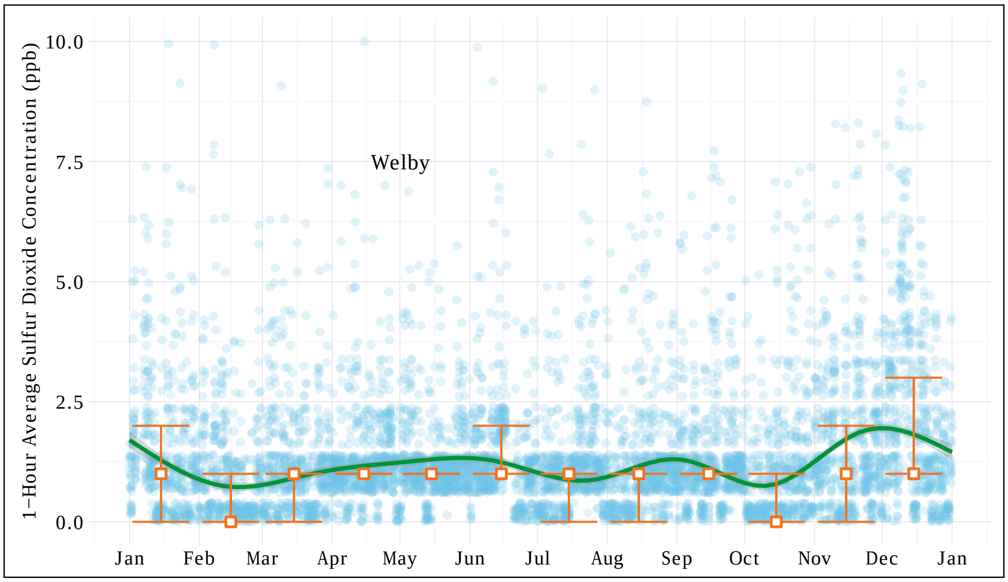


Figure 5.9: 1-hour average SO_2 concentrations at the Welby station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

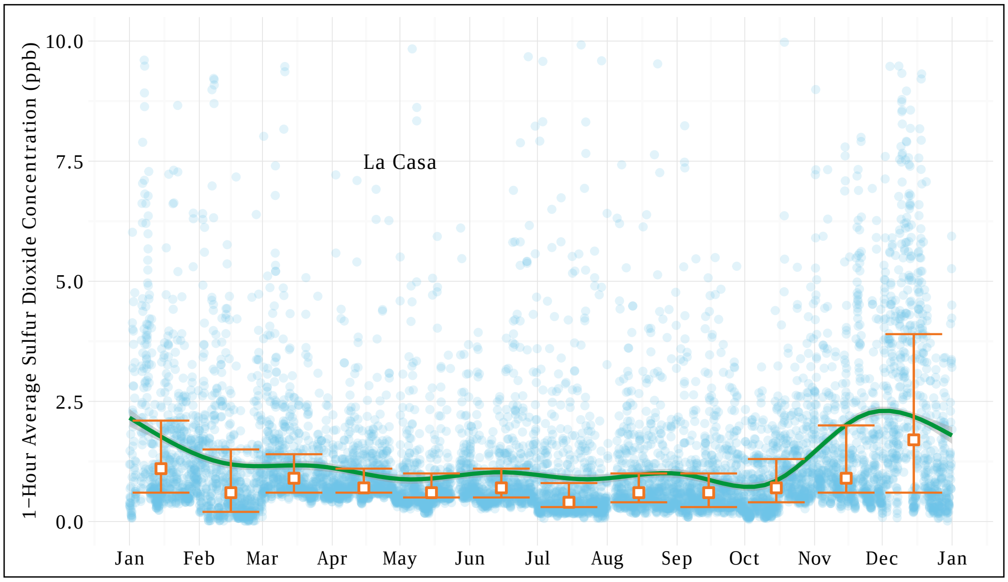


Figure 5.10: 1-hour average SO_2 concentrations at the La Casa station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

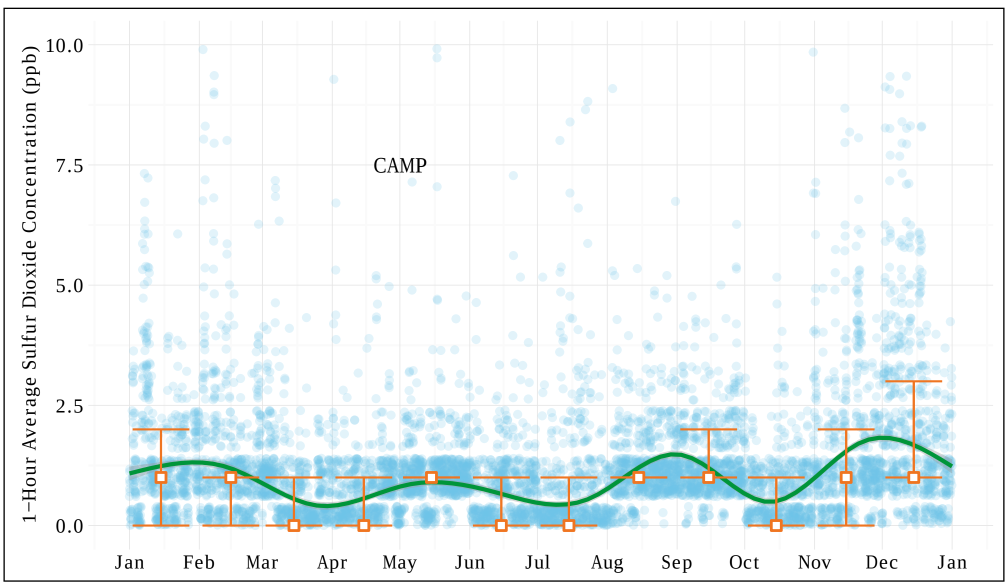


Figure 5.11: 1-hour average SO_2 concentrations at the CAMP station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

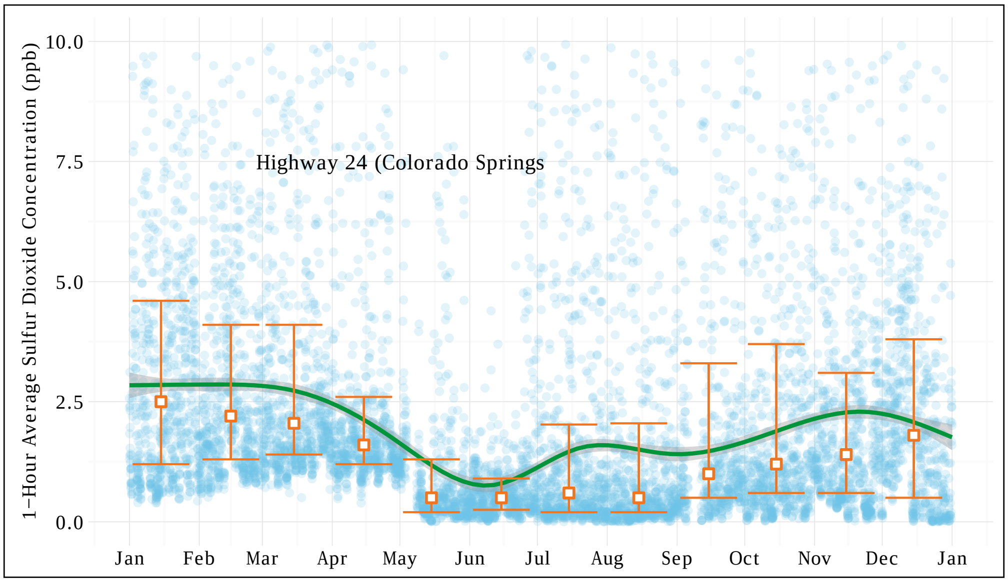


Figure 5.12: 1-hour average SO_2 concentrations at the Highway 24 (Colorado Springs) station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

5.3 Ozone

Ozone follows an opposite seasonal pattern relative to CO. The summer months see high ozone and the winter experiences lower levels, in part because of seasonal variations in day length and the angle of the sun relative to the ground. Remember that ozone may be indicative of ground-level smog or the "Denver Brown Cloud." Generally speaking, sites in the Northern Front Range counties experienced higher concentrations of ozone than other areas (especially sites directly west of, and at higher elevation than, metro Denver), though sites outside the Front Range occasionally had the highest averages.

It is important to note here that while O_3 concentrations were somewhat lower in 2014 than in previous years, there has been an upward trend overall since 2010.

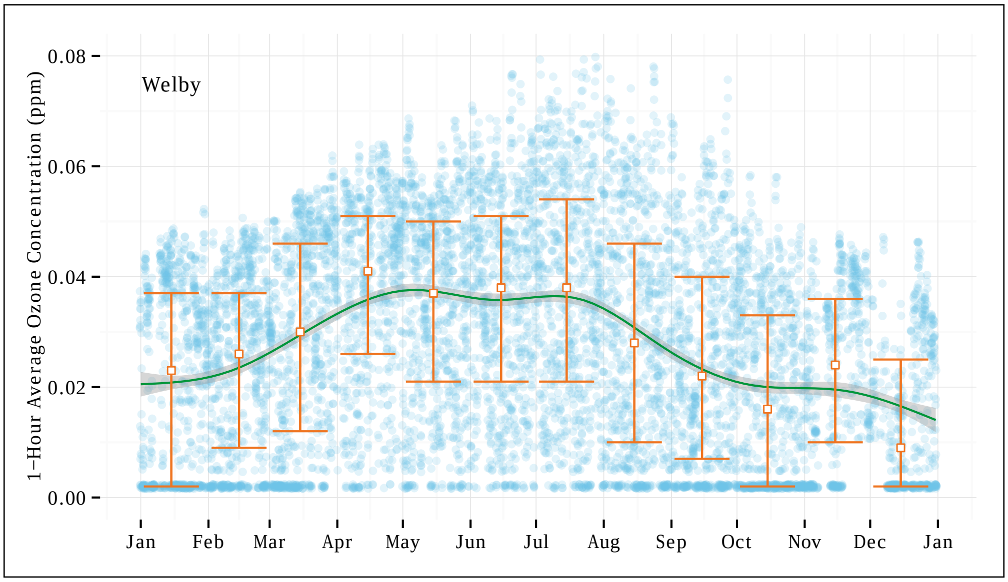


Figure 5.13: 8-hour average O_3 concentrations at the Welby station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

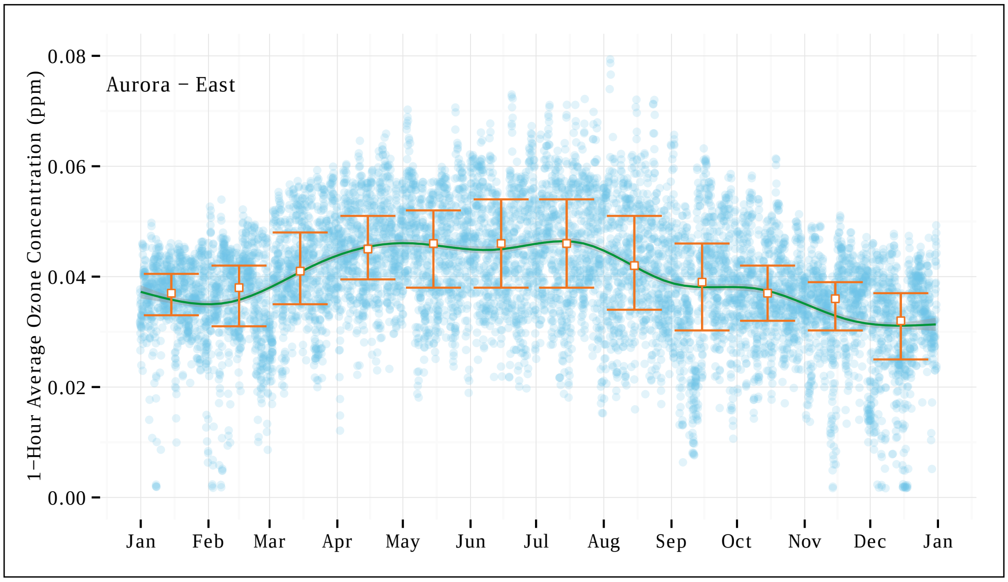


Figure 5.14: 8-hour average O_3 concentrations at the Aurora - East station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

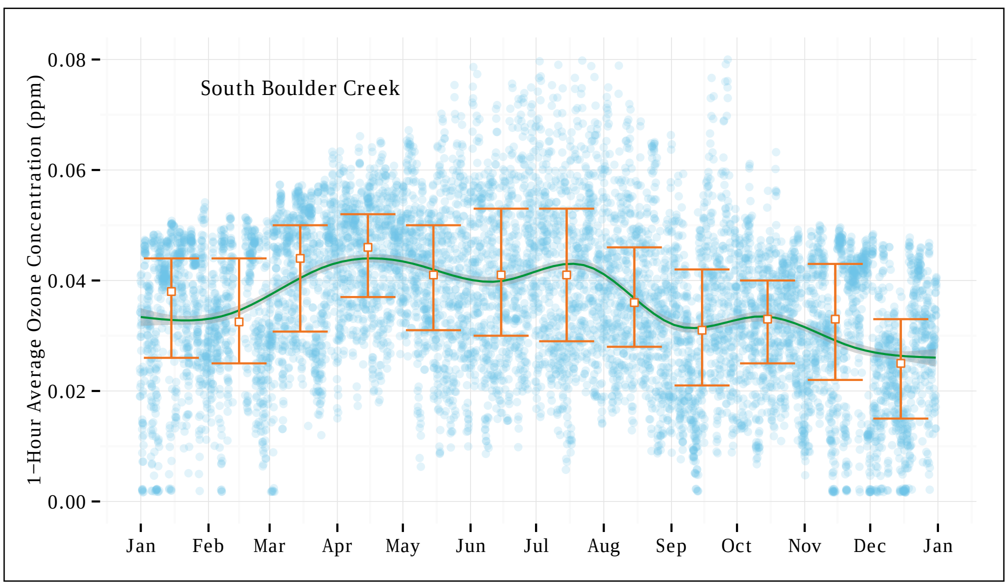


Figure 5.15: 8-hour average O_3 concentrations at the South Boulder Creek station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

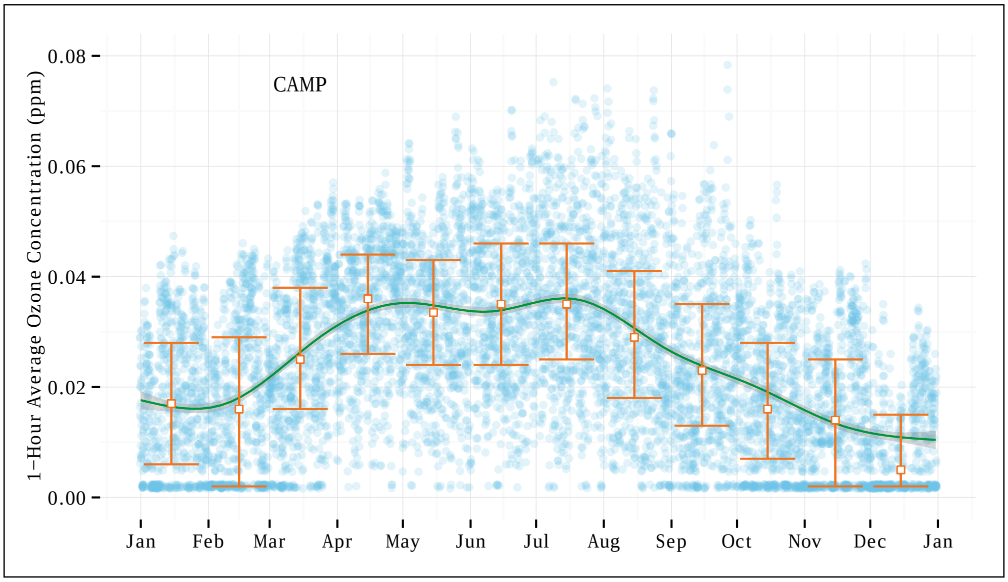


Figure 5.16: 8-hour average O_3 concentrations at the CAMP station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

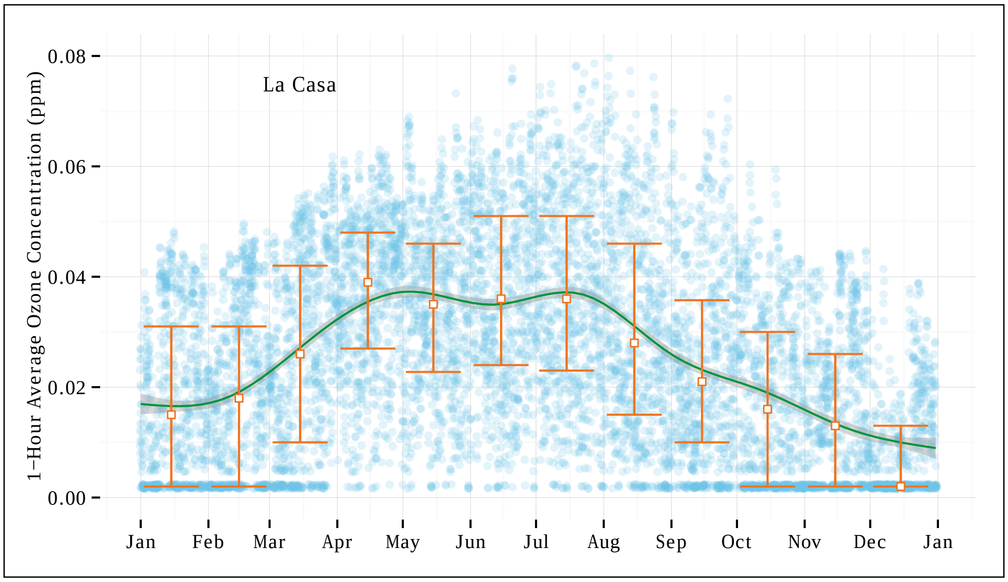


Figure 5.17: 8-hour average O_3 concentrations at the La Casa station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

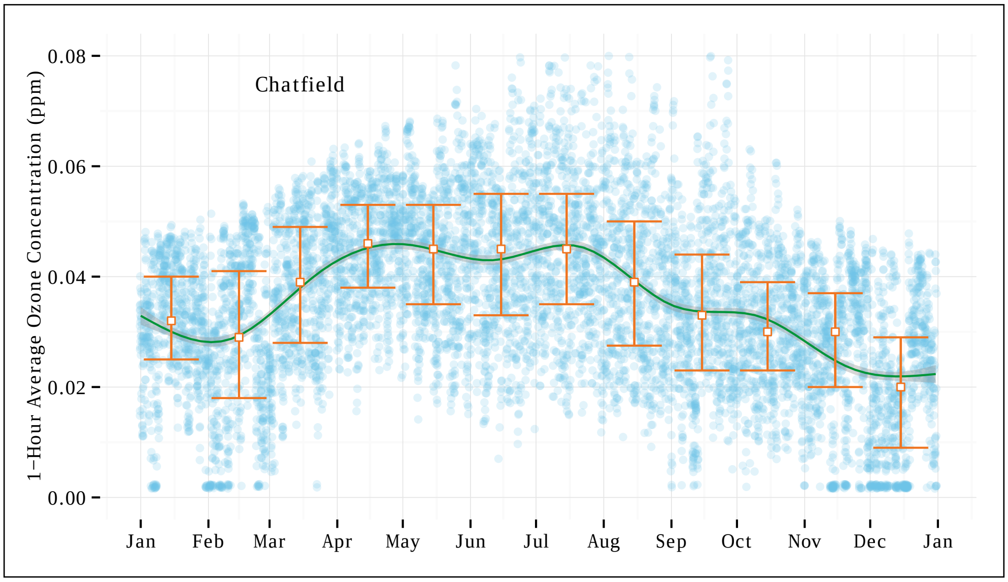


Figure 5.18: 8-hour average O_3 concentrations at the Chatfield State Park station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

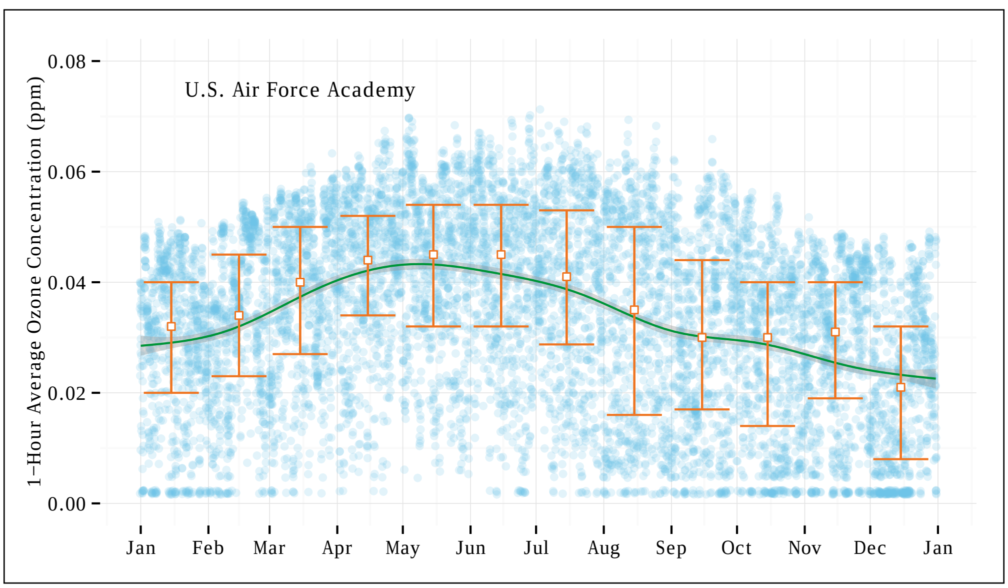


Figure 5.19: 8-hour average O_3 concentrations at the U.S. Air Force Academy station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

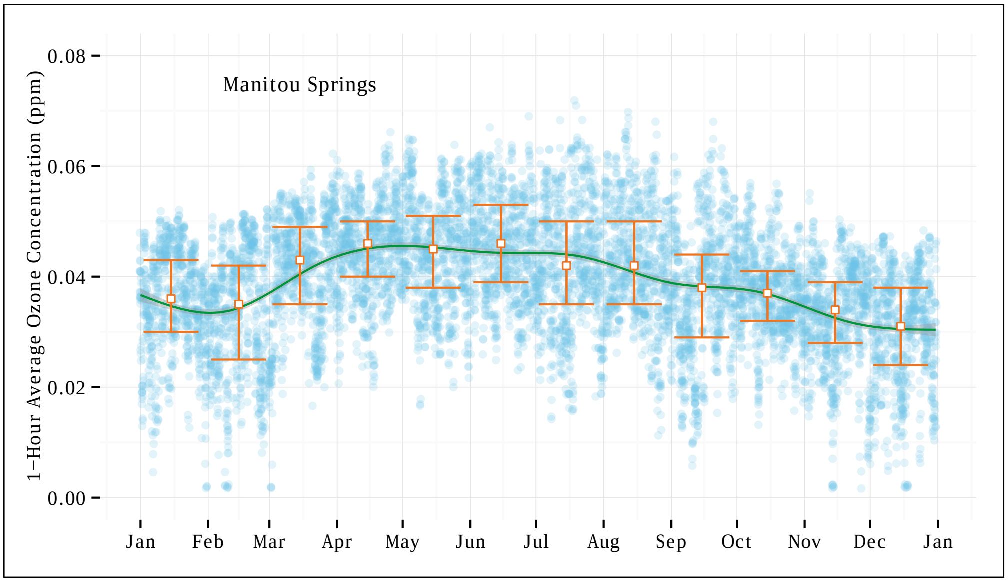


Figure 5.20: 8-hour average O_3 concentrations at the Manitou Springs station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

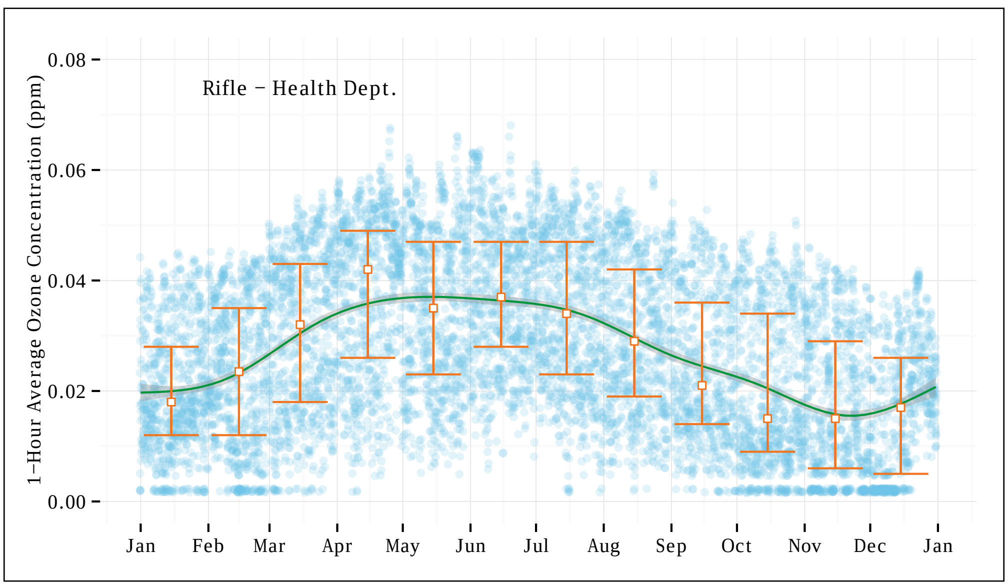


Figure 5.21: 8-hour average O_3 concentrations at the Rifle - Health Dept. station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

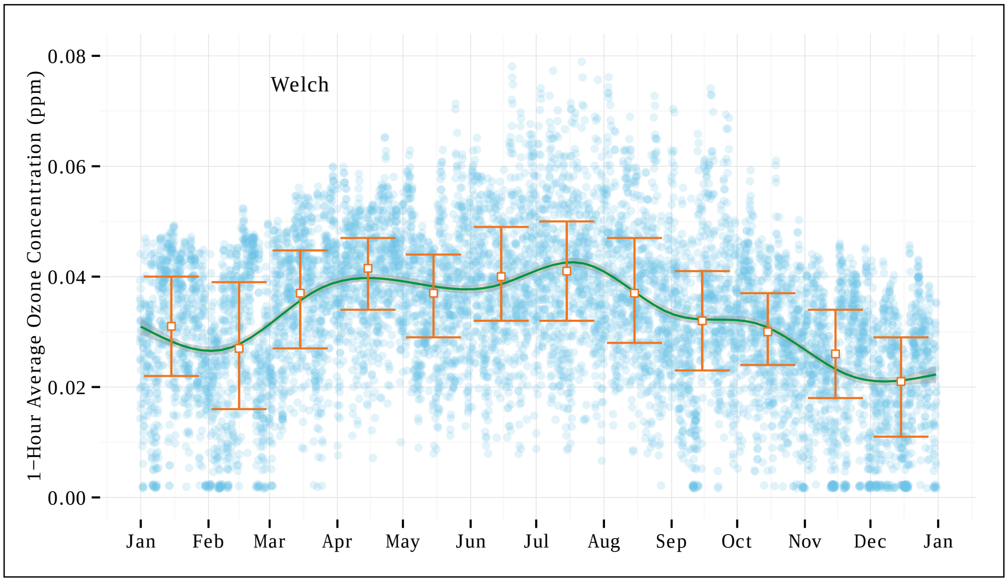


Figure 5.22: 8-hour average O_3 concentrations at the Welch station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

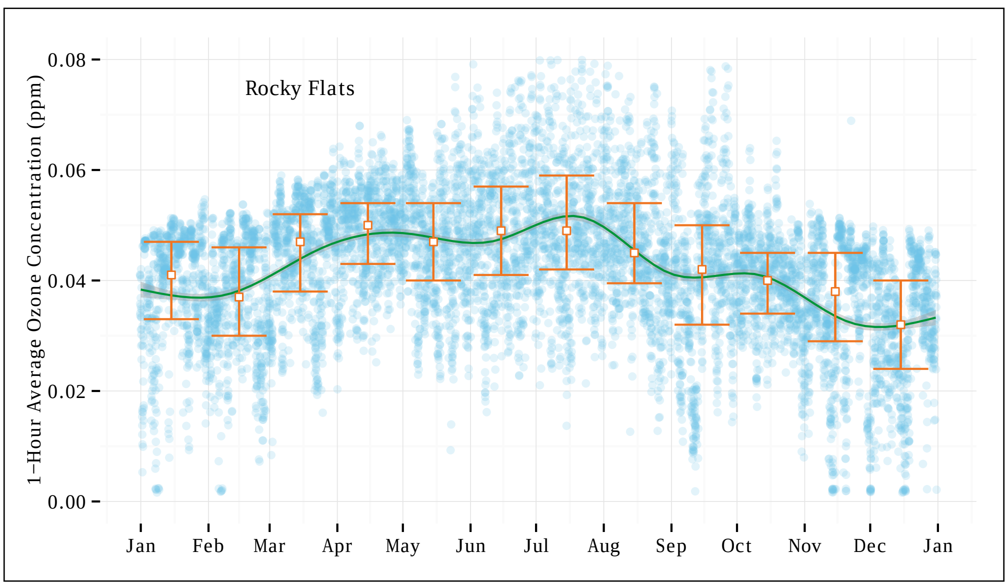


Figure 5.23: 8-hour average O_3 concentrations at the Rocky Flats - N. station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

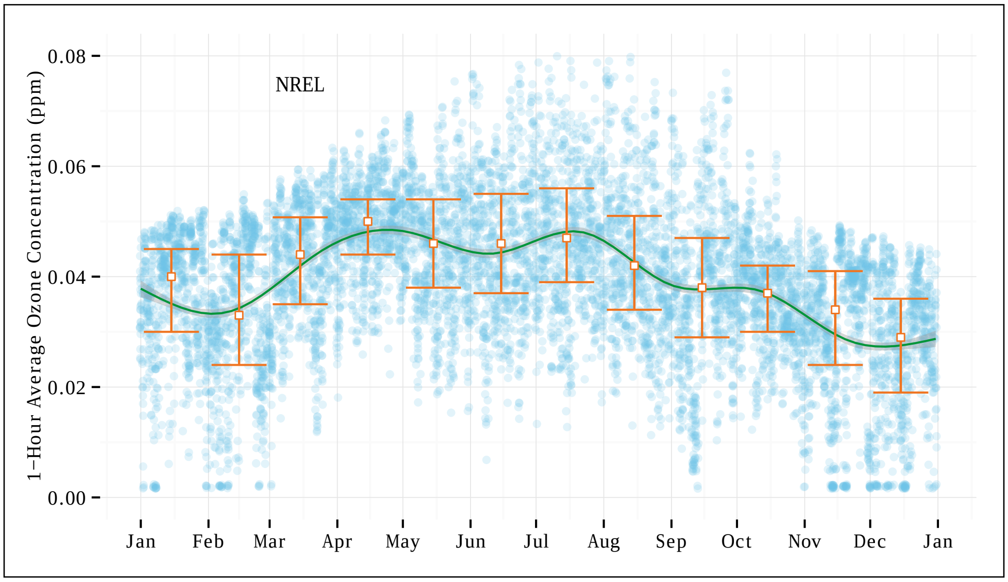


Figure 5.24: 8-hour average O_3 concentrations at the NREL station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

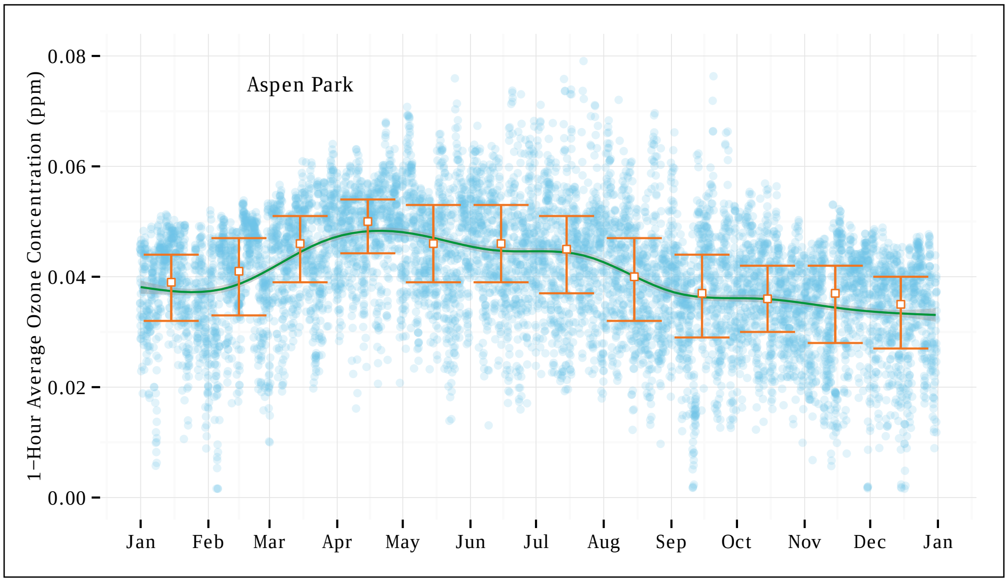


Figure 5.25: 8-hour average O_3 concentrations at the Aspen Park station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

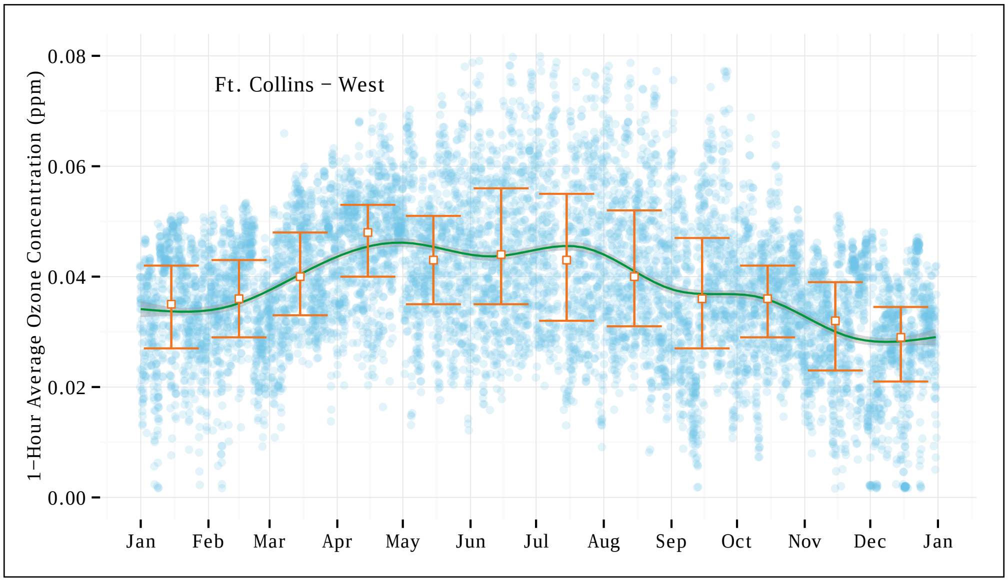


Figure 5.26: 8-hour average O_3 concentrations at the Ft. Collins - West station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

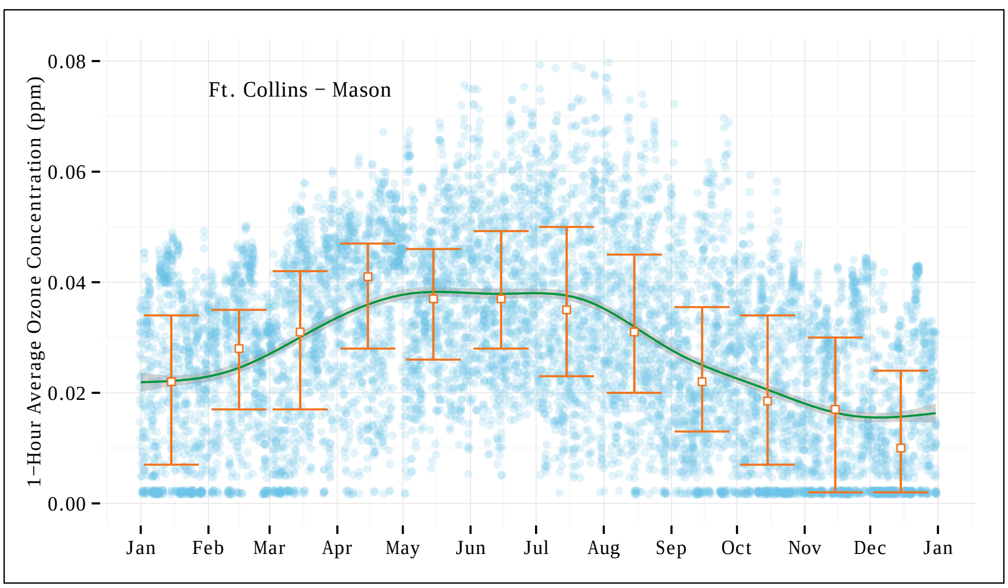


Figure 5.27: 8-hour average O_3 concentrations at the Ft. Collins - Mason station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

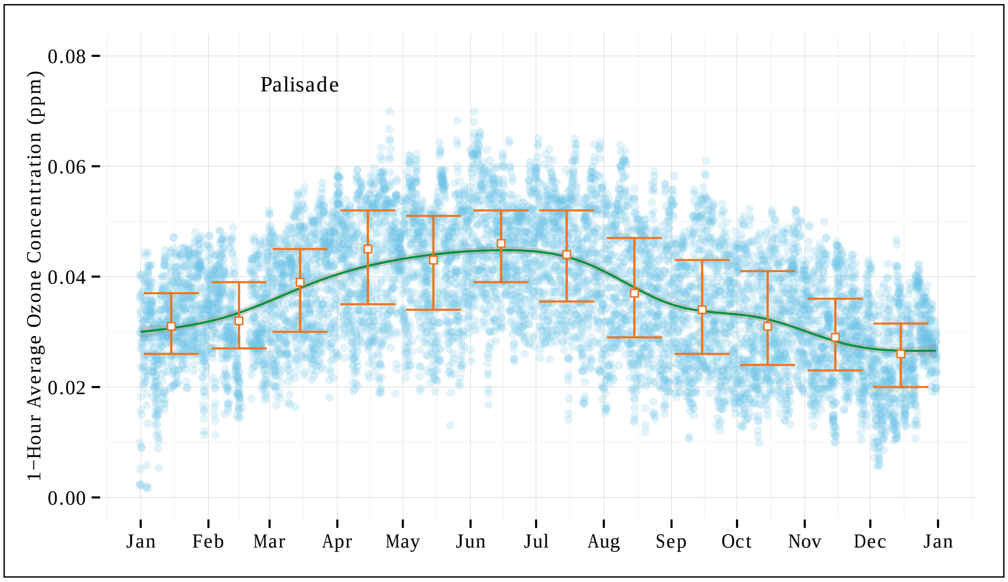


Figure 5.28: 8-hour average O_3 concentrations at the Palisade station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

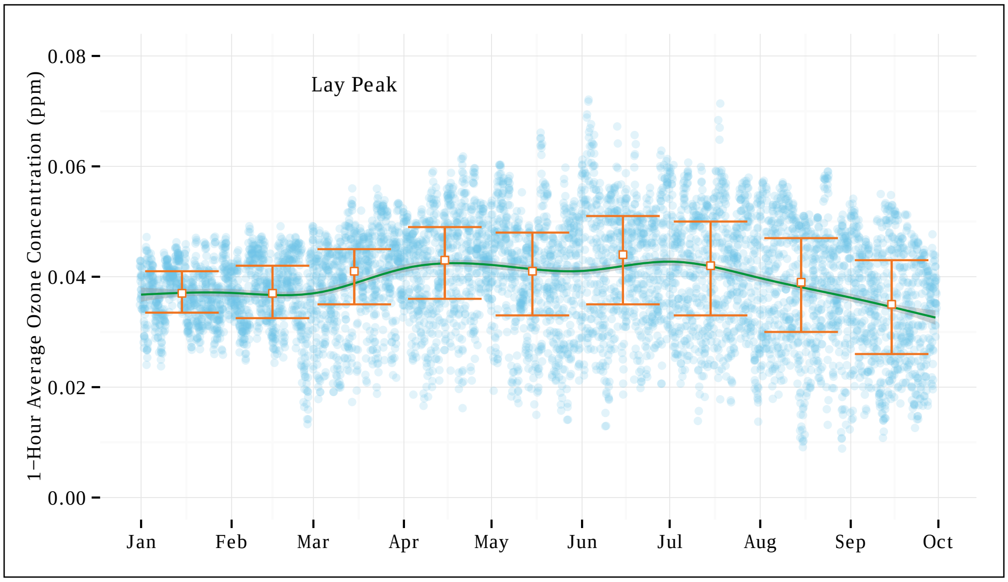


Figure 5.29: 8-hour average O_3 concentrations at the Lay Peak station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

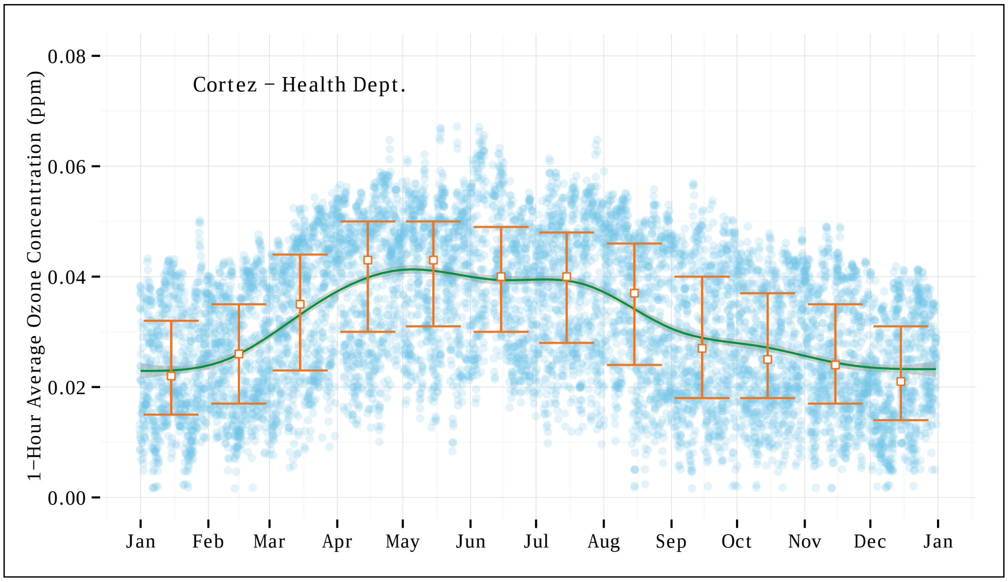


Figure 5.30: 8-hour average O_3 concentrations at the Cortez - Health Dept. station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

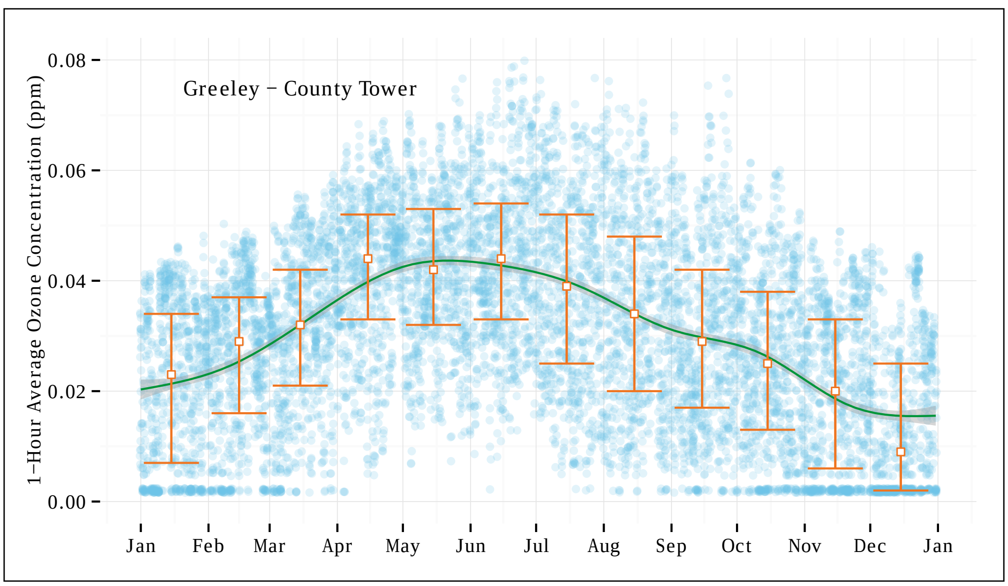


Figure 5.31: 8-hour average O_3 concentrations at the Greeley - County Tower station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

5.4 Nitrogen Dioxide

Nitrogen dioxide generally follows the same pattern as that for CO, typically being lower in concentration during the warmer months and higher in concentration during the colder months. NO_2 concentrations at sites in fairly close proximity appear to track well with one another.

Due to the photochemical coupling of NO_2 and O_3, their ambient concentration levels are inextricably linked. NO in the air reacts with ozone to form NO_2, thus lowering O_3 levels as NO_2 is created. This dynamic is displayed graphically in this section for APCD sites equipped with both NO_2 and O_3 monitors (Welby, CAMP, and La Casa). Plots of the NO_2/O_3 dependency show the density of 1-hour O_3 measurements throughout 2014 as a function of 1-hour NO_2 concentrations. These plots also show probability density functions for NO_2 and O_3, as well as the Spearman correlation coefficient between the two variables ($p = 0$ indicates that the correlation coefficient is statistically significant in all cases).

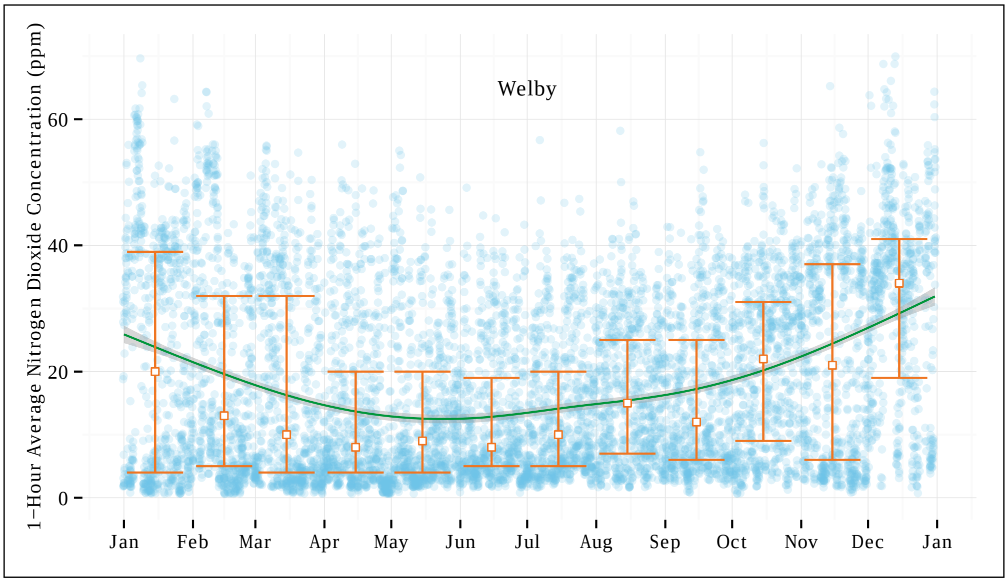


Figure 5.32: 1-hour average NO_2 concentrations at the Welby station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

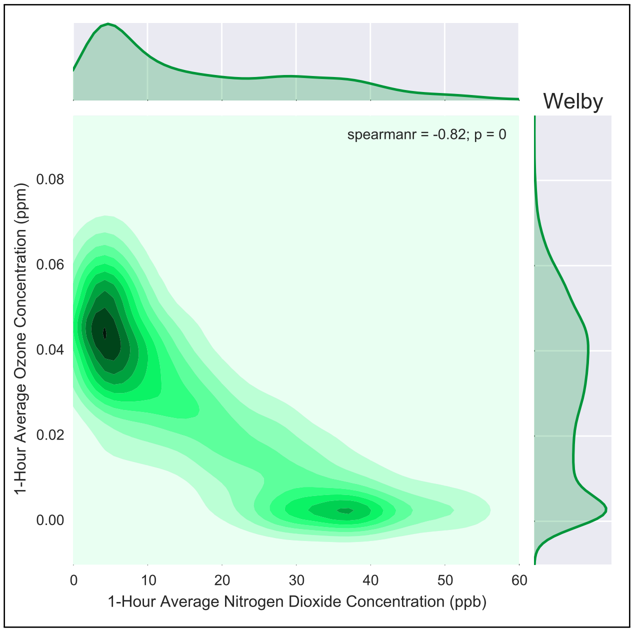


Figure 5.33: Density plot showing O_3 as a function of NO_2 at the Welby station during 2014.

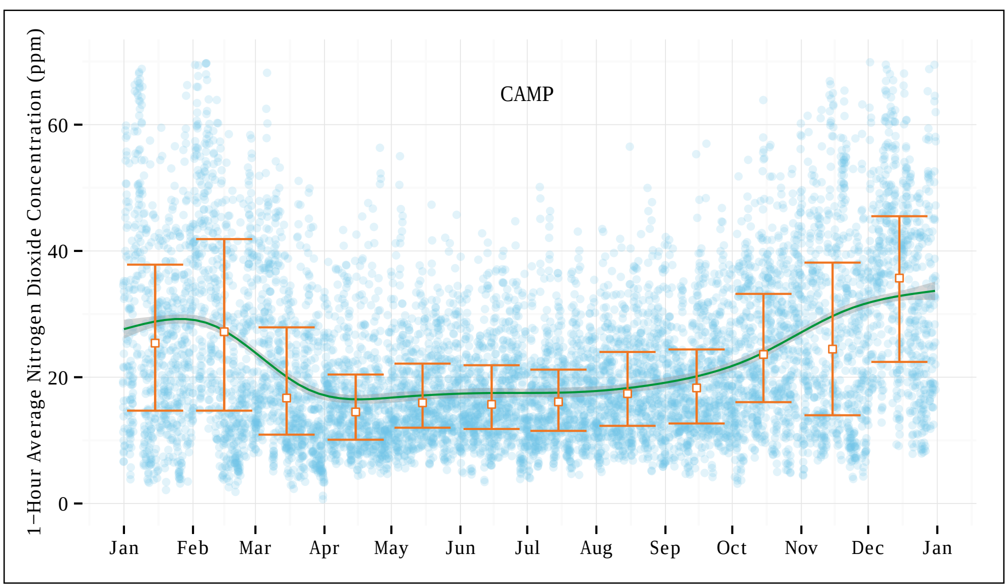


Figure 5.34: 1-hour average NO_2 concentrations at the CAMP station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

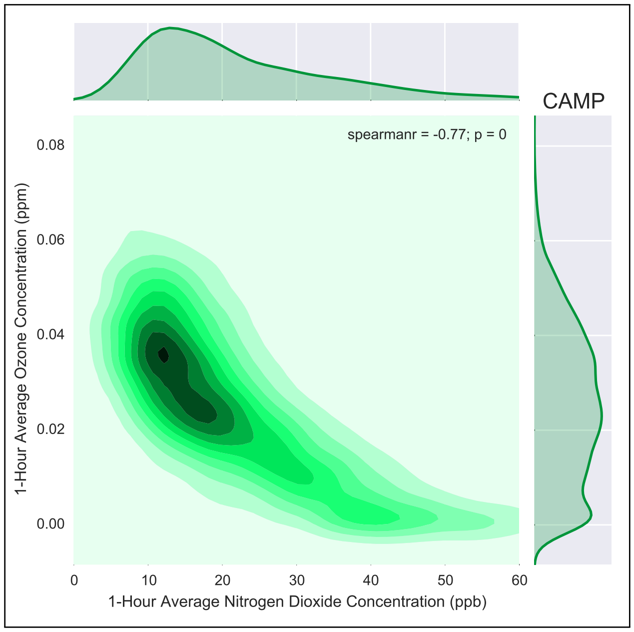


Figure 5.35: Density plot showing O_3 as a function of NO_2 at the CAMP station during 2014.

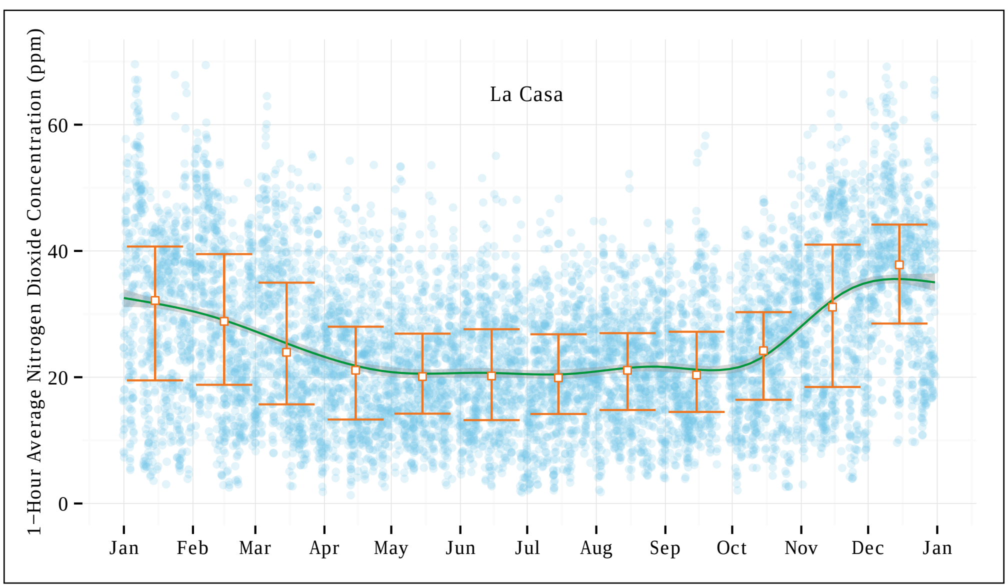


Figure 5.36: 1-hour average NO_2 concentrations at the La Casa station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

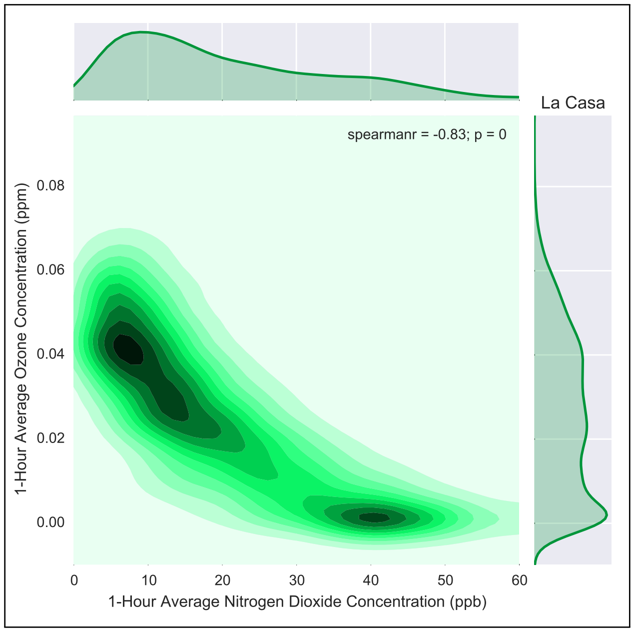


Figure 5.37: Density plot showing O_3 as a function of NO_2 at the La Casa station during 2014.

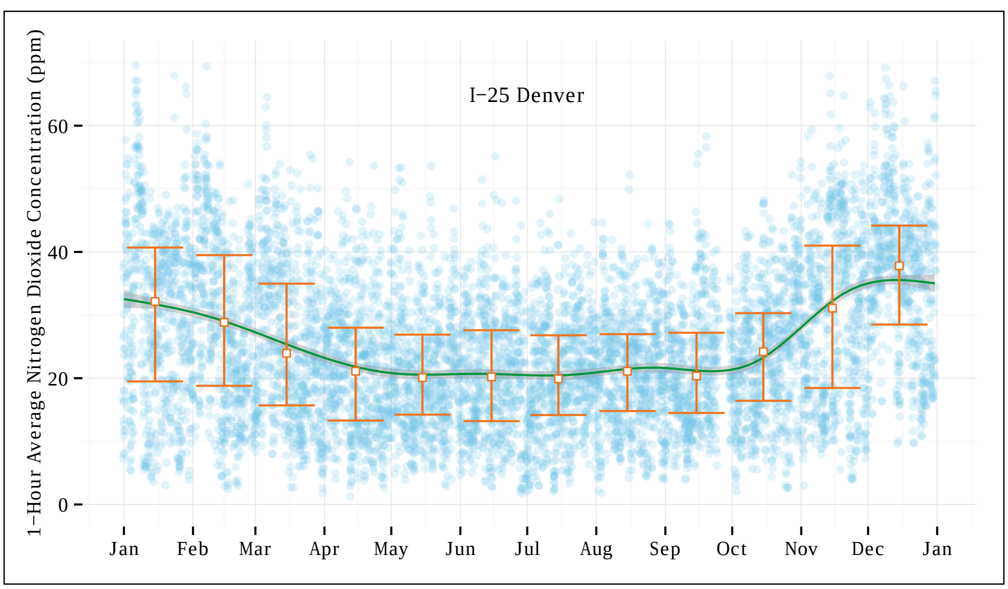


Figure 5.38: 1-hour average NO_2 concentrations at the I-25 Denver station (blue dots). The mean trend obtained using a generalized additive model is shown as a blue line. The error bars represent the median and interquartile range of values observed during each month.

5.5 PM_{10}

PM_{10} concentrations can be elevated for a variety of reasons, including both anthropogenic and natural occurrences. Higher PM_{10} concentrations might be expected during dry months and or droughts, since the soil has a chance to dry out and be entrained by the winds. This is reflected somewhat in the range of PM_{10} concentrations found in the following graphs, but the peaks in concentrations are often due to single-point high-concentration events. The data below contains exceptional events. See subsubsection 2.2.5.4 for an explanation of exceptional events. Many of these exceptional events will be analyzed and documented as natural events and be demonstrated as beyond reasonable control and or not preventable. The documentation package is then sent to the EPA for concurrence. If the EPA concurs with the APCD‘s analysis, then the exceedance or high PM_{10} reading will be removed from regulatory consideration and will not be used in NAAQS calculations.

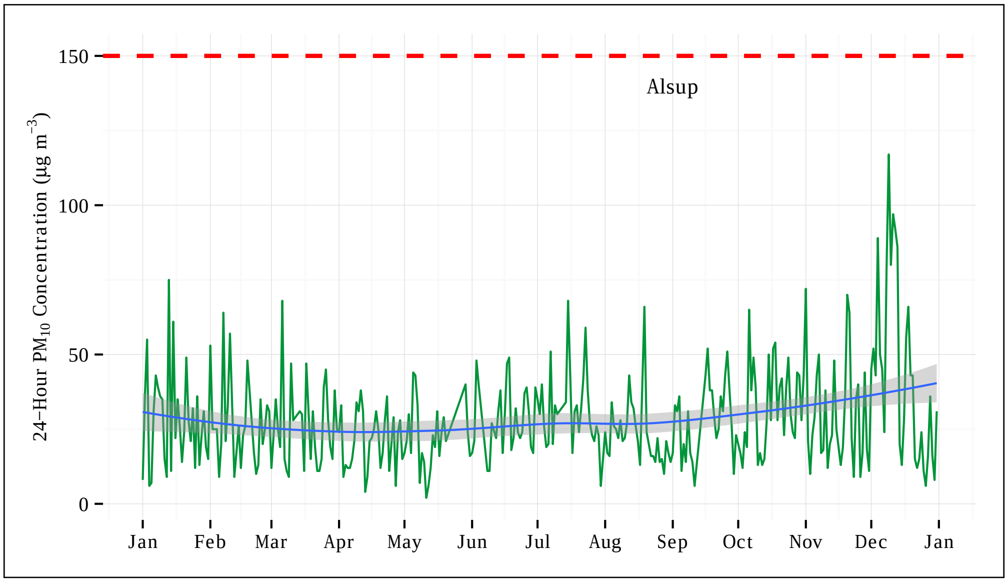


Figure 5.39: 24-hour average PM_{10} concentrations at the Alsup station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (150 $\mu g\ m^{-3}$) is shown as a dashed red line.

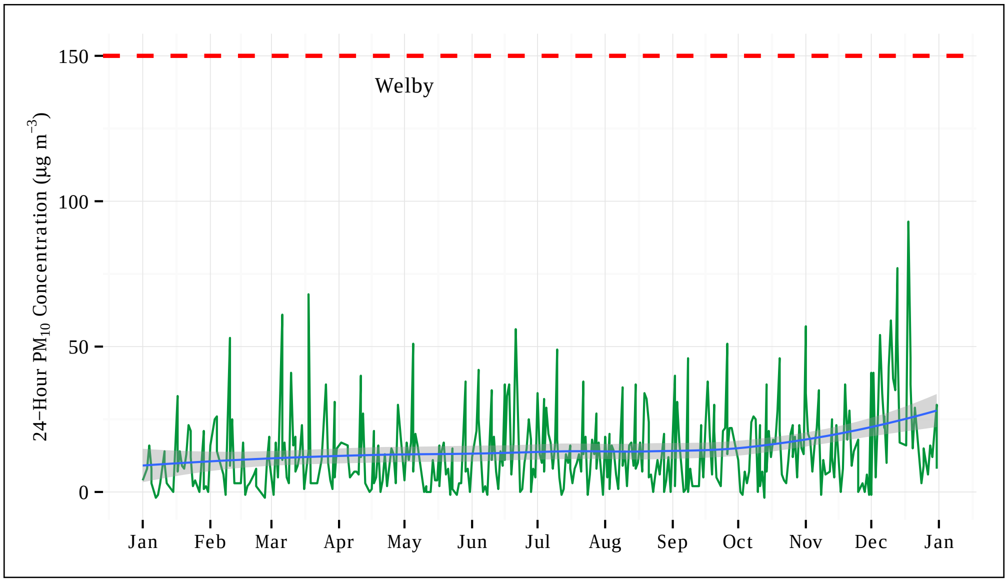


Figure 5.40: 24-hour average PM_{10} concentrations at the Welby station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

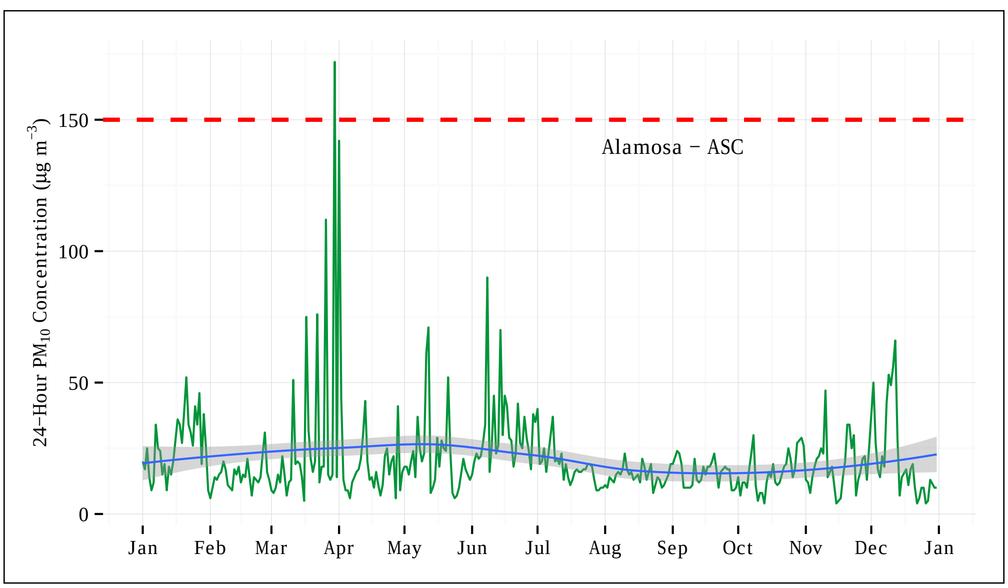


Figure 5.41: 24-hour average PM_{10} concentrations at the Alamosa - ASC station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

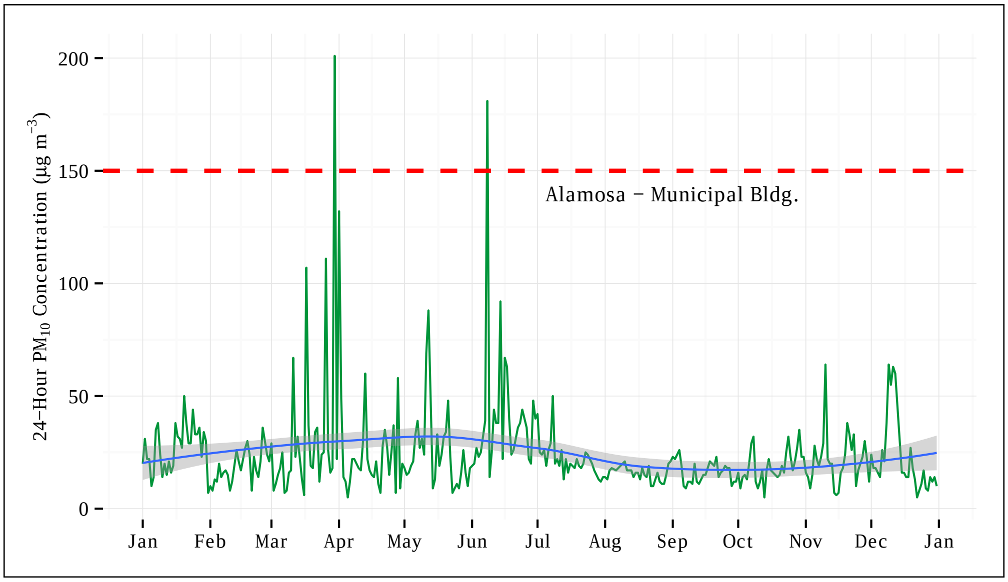


Figure 5.42: 24-hour average PM_{10} concentrations at the Alamosa - Municipal Bldg. station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

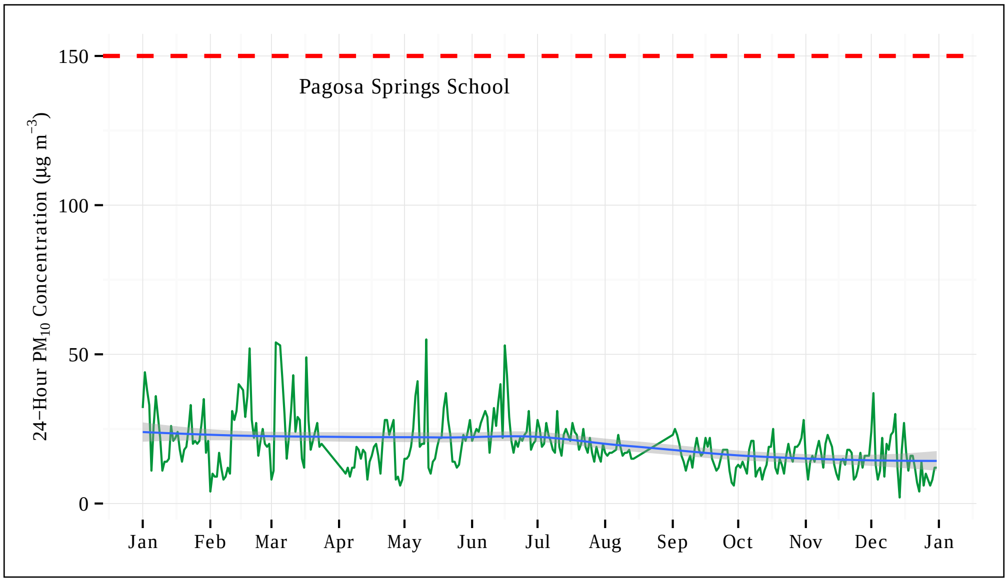


Figure 5.43: 24-hour average PM_{10} concentrations at the Pagosa Springs School station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

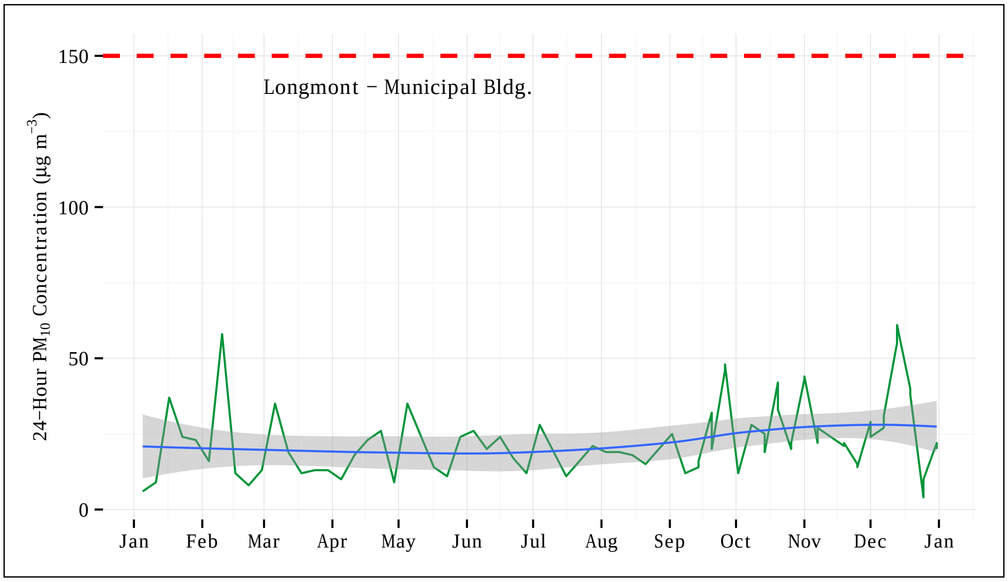


Figure 5.44: 24-hour average PM_{10} concentrations at the Longmont - Municipal Bldg. station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

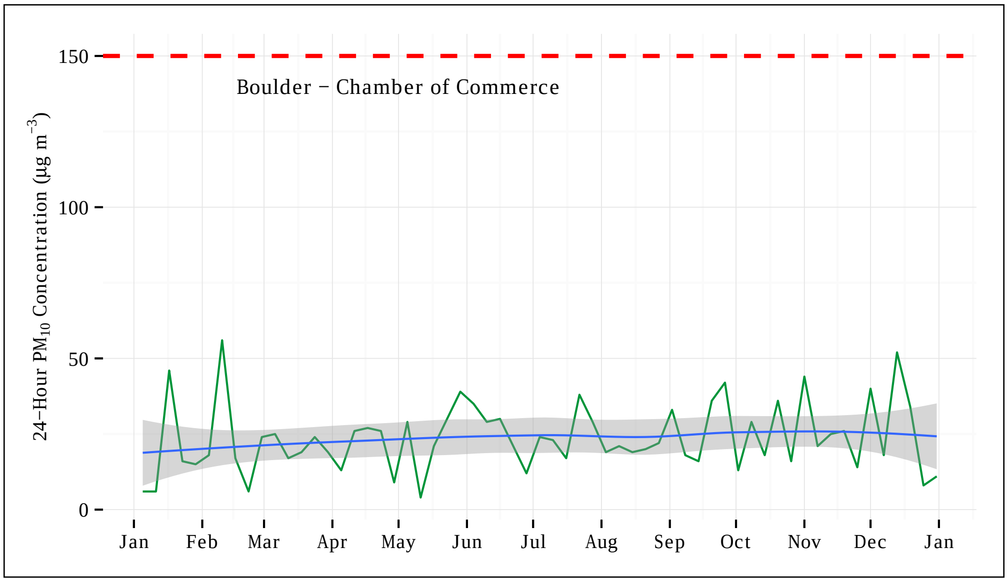


Figure 5.45: 24-hour average PM_{10} concentrations at the Boulder Chamber of Commerce station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

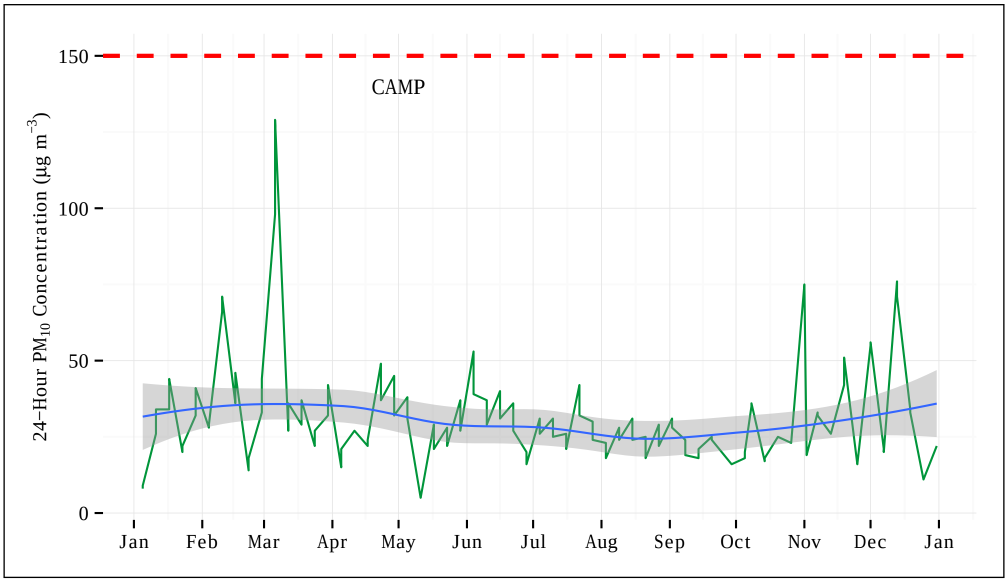


Figure 5.46: 24-hour average PM_{10} concentrations at the CAMP station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (150 $\mu g\ m^{-3}$) is shown as a dashed red line.

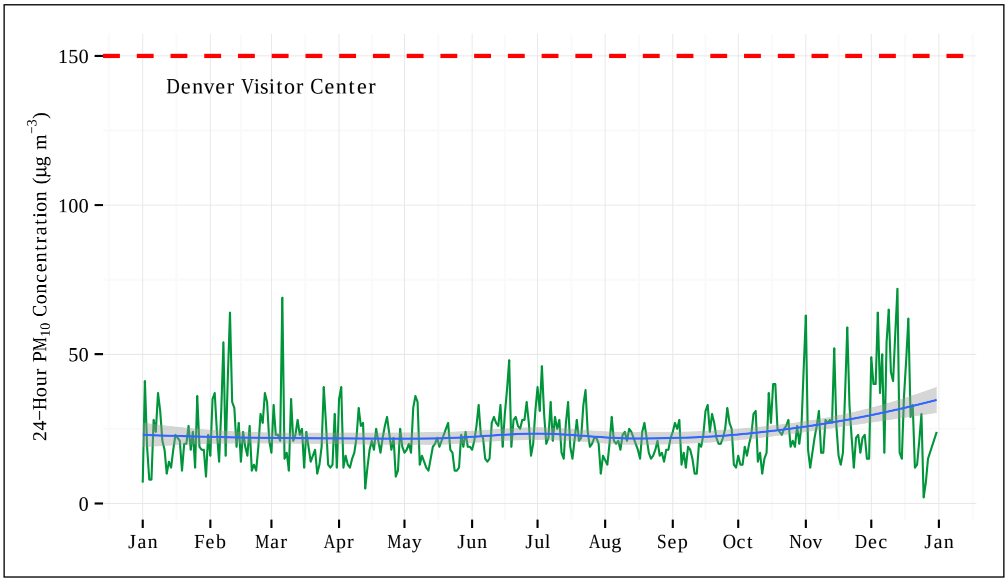


Figure 5.47: 24-hour average PM_{10} concentrations at the Denver Visitor Center station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (150 $\mu g\ m^{-3}$) is shown as a dashed red line.

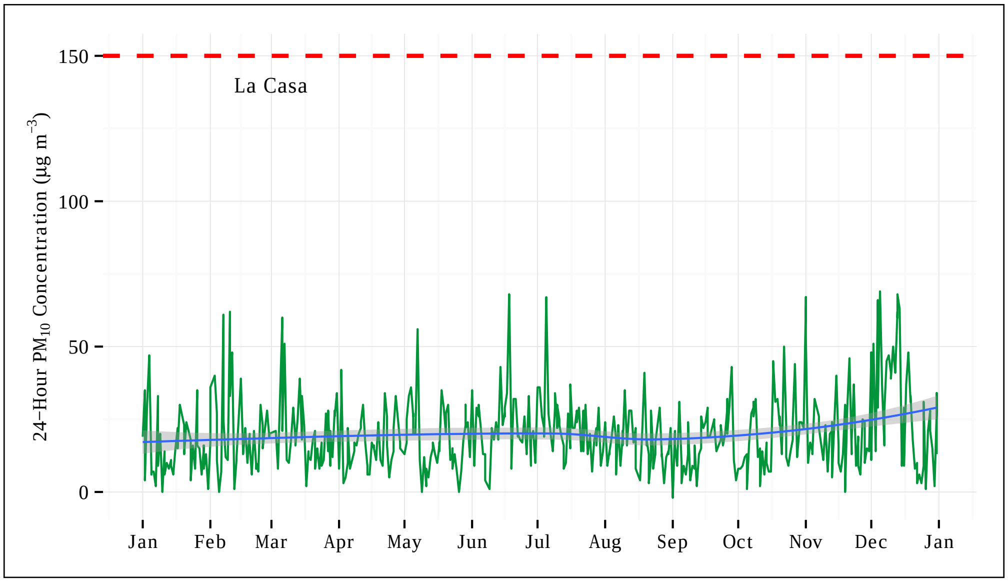


Figure 5.48: 24-hour average PM_{10} concentrations at the La Casa station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (150 μg m^{-3}) is shown as a dashed red line.

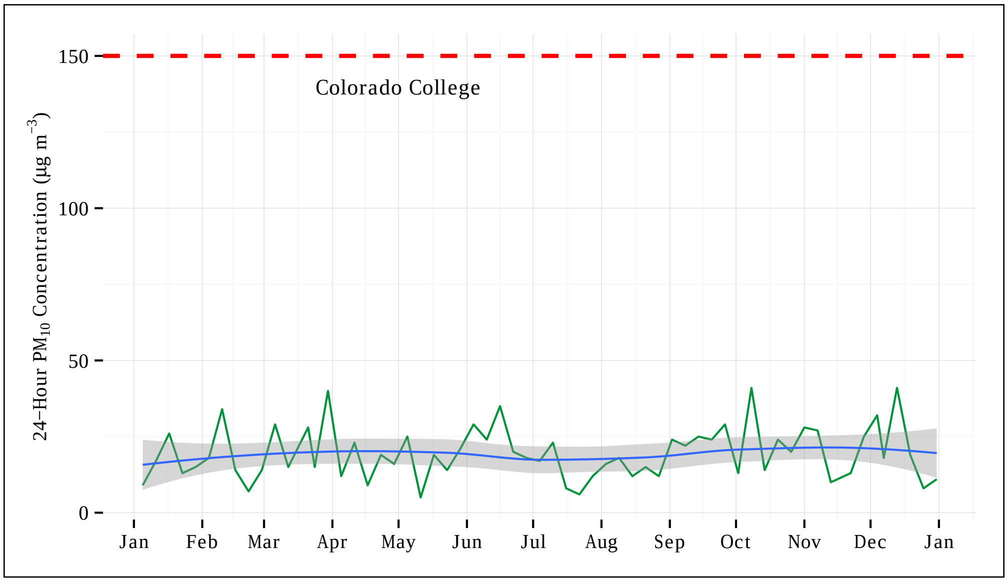


Figure 5.49: 24-hour average PM_{10} concentrations at the Colorado College station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (150 μg m^{-3}) is shown as a dashed red line.

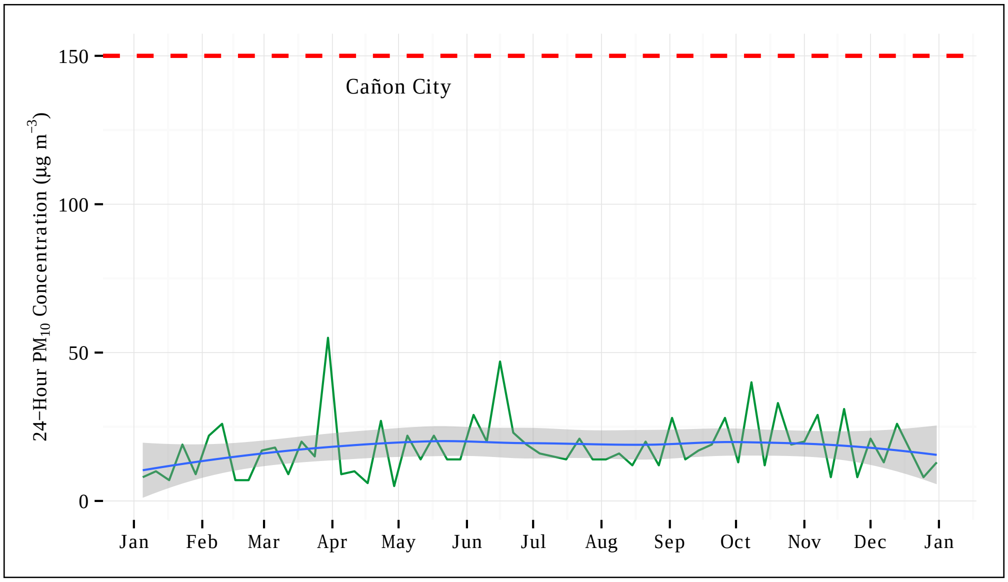


Figure 5.50: 24-hour average PM$_{10}$ concentrations at the Cañon City station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

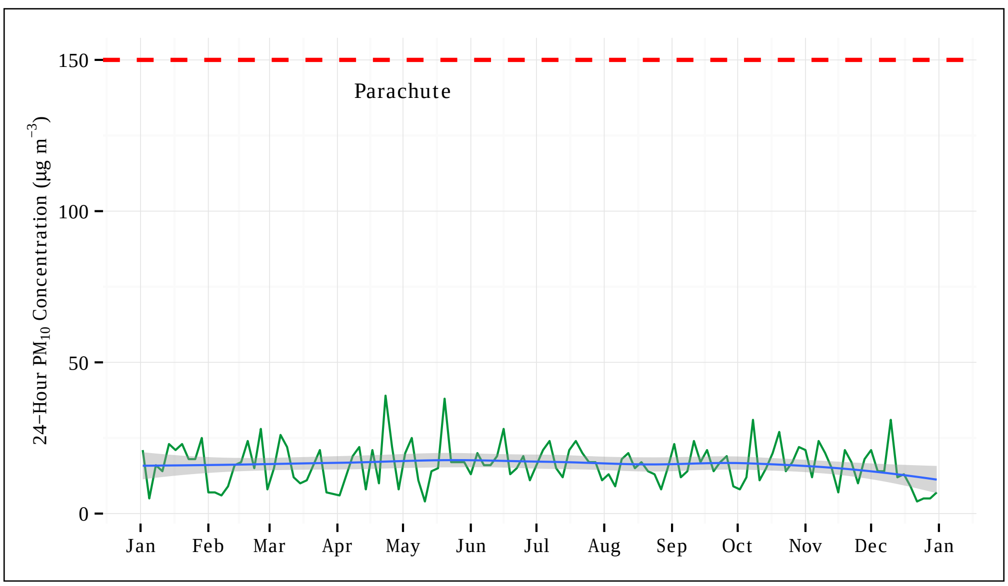


Figure 5.51: 24-hour average PM$_{10}$ concentrations at the Parachute station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

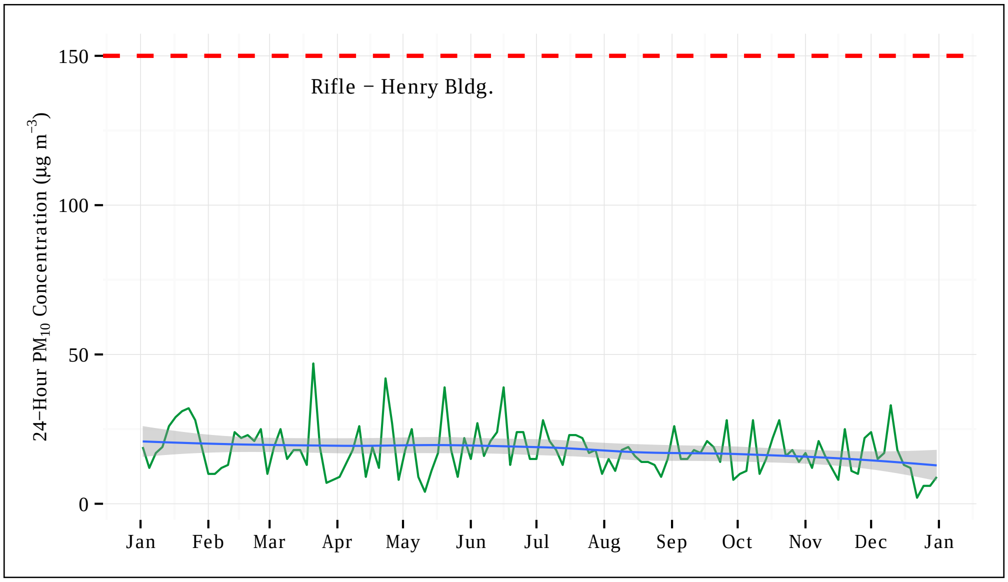


Figure 5.52: 24-hour average PM_{10} concentrations at the Rifle - Henry Bldg. station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

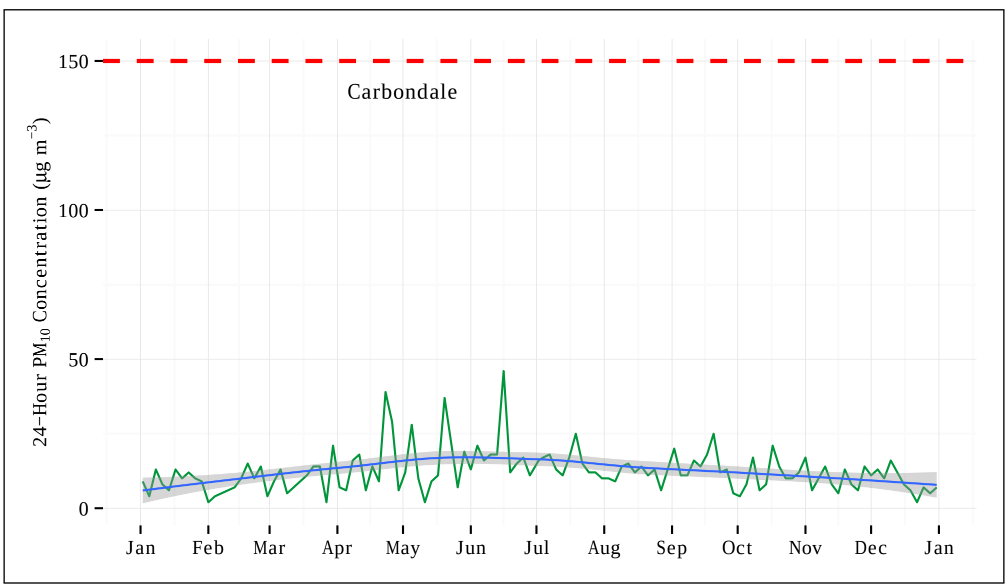


Figure 5.53: 24-hour average PM_{10} concentrations at the Carbondale station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

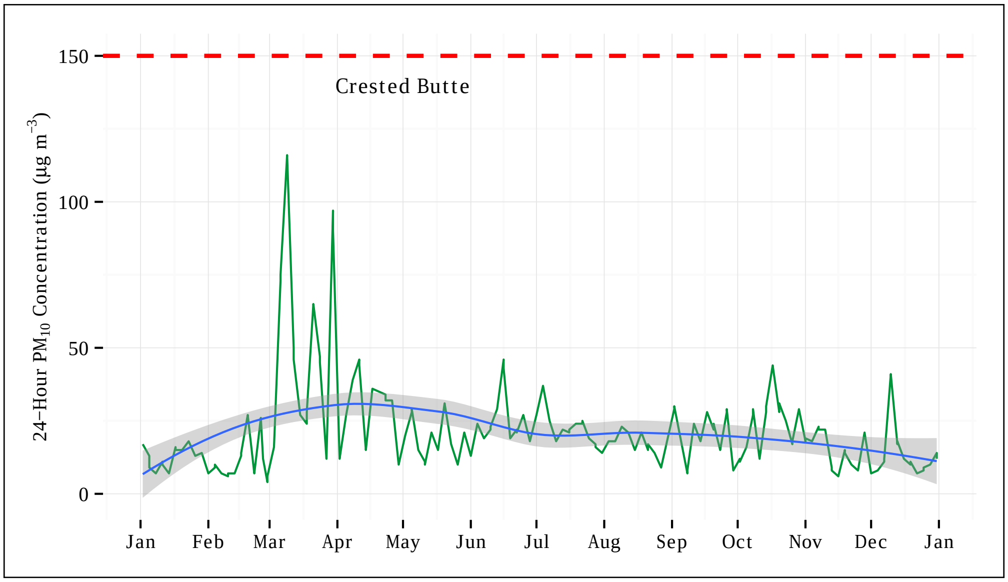


Figure 5.54: 24-hour average PM_{10} concentrations at the Crested Butte station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

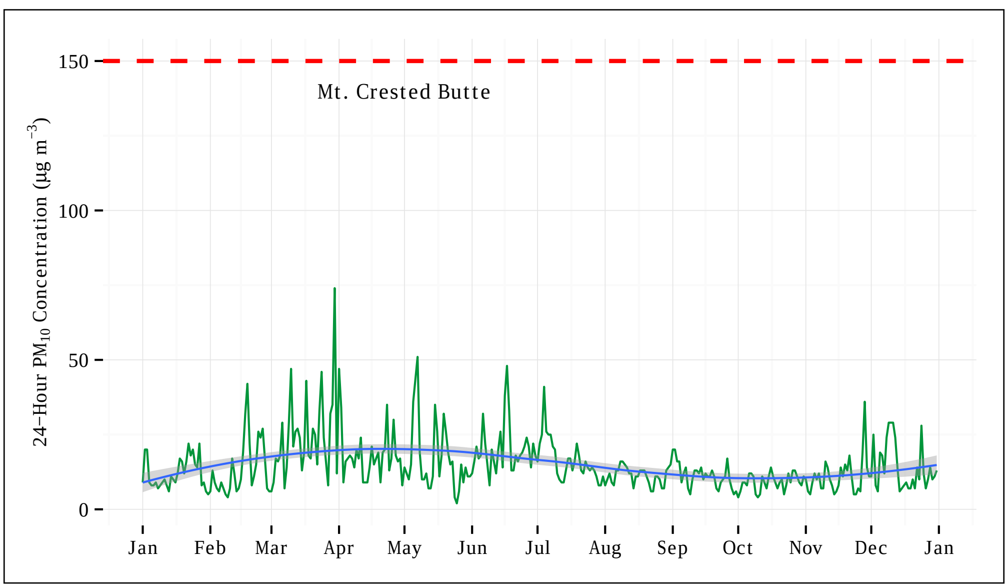


Figure 5.55: 24-hour average PM_{10} concentrations at the Mt. Crested Butte station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

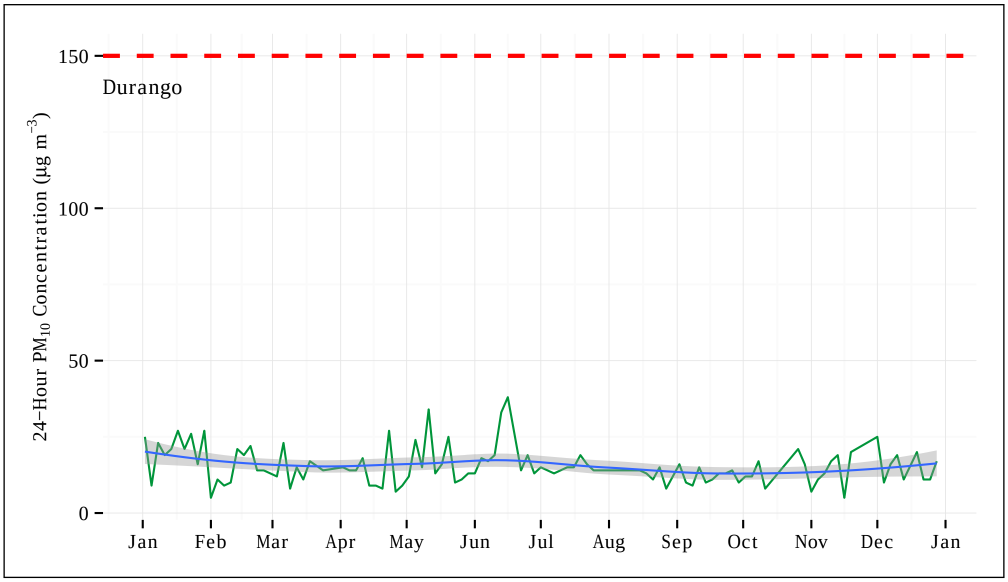


Figure 5.56: 24-hour average PM_{10} concentrations at the Durango station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (150 $\mu g\ m^{-3}$) is shown as a dashed red line.

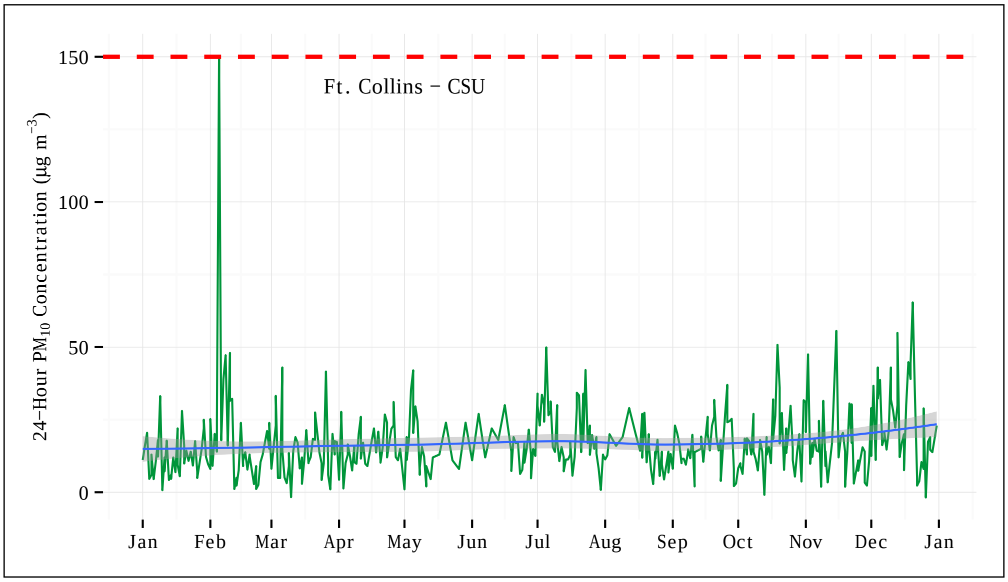


Figure 5.57: 24-hour average PM_{10} concentrations at the Ft. Collins - CSU station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (150 $\mu g\ m^{-3}$) is shown as a dashed red line.

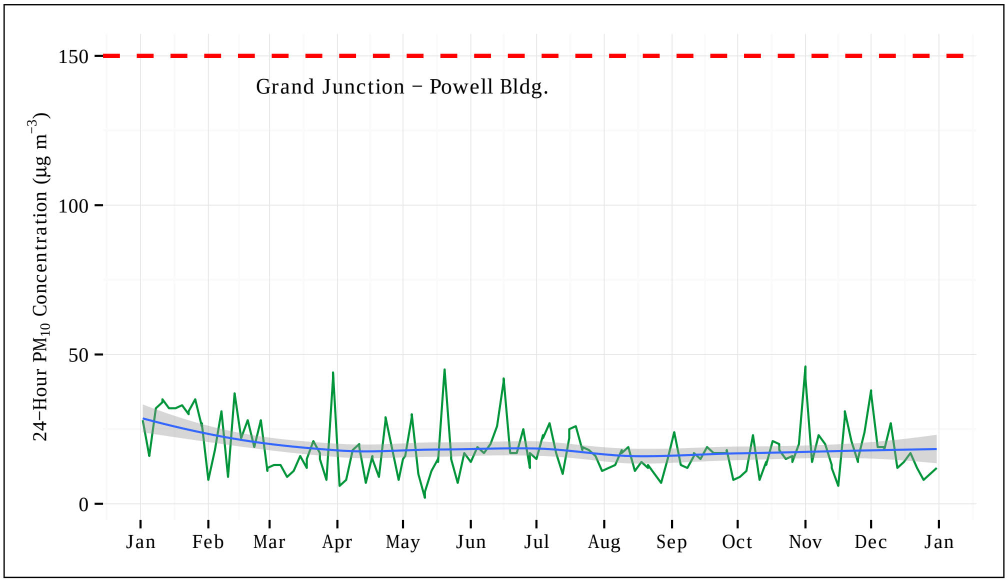


Figure 5.58: 24-hour average PM_{10} concentrations at the Grand Junction - Powell station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

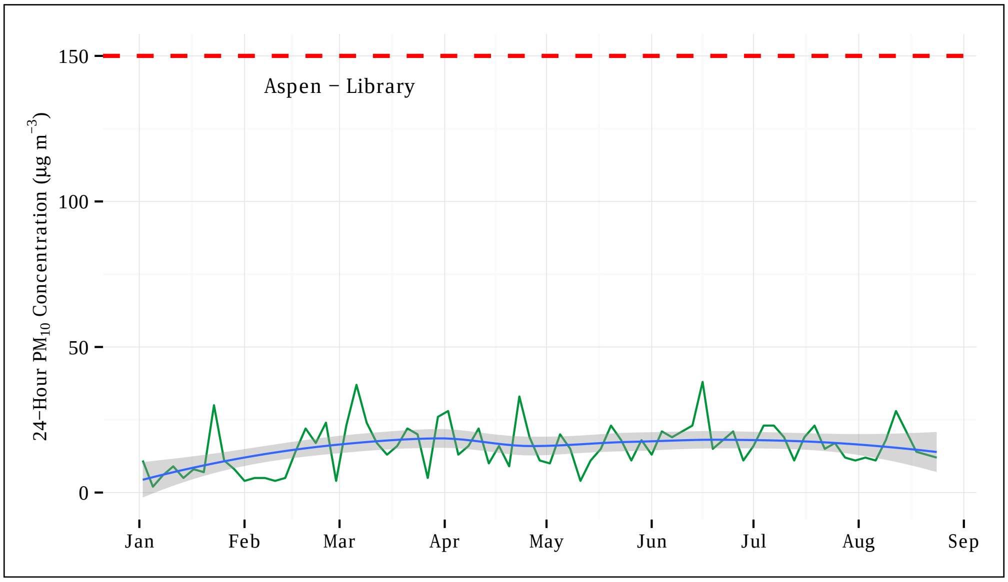


Figure 5.59: 24-hour average PM_{10} concentrations at the Aspen - Library station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

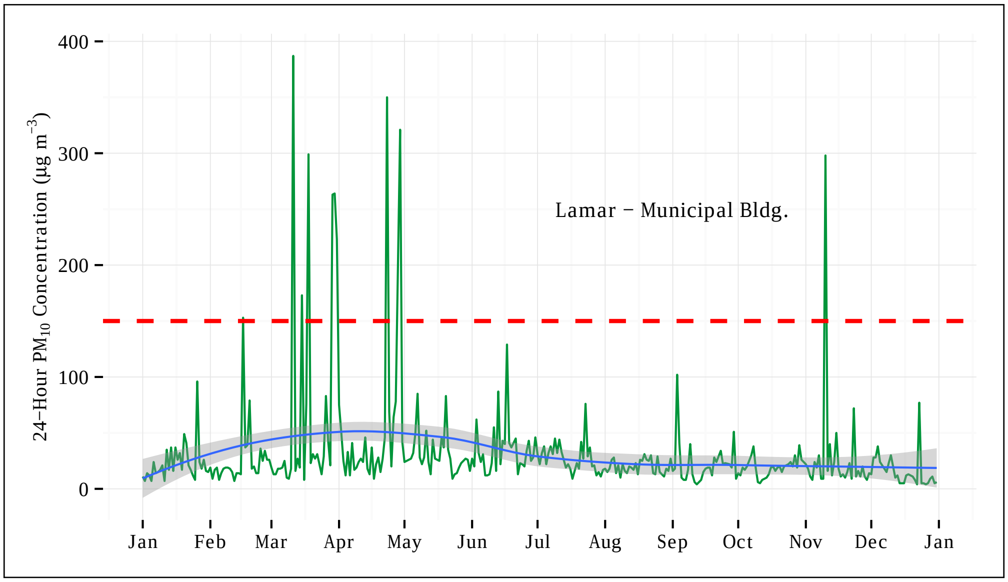


Figure 5.60: 24-hour average PM_{10} concentrations at the Lamar - Municipal Bldg. station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

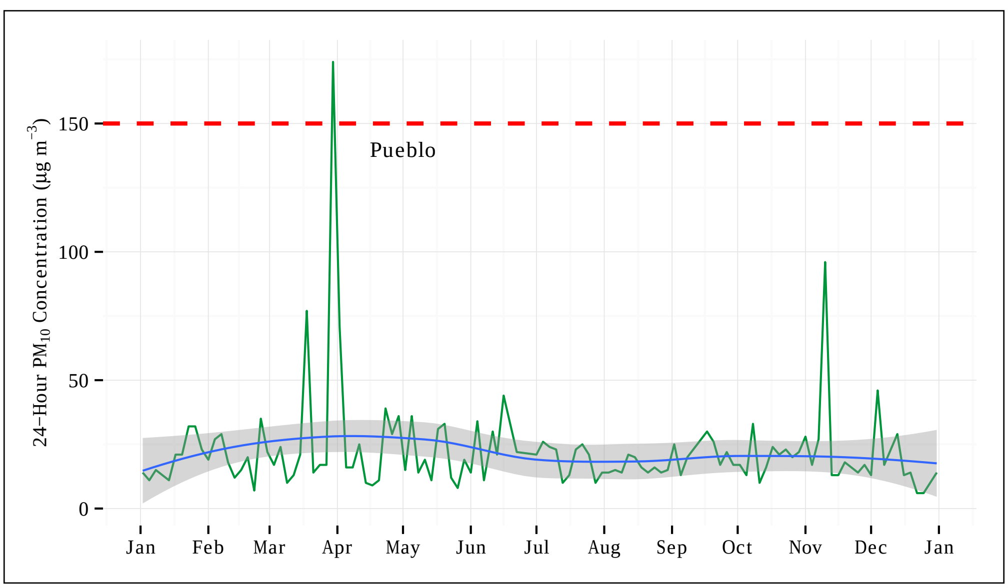


Figure 5.61: 24-hour average PM_{10} concentrations at the Pueblo station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

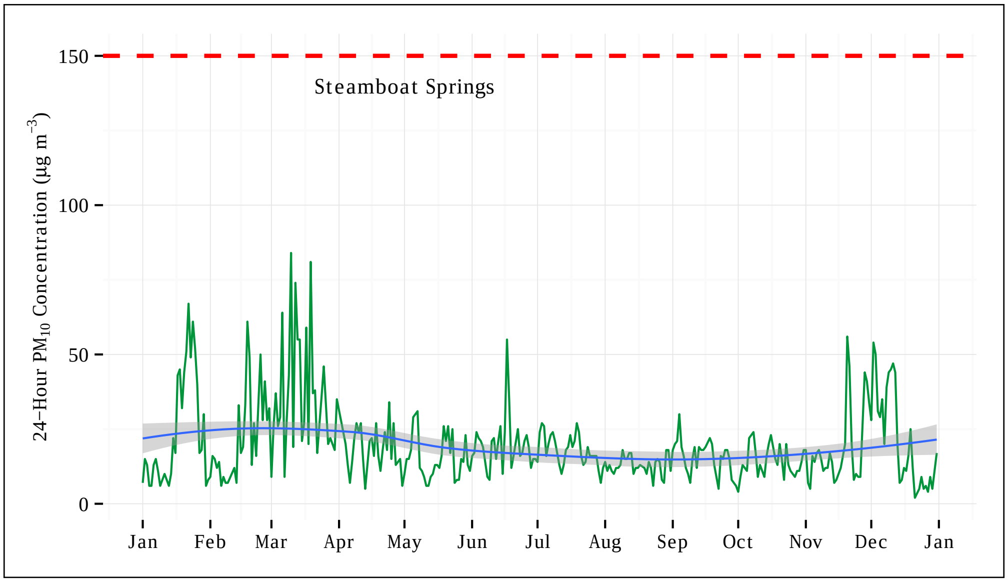


Figure 5.62: 24-hour average PM_{10} concentrations at the Steamboat Springs station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

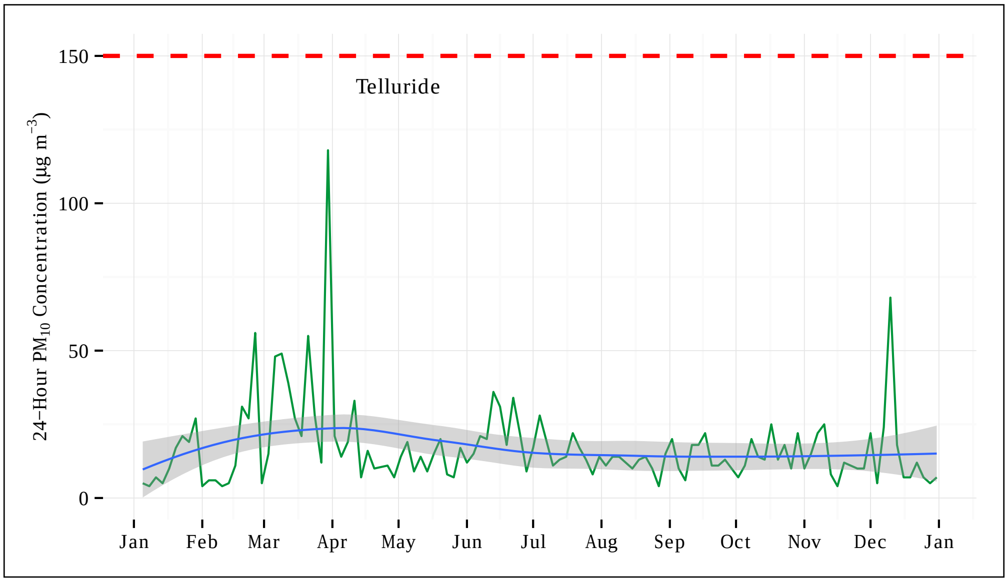


Figure 5.63: 24-hour average PM_{10} concentrations at the Telluride station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

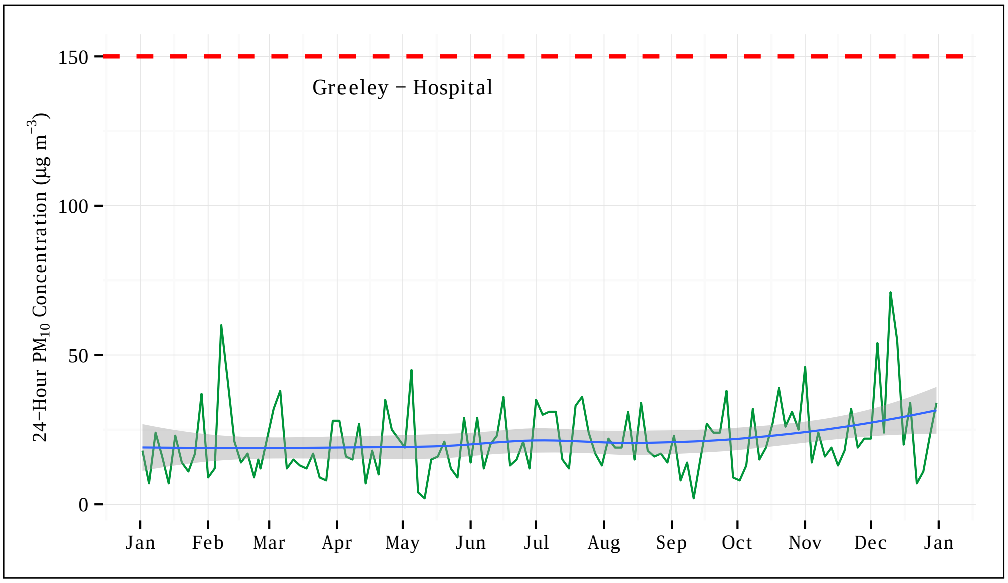


Figure 5.64: 24-hour average PM_{10} concentrations at the Greeley - Hospital station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (150 µg m^{-3}) is shown as a dashed red line.

5.6 PM$_{2.5}$

PM$_{2.5}$ concentrations are generally stable throughout much of the year, and relatively similar values are measured at sites throughout the state. Concentrations are typically highest during the winter months, due to thermal inversions that lead to a reduction in the vertical exchange of low-level air, effectively trapping particulate and gaseous pollutants at the earth's surface. Platteville, Longmont, and Greeley experienced elevated concentrations in December and most other sites had their highest concentrations in January. The graphs here may include exceptional event data.

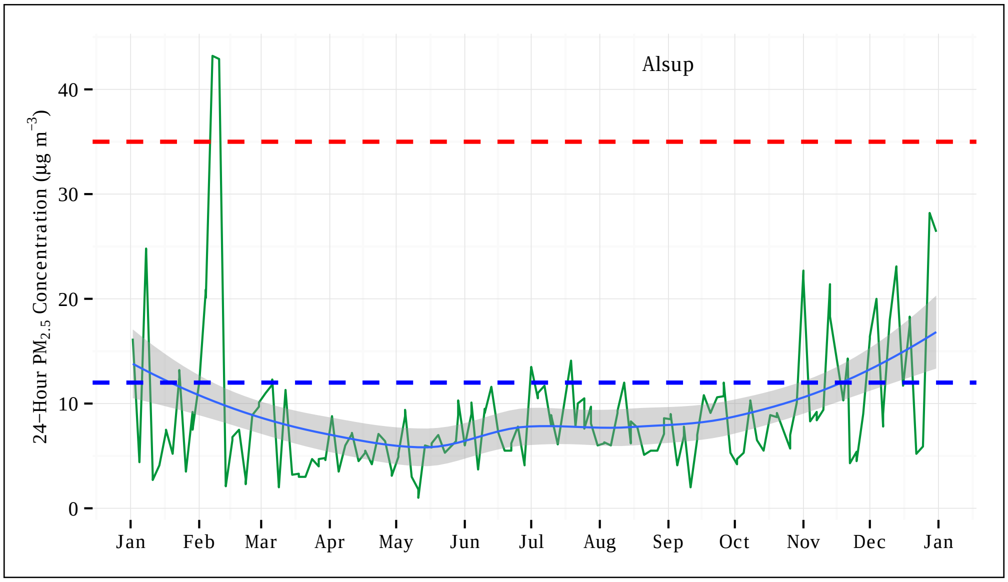


Figure 5.65: 24-hour average PM$_{2.5}$ concentrations at the Alsup station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (35 µg m^{-3}) is shown as a dashed red line. The annual mean standard (12 µg m^{-3}) is shown as a dashed blue line.

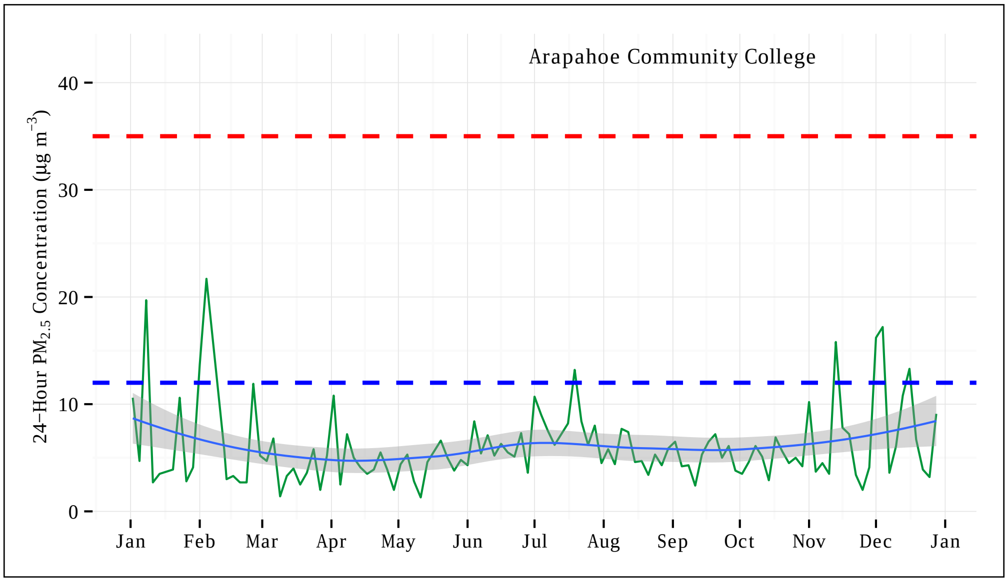


Figure 5.66: 24-hour average PM$_{2.5}$ concentrations at the Arapaho Community College station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (35 µg m^{-3}) is shown as a dashed red line. The annual mean standard (12 µg m^{-3}) is shown as a dashed blue line.

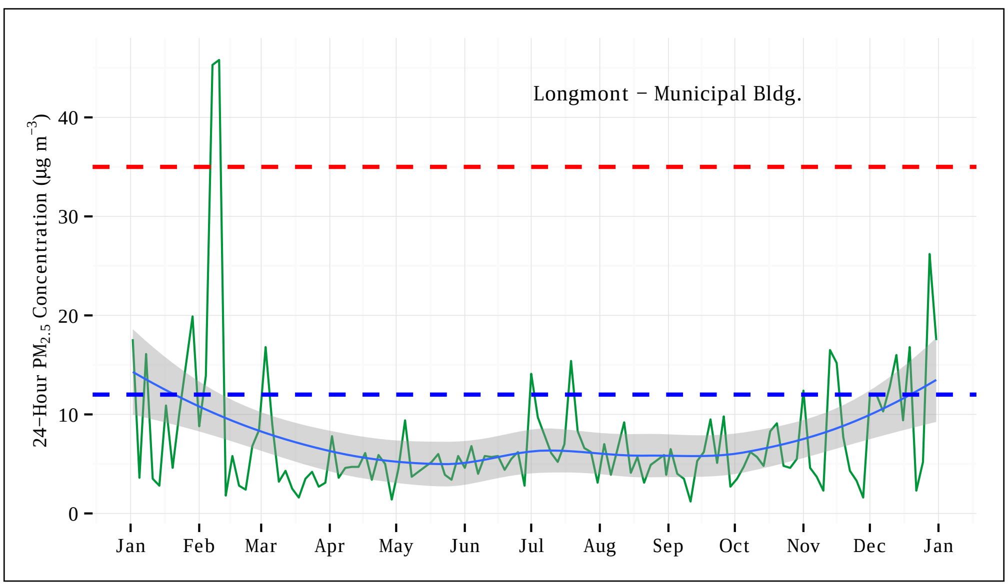


Figure 5.67: 24-hour average PM$_{2.5}$ concentrations at the Longmont - Municipal Bldg. station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (35 µg m^{-3}) is shown as a dashed red line. The annual mean standard (12 µg m^{-3}) is shown as a dashed blue line.

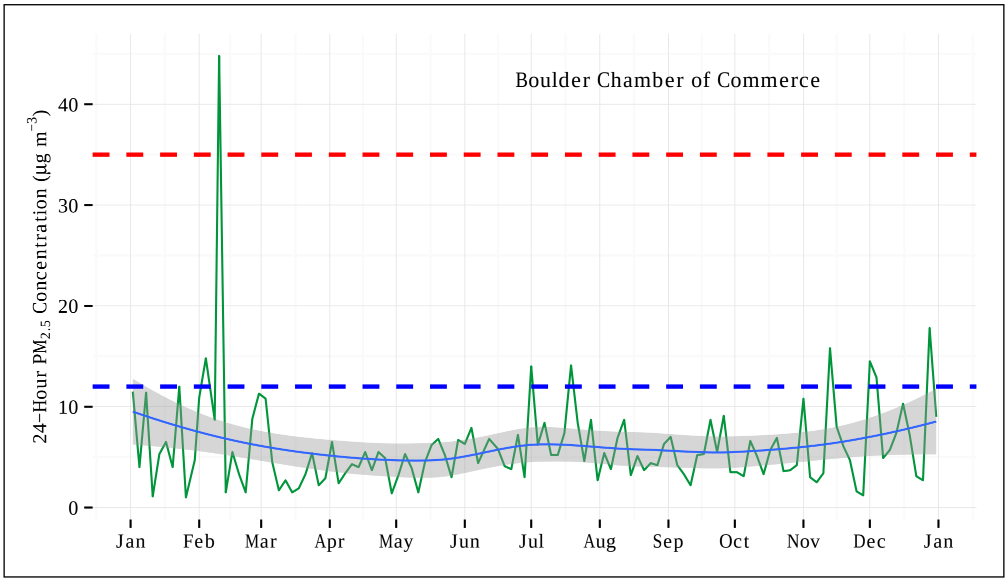


Figure 5.68: 24-hour average $PM_{2.5}$ concentrations at the Boulder Chamber of Commerce station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (35 µg m^{-3}) is shown as a dashed red line. The annual mean standard (12 µg m^{-3}) is shown as a dashed blue line.

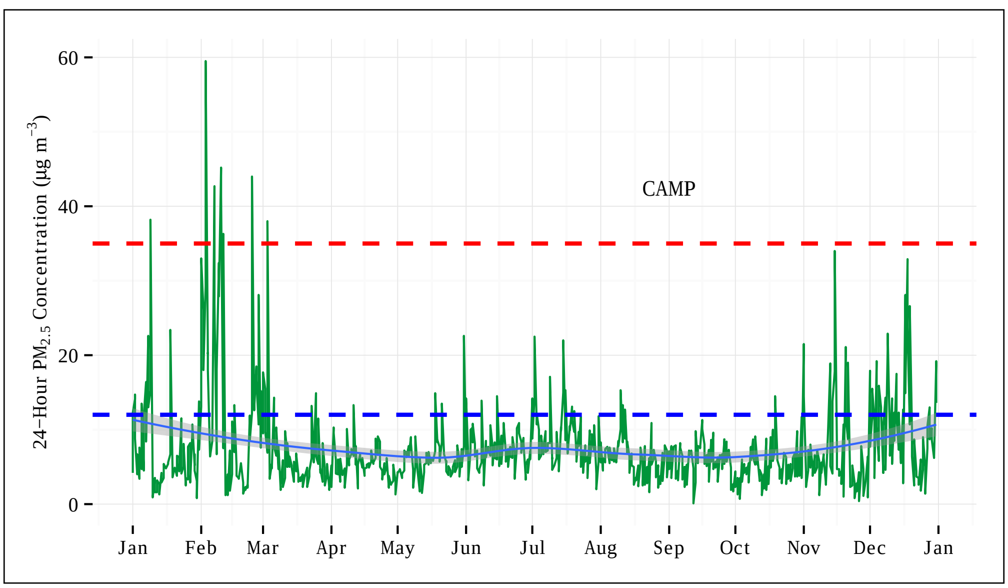


Figure 5.69: 24-hour average $PM_{2.5}$ concentrations at the CAMP station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (35 µg m^{-3}) is shown as a dashed red line. The annual mean standard (12 µg m^{-3}) is shown as a dashed blue line.

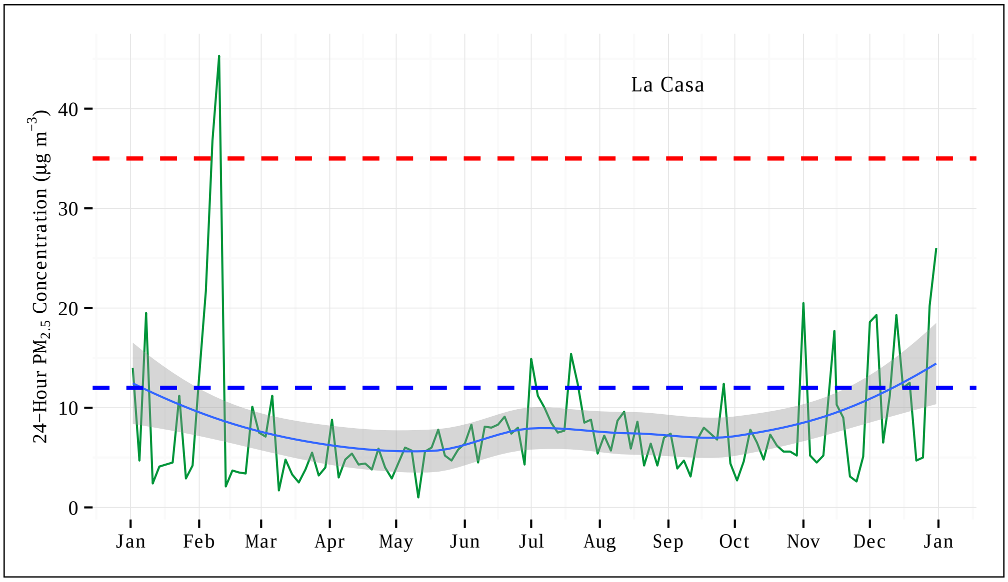


Figure 5.70: 24-hour average $PM_{2.5}$ concentrations at the La Casa station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (35 µg m^{-3}) is shown as a dashed red line. The annual mean standard (12 µg m^{-3}) is shown as a dashed blue line.

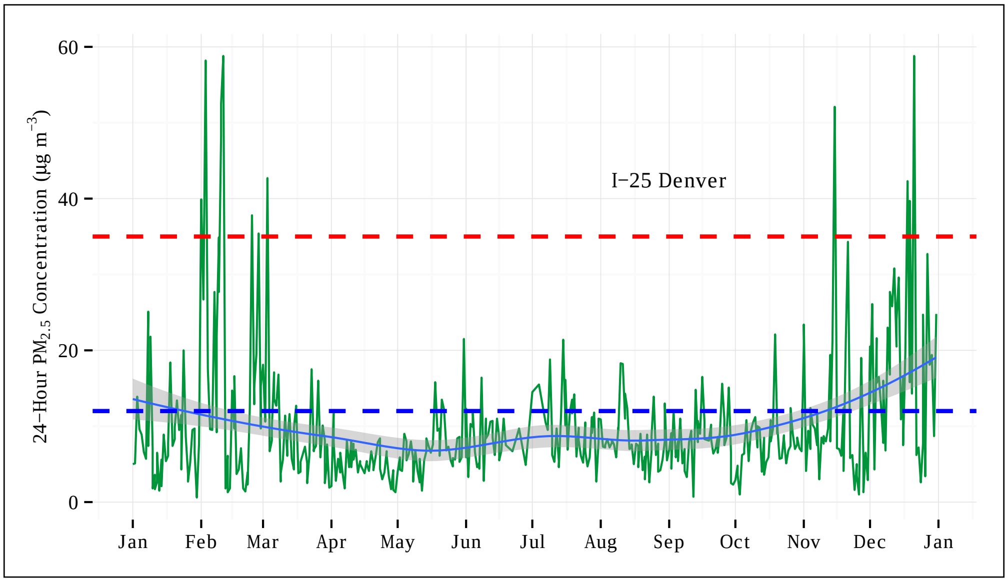


Figure 5.71: 24-hour average $PM_{2.5}$ concentrations at the I-25 Denver station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (35 µg m^{-3}) is shown as a dashed red line. The annual mean standard (12 µg m^{-3}) is shown as a dashed blue line.

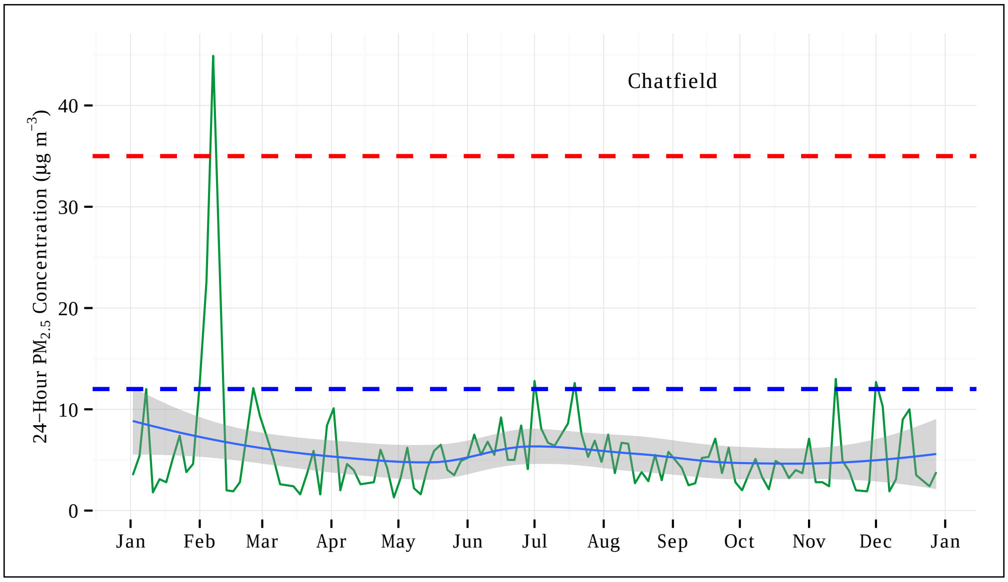


Figure 5.72: 24-hour average $PM_{2.5}$ concentrations at the Chatfield State Park station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (35 µg m^{-3}) is shown as a dashed red line. The annual mean standard (12 µg m^{-3}) is shown as a dashed blue line.

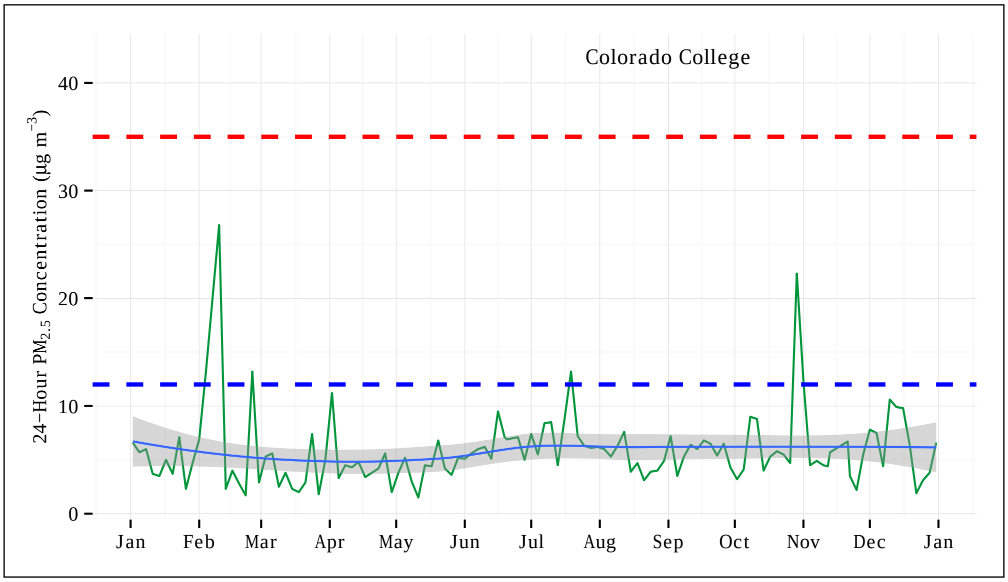


Figure 5.73: 24-hour average $PM_{2.5}$ concentrations at the Colorado College station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (35 µg m^{-3}) is shown as a dashed red line. The annual mean standard (12 µg m^{-3}) is shown as a dashed blue line.

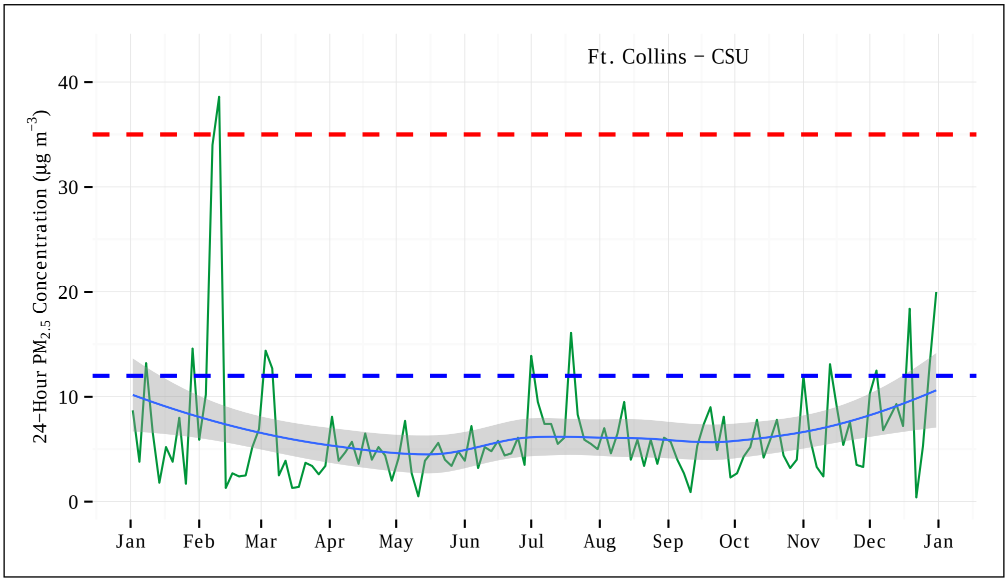


Figure 5.74: 24-hour average PM$_{2.5}$ concentrations at the Ft. Collins - CSU station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (35 µg m^{-3}) is shown as a dashed red line. The annual mean standard (12 µg m^{-3}) is shown as a dashed blue line.

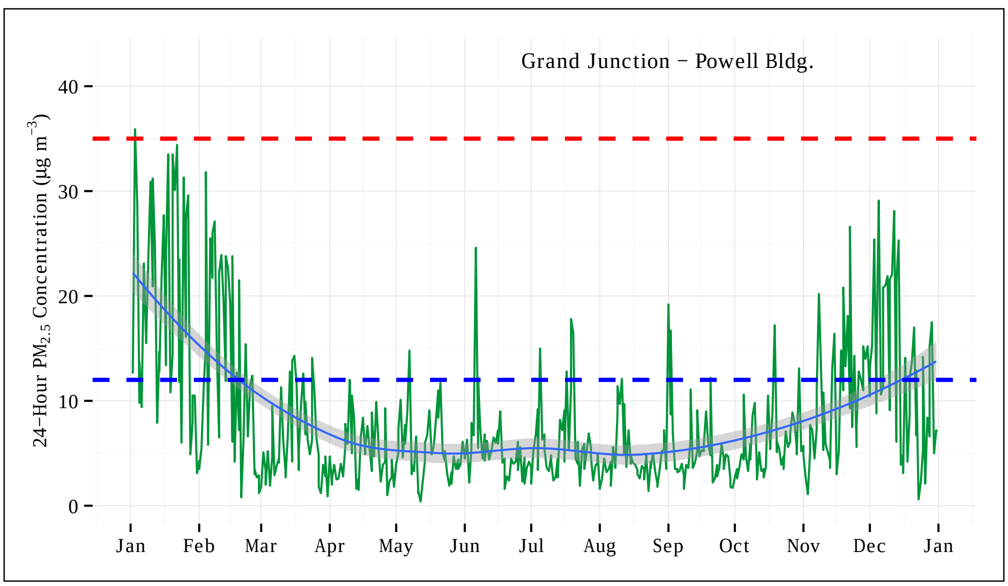


Figure 5.75: 24-hour average PM$_{2.5}$ concentrations at the Grand Junction - Powell Bldg. station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (35 µg m^{-3}) is shown as a dashed red line. The annual mean standard (12 µg m^{-3}) is shown as a dashed blue line.

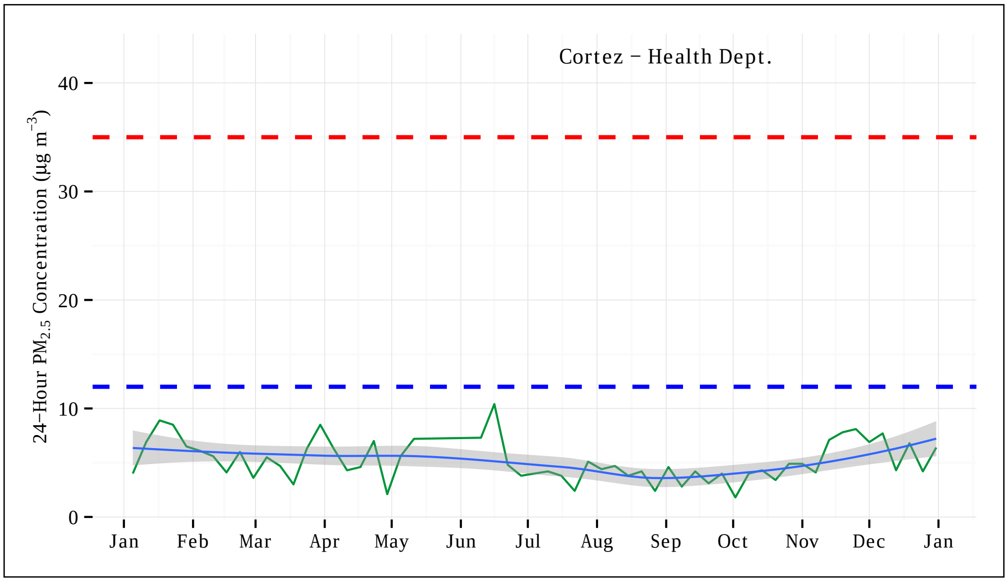


Figure 5.76: 24-hour average $PM_{2.5}$ concentrations at the Cortez - Health Dept. station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (35 μg m^{-3}) is shown as a dashed red line. The annual mean standard (12 μg m^{-3}) is shown as a dashed blue line.

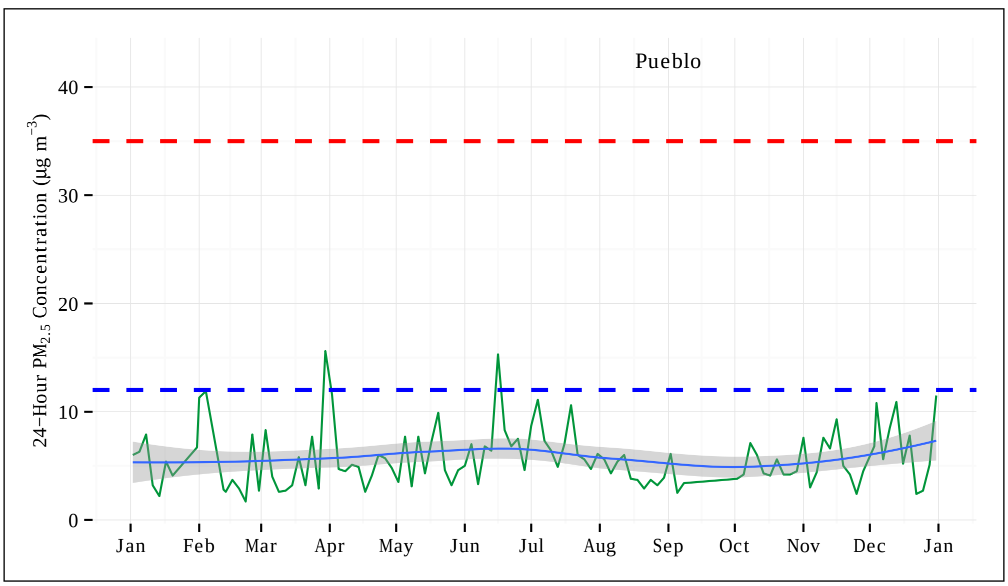


Figure 5.77: 24-hour average $PM_{2.5}$ concentrations at the Pueblo station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (35 μg m^{-3}) is shown as a dashed red line. The annual mean standard (12 μg m^{-3}) is shown as a dashed blue line.

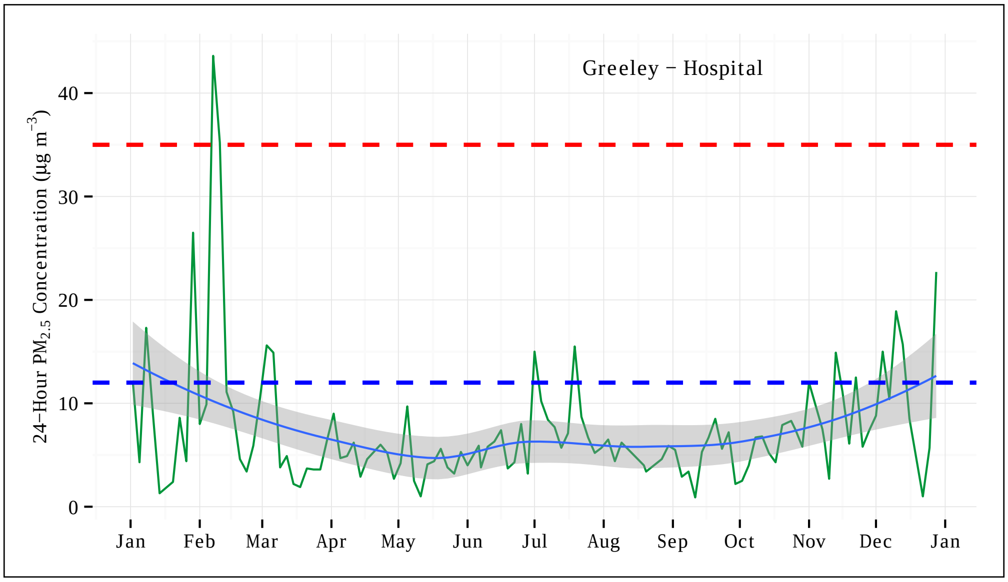


Figure 5.78: 24-hour average $PM_{2.5}$ concentrations at the Greeley - Hospital station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (35 µg m^{-3}) is shown as a dashed red line. The annual mean standard (12 µg m^{-3}) is shown as a dashed blue line.

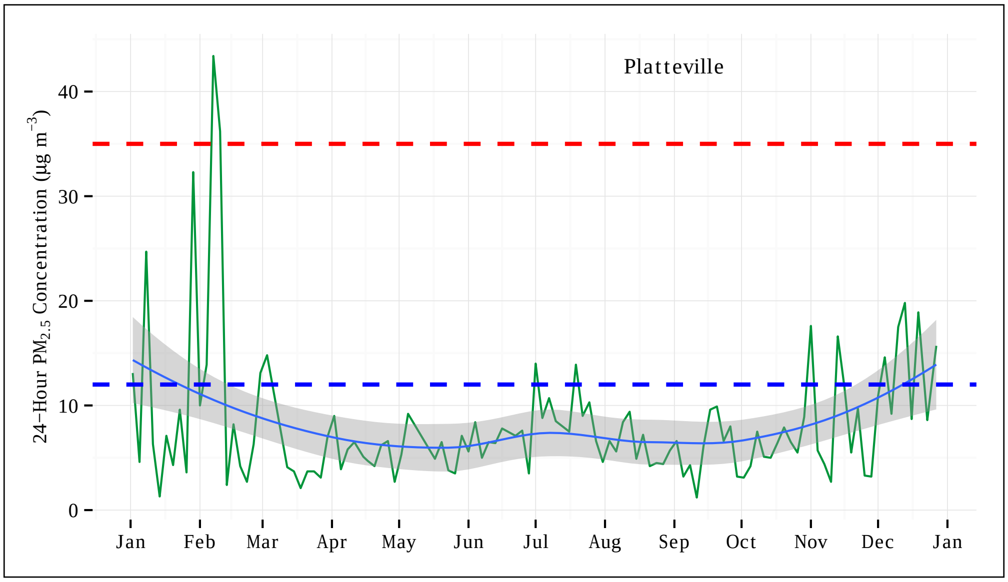


Figure 5.79: 24-hour average $PM_{2.5}$ concentrations at the Platteville station. The mean trend obtained using a generalized additive model is shown as a blue line. The 24-hour standard (35 µg m^{-3}) is shown as a dashed red line. The annual mean standard (12 µg m^{-3}) is shown as a dashed blue line.

6

Data Quality Assurance / Quality Control

This section describes the APCD Technical Services Program's success in meeting its data quality objectives for ambient air pollution monitoring data of criteria pollutants. This section has been prepared in accordance with 40 CFR Part 58 requirements. The statistical methodology used in this assessment is described in detail in the document "*Guideline on the Meaning and Use of Precision and Accuracy Data Required by 40 CFR Part 58 Appendix A*."

Other quality objectives were assessed via laboratory and site system audits. The results of these audits indicate compliance with APCD's standard operating procedures and EPA acceptance criteria. Copies of APCD laboratory audits may be obtained from the Quality Assurance Unit of the APCD.

Other audits were performed and can be made available for review, including National Air Toxics Trends Station (NATTS) audits, Speciation Trend Network (STN) audits, and audits conducted within Colorado by other organizations. These results are not included in this report because other agencies perform the data assessments for these audits. CDPHE meteorological network audits are not included in this report, as meteorological data is not considered a priority pollutant and so a statistical assessment of this data is not provided.

6.1 Data Quality

In order to provide decision makers with data of adequate quality, the CDPHE uses the Data Quality Objectives (DQO) process to develop performance and acceptance criteria (or data quality objectives) that specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions. Quality objectives for measurement data are designed to ensure that the data end user's DQOs are met. Measurement quality objectives include quantitative objectives, such as representativeness, completeness, accuracy, precision, and detection level, as well as qualitative objectives, such as site placement, operator training, and sample handling techniques. There are some data quality indicators underlying the DQOs that relate directly to the measurement system being used to collect ambient air measurements. These data quality indicators include precision, bias, completeness, and sampling frequency. These variables need to be maintained within certain acceptable ranges so that end data users can make decisions with specified levels of confidence.

6.2 Quality Assurance Procedures

Quality assurance is a general term for the procedures used to ensure that a particular measurement meets the quality requirements for its intended use. In addition to performing tests to determine bias and precision, additional quality indicators (such as sensitivity, representativeness, completeness, timeliness, documentation quality, and sample custody control) are also evaluated. Quality assurance procedures fall under two categories:

- Quality Control (QC): procedures built into the daily sampling and analysis methodologies to ensure data quality, and
- Quality Assessment (QA): periodic independent evaluations of data quality.

Some ambient air monitoring is performed by automated equipment located at field sites, while other measurements are made by taking samples from the field to the laboratory for analysis. For this reason, we will divide quality assurance procedures into two parts: field and laboratory quality assurance.

6.2.1 Field Quality Assurance

Quality assurance is a general term for the procedures used to ensure that a particular measurement meets the quality requirements for its intended use. Quality control of continuous analyzers consists of precision checks or flow verifications. The overall precision of filter-based sampling methods is measured using collocated samplers. Quality assurance is evaluated by periodic performance and system audits.

Automated analyzers (except O_3) are calibrated by challenging the instrument's response to a known concentration of EPA protocol gas delivered through a dilution system. The analyzer is then adjusted to produce the correct response. O_3 analyzers are calibrated by challenging the analyzer's response with O_3 produced by an independently certified NIST-traceable ozone generator. The site's analyzer is then adjusted to produce the same measured concentration as the traceable analyzer. Manual samplers are calibrated by comparing their volumetric flow rate at one or more levels to the flow measured by a flow transfer standard. Calibrations are performed when an instrument is first installed and at assigned intervals thereafter depending on the analyzer type. Calibrations are also performed after instrument repairs or when quality control charts indicate a drift in response to quality control checks.

Precision is a measure of the variability of an instrument or the variability of the testing source. The precision of continuous gaseous analyzers are evaluated by comparing a sample of a known concentration against the instrument's response. The precision of filter-based particulate samplers is determined by collocated sampling (i.e., the simultaneous operation of two identical samplers placed side by side). The difference in the results of the two samplers is used to estimate the precision of the entire measurement process (i.e., both field and laboratory precision). Precision of manual particulate samplers is assessed by regular periodic flow checks. Precision of continuous particulate samplers is assessed through the comparison of the ambient data to the FRM data and by regular periodic flow checks. produced by an independently certified NIST-traceable ozone generator. The site's analyzer is then adjusted to produce the same measured concentration as the traceable analyzer. Manual samplers are calibrated by comparing their volumetric flow rate at one or more levels to the flow measured by a flow transfer standard. Calibrations are performed when an instrument is first installed and at assigned intervals thereafter depending on the analyzer type. Calibrations are also performed after instrument repairs or when quality control charts indicate a drift in response to quality control checks.

The bias of automated methods is assessed through field performance evaluations (also called accuracy audits) and through site precision checks. Performance audits are conducted by challenging the instrument with a gas of known NIST-traceable concentration. Bias is evaluated by comparing the measured response to the known value. Typically, performance evaluations are performed biannually using samples of several different concentrations.

System audits indicate how well a sampling site and site operator conforms to the standard operating procedures as well as how well the site is located with respect to its mission (e.g., urban or rural sampling, SLAMS or special purpose sampling site, etc.). Some areas reviewed include: site location (possible obstruction, presence of nearby pollutant sources), site security, site characteristics (urban versus suburban or rural), site maintenance, physical facilities (maintenance, type and operational quality of equipment, buildings, etc.), record-keeping, sample handling, storage, and transport.

6.2.2 Laboratory Technical Systems Audit

Laboratory quality control includes calibration of analytical instrumentation, analysis of blank samples to check for contamination, analysis of spikes to evaluate interferences and target analyte matrix recovery, and analysis of duplicate samples to evaluate precision. Quality assurance is accomplished through laboratory performance and system audits.

Laboratory analytical instruments are calibrated by comparing the instrument's response with standards of a known concentration level. The differences between the measured and known concentrations are then used to adjust the instrument to produce the correct response.

A blank sample is one that has intentionally not been exposed to the pollutant of interest. Analysis of blank samples reveals possible contamination in the laboratory, during field handling, or during transportation.

Duplicate analyses of the same sample are performed to monitor the precision of the analytical method.

A regular sample is spiked with a known concentration to determine if the sample matrix is interfering with detection capabilities of the instrumentation. Regular performance audits are conducted by having the laboratory analyze samples whose physical or chemical properties have been certified by an external laboratory or standards organization. The difference between the laboratory's reported value and the certified value is used to evaluate the analytical method's accuracy.

System audits indicate how well the laboratory conforms to its standard operating procedures. System audits involve sending a QA Auditor to the laboratory to review compliance with standard operating conditions. Areas examined include: record keeping, sample custody, equipment maintenance, personnel training and qualifications, and a general review of facilities and equipment.

The CDPHE Laboratory Services Division (LSD) performs the gravimetric analysis for the filter-based particulate samples. APCD conducted a full Laboratory Technical Systems Audit of the High-Volume (High-Vol) and Low-Volume (Low-Vol) particulate matter gravimetric laboratories, and the chemistry metals laboratories during the period of December 2nd - December 4th 2014. Results of these audits are available upon request from the APCD Quality Assurance Unit.

6.3 Gaseous Criteria Pollutants

6.3.1 Quality Objectives for Measurement Data

Data Quality Objectives for the APCD's ambient air monitoring program for gaseous criteria pollutants are shown in Table 6.1.

Table 6.1: Data quality objectives for gaseous criteria pollutants.

Data Quality Indicator	APCD Goal	EPA Requirement
Precision for O_3	7%	7%
Precision for CO, SO_2, NO_2	10%	10%
Precision Completeness	90%	75%
Bias for O_3	7%	7%
Bias for CO, SO_2, NO_2	10%	10%
Accuracy for O_3	10%	10%
Accuracy Audits Completeness	2 audits per analyzer per year	25% of analyzers quarterly
90% Probability Intervals	Meet EPA requirement	95% of audit values
NPAP TTP Audits for O_3	Meet EPA requirement	10%
NPAP TTP Audits for for CO, SO_2, NO_2	Meet EPA requirement	15%
Overall Data Completeness	90%	75%

6.3.2 Gaseous Data Quality Assessment

6.3.2.1 Summary

Assessment of the data for APCD gaseous criteria pollutants showed that all gaseous analyzers met the minimum EPA criteria and most monitoring sites met APCD goals for precision, bias, accuracy, national performance evaluations, and completeness.

6.3.2.2 Coefficient of Variation (CV)

At least once every two weeks, precision is determined by sampling a gas of known concentration for every gaseous analyzer. The tables below summarize the number of precision checks that were performed (precision count) by site (Table 6.2) as well as the percent completeness of those precision checks and an annual summary by organization (Table 6.3) of the percent of precision checks that fell within the acceptance criteria of ±10% (±7% for O_3). Table 6.2 also summarizes the statistical data quality assessment of these precision checks for all gaseous criteria pollutants. The coefficient of variation (CV) for the precision checks is summarized annually by site (Table 6.2) and quarterly/annually by organization (Table 6.3). The equations used to calculate precision, bias, and upper and lower probability limits for the 90% probability intervals using the bi-weekly precision checks are described in detail in the document "*Guideline on the Meaning and Use of Precision and Accuracy Data Required by 40 CFR Part 58 Appendix A*."

6.3.2.3 Bias

For gaseous pollutants the bias is also calculated using the bi-weekly precision checks. Bias is summarized in Table 6.2 by the same groupings as CV. Additionally a plus or minus bias is assigned to the annual site and organization grouping levels based on an evaluation of where the 25th and 75th percentiles of percent differences for the precision data fell. If both percentiles fell below zero then the bias was assigned a minus sign, and if both percentiles fell above zero, then the bias was assigned a plus sign. If one bias was positive and one bias was negative (i.e. straddling zero), no sign was associated with the bias. Organizationally, CO showed a non-signed bias of 1.57% in 2014. SO_2 showed a non-signed bias of 3.13%. O_3 showed a non-signed bias of 1.82% for 2014. There was no sign associated with the calculated bias (3.44%) for the NO_2 precision checks for the organization as a whole in 2014.

6.3.2.4 Performance Evaluation (Accuracy Audits)

Audits were performed at least twice on every gaseous analyzer within the APCD network during the 2014 calendar year. The primary goal of these audits is to evaluate the analyzer performance and calibration. Other factors are also noted during these audits such as operator performance, station operational criteria, record keeping, site upkeep issues, and general safety problems.

All Performance Evaluations (accuracy audits) performed for all gaseous analyzers during 2014 passed the EPA criteria of 15%.

6.3.2.5 Probability Intervals (Upper and Lower Probability Limits)

Probability intervals (upper and lower probability limits) are calculated per 40 CFR 58 Appendix A section 4, by using the percent differences retrieved from station precision checks. The EPA has established that 95% of the independent audit points taken for a given year should fall within this calculated probability interval to validate the bias calculated from the precision checks. The percent differences between the audit concentrations and the indicated concentrations taken in 2014 for CO were compared to the probability intervals. Out of the 48 audit concentration points taken for CO in 2014, 81% fell between the probability intervals for the organization. There were 90 audit concentration points taken during 2014 for the APCD's O_3 network. Of those 90 ozone audit points, 11 fell outside the probability intervals. This means that 88% of the audit points for O_3 fell between the probability intervals in 2014. Out of the 24 audit points

Table 6.2: Summary of precision, accuracy, bias, and completeness for site-level gaseous monitoring data.

Site	Analyte	Precision Count	Precision Complete (%)	CV (%)	Bias (%)	Prob. Limits Lower	Prob. Limits Upper	Data Complete (%)
Welby	CO	25	96	2.27	±1.60	−3.70	3.50	98
CAMP	CO	26	100	2.23	±1.74	−2.88	4.22	99
La Casa	CO	27	100	3.43	5.12	−1.41	9.56	99
I-25	CO	26	100	0.33	±0.24	−0.42	0.63	99
Hwy. 24	CO	26	100	–	–	–	–	99
Ft. Collins - Mason	CO	26	100	2.04	±1.34	−3.15	3.34	99
GJ - Pitkin	CO	26	100	1.90	±1.58	−2.25	3.80	94
Greeley	CO	26	100	2.42	±1.83	−3.45	4.23	99
Welby	SO_2	26	100	3.29	±4.01	−8.36	2.13	97
CAMP	SO_2	26	100	3.99	±3.85	−3.85	8.85	98
La Casa	SO_2	27	100	3.77	±2.94	−5.05	7.01	92
Hwy. 24	SO_2	25	96	3.39	−3.33	−7.11	3.63	91
Welby	NO_2	26	100	2.42	3.68	−0.92	6.79	94
CAMP	NO_2	26	100	2.48	±1.93	−3.75	4.13	94
La Casa	NO_2	11	42	3.80	±2.98	−5.79	4.61	87
I-25	NO_2	26	100	3.84	5.53	−1.87	10.36	92
Welby	O_3	25	96	2.61	−2.50	−5.46	2.81	98
Aurora - East	O_3	26	100	1.77	±1.85	−4.10	1.54	99
South Boulder Creek	O_3	26	100	2.60	±2.13	−4.67	3.62	99
CAMP	O_3	26	100	2.67	±2.12	−4.24	4.25	99
La Casa	O_3	27	100	2.45	±2.41	−5.34	2.50	99
Chatfield	O_3	26	100	2.40	±2.19	−5.17	2.47	99
USAFA	O_3	26	100	2.79	±2.10	−4.69	4.18	99
Manitou Springs	O_3	26	100	2.66	±2.22	−4.75	3.71	99
Rifle - Health Dept.	O_3	29	100	1.94	−3.12	−5.68	0.53	96
Welch	O_3	26	100	3.17	±2.75	−3.82	6.26	98
Rocky Flats	O_3	26	100	2.20	±1.91	−2.66	4.34	99
NREL	O_3	26	100	2.48	±1.71	−4.07	3.81	99
Aspen Park	O_3	26	100	3.16	±3.16	−6.64	3.43	99
Ft. Collins - West	O_3	26	100	1.70	±1.84	−1.40	4.00	98
Ft. Collins - Mason	O_3	26	100	1.80	±1.24	−2.94	2.80	99
Palisade	O_3	30	100	3.28	3.71	−2.72	7.87	100
Cortez	O_3	33	100	2.89	±2.67	−3.54	5.89	98
Weld Co. Tower	O_3	27	100	3.62	±2.86	−6.04	5.55	98

taken in 2014 for NO_2, 88% fell between the probability limits. Out of the 21 audit points taken for SO_2 in 2014, 95% fell between the probability intervals. Therefore, three out of the four gaseous criteria pollutants do not meet the requirement that specifies that ninety-five percent of the individual percent differences (all audit concentration levels) for the performance evaluations should be captured within the probability intervals for the primary quality assurance organization (40CFR 58 Appendix A section 4.1.5).

APCD believes the reason it did not meet the above requirement in 2014 is due to the fact that the probability intervals are calculated based on precision checks that are closer to the middle of the calibration scale, which give small percent differences and tight probability intervals. A newer requirement in the CFR is forcing APCD to audit in the lower portion of the site instrumentation's calibration scale, due to the fact that this is where 80% of the ambient data is being captured. By auditing in the low end of the calibration scale, APCD is seeing higher percent differences between the audit concentration and the instrument response. APCD believes this is due in part to the low audit concentration differences producing large percent differences and partly because the instruments are calibrated on a higher scale than where the audits are being conducted. The instruments are being calibrated at a higher scale than where 80% of the ambient data falls due to the relatively small number of episodes that do produce high ambient concentrations which have an effect on public health. Recently, APCD has begun to lower the calibration range on most pollutants and lower the precision values at most of its sites. This will hopefully help to rectify this problem but still allow APCD to capture the higher concentration pollution episodes within the instrument's calibration range.

Table 6.3: Summary of precision, accuracy, bias, and completeness for PQAO-level gaseous monitoring data.

Analyte	Quarter / Year	Precision Count	CV (%)	Bias (%)	Prob. Limits Lower	Prob. Limits Upper	% Audit Points within Prob. Limits
CO	Q1	56	2.87	±2.03	–4.29	5.57	
CO	Q2	55	2.35	±2.15	–2.52	5.52	
CO	Q3	49	2.46	±1.59	–4.10	4.23	
CO	Q4	48	1.90	±1.24	–2.68	3.76	
CO	2014	208	2.32	±1.57	–3.54	4.96	81
SO_2	Q1	26	4.58	±3.58	–8.39	6.17	
SO_2	Q2	29	3.64	±2.76	–6.06	5.66	
SO_2	Q3	24	5.49	±4.33	–8.48	8.83	
SO_2	Q4	25	4.42	±3.60	–7.10	6.90	
SO_2	2014	104	4.02	±3.13	–7.47	6.84	95
NO_2	Q1	26	2.17	±3.40	–0.65	6.27	
NO_2	Q2	27	4.00	±3.39	–5.70	7.07	
NO_2	Q3	18	3.98	±3.62	–4.40	7.63	
NO_2	Q4	18	4.43	±5.20	–3.11	10.27	
NO_2	2014	89	3.39	±3.44	–3.91	8.07	88
O_3	Q1	104	2.48	±2.11	–5.23	3.62	
O_3	Q2	105	2.37	±1.81	–4.12	4.33	
O_3	Q3	90	2.72	±2.17	–5.54	4.06	
O_3	Q4	92	2.28	±1.72	–4.05	4.02	
O_3	2014	391	2.37	±1.82	–4.79	4.07	88

6.3.2.6 Completeness

Data completeness for the year is shown by site in Table 6.2. Precision completeness is shown as the number of precision checks that were performed and submitted to AQS for the year. Precision completeness is evaluated against the number of checks that should have been performed at each site during the year. Completeness for accuracy audits in 2014 met or exceeded APCD DQO goals for every gaseous analyzer, with a minimum of two audits performed on every analyzer.

Table 6.2 and Table 6.3 summarize the statistical evaluations for all gaseous precision, accuracy, bias, and completeness data by site-level and PQAO-level, respectively. The basis for these calculations can be found in 40 CFR 58 Appendix A section 4.1.

6.4 Particulate Data Quality Assessment

6.4.1 Summary

Assessment of the data quality for APCD particulate criteria pollutants showed that most samplers met minimum EPA criteria and most monitoring sites met APCD goals for accuracy, precision, completeness, and bias.

6.4.2 Precision

The CV for filter-based particulate monitoring is determined from the collocated precision data collected (i.e., two identical samplers operated in an identical manner). Due to the anticipated poor precision for very low levels of pollutants, only collocated measurements at or above a minimum level (greater than or equal 15 $\mu g\ m^{-3}$ for PM_{10}, 20 $\mu g\ m^{-3}$ for Total Suspended Particulate or TSP, and 3 $\mu g\ m^{-3}$ for $PM_{2.5}$) would be called valid pairs and are used to evaluate precision. The calculations for the statistical presentations in Table 6.6 are found in 40 CFR 58 Appendix A section 4.2.

The CV for continuous based particulate monitoring is determined by monthly flow verifications (precision checks) performed on the continuous particulate monitors. The calculations for the statistical presentations in Table 6.6 are the same calculations that were performed on the precision data for gaseous analyzers.

6.4.3 Bias

Results of the annual flow rate audits conducted by APCD personnel are shown in Table 6.6 below. There is no requirement for bias on the High-Vol filter-based particulate monitoring, since the precision is based on collocated sampling. For the filter-based particulate monitoring, Table 6.6 summarizes bias based on the audits that were performed during the year, since APCD performs particulate audits four times more frequently than the EPA requires. These additional audits are conducted to compensate for the lack of a flow verification precision check program in place for the High-Vol samplers. The bias calculations were also conducted using the Low-Vol audit results since the flow verifications performed on the Low-Vol samplers are not reported to the EPA AQS database. The bias for the continuous particulate monitoring was calculated on the monthly flow verification precision checks with the same calculations that were used to determine the gaseous bias.

6.4.4 Performance Evaluation (Accuracy Audits)

Audits were performed at least quarterly on every particulate sampler within the APCD network during the 2014 calendar year. The primary goal of these audits is to evaluate the analyzer performance and calibration. Other factors are also noted during these audits such as operator performance, station operational criteria, record keeping, site upkeep issues, and general safety problems.

6.4.5 Completeness

Data completeness for the year is shown by site in Table 6.6. Precision completeness is based on the number of monthly flow verifications that were performed. Precision completeness is evaluated against the number of checks that should have been performed at each site during the year. Completeness for accuracy audits met or exceeded all APCD DQO goals for every particulate analyzer, with a minimum of two audits performed on every analyzer per year.

6.4.6 PEP / NPAP Particulate Audits

Performance Audit Program (NPAP) audits conducted during 2014 are summarized in Table 6.4.

Table 6.4: $PM_{2.5}$ PEP results.

Audit Date	Site	PEP Result (mug)	Site Result (mug)	Percent Difference
2014/03/06	Longmont - Muni.	10.5	9	14.3%
2014/04/29	La Casa	2.7	2.9	7.1%
2014/04/29	Ft. Collins - CSU	2.2	2.0	9.5%
2014/07/10	Longmont - Muni.	6.0	6.1	1.7%
2014/07/28	La Casa	8.2	8.8	7.1%
2014/11/04	Boulder - COC	3.2	3	6.5%
2014/12/16	Boulder - COC	11.5	10.3	11.0%

6.4.7 Results

Table 6.6 below summarizes statistical evaluations for all filter-based particulate precision, accuracy, bias, and completeness data. The values were calculated as described in 40 CFR 58 Appendix A section 4.2. Values are summarized

Table 6.5: O_3 NPAP results.

Audit Date	**Site**	**NPAP Result (ppm)**	**Site Result (ppm)**	**Percent Difference**
2014/09/03	Weld Co. Tower	0.054	0.056	5.2%
2014/09/04	Ft. Collins - Mason	0.073	0.074	0.7%
2014/09/04	Ft. Collins - Mason	10.99	11.34	3.8%
2014/09/22	Aspen Park	0.054	0.055	3.1%
2014/09/26	Manitou Springs	0.073	0.074	1.6%
2014/09/26	USAFA	0.076	0.078	3.2%

at the PQAO-level in Table 6.7.

Table 6.6: Summary of precision, accuracy, bias, and completeness for site-level particulate monitoring data.

Site	Parameter	n	Bias (%)	Prob. Limits Lower	Prob. Limits Upper	Data Complete (%)
Alsup	PM_{10}	12	–0.82	–0.94	–0.71	92
Welby	PM_{10}	3	–3.64	–8.13	0.86	96
Alamosa - ASC	PM_{10}	16	–2.07	–3.02	–1.13	96
Alamosa - Muni.	PM_{10}	16	–3.72	–6.45	–1.00	98
Pagosa Springs	PM_{10}	16	–2.12	–3.08	–1.19	92
Longmont - Muni.	PM_{10}	4	–1.31	–2.24	–0.39	93
Boulder - COC	PM_{10}	5	–0.65	–1.60	0.29	100
Delta - Health Dept.	PM_{10}	8	–1.32	–2.65	0.02	97
CAMP (1)	PM_{10}	4	–0.21	–2.40	1.98	100
CAMP (2)	PM_{10}	4	–0.02	–1.66	1.63	100
Denver VC	PM_{10}	16	–2.51	–3.67	–1.36	98
La Casa (1)	PM_{10}	12	–0.30	–0.62	0.01	95
La Casa (2)	PM_{10}	12	0.53	0.40	0.66	100
Colorado College	PM_{10}	12	1.10	0.67	1.54	100
Cañon City	PM_{10}	4	–0.92	–2.54	0.70	98
Parachute	PM_{10}	8	0.30	–0.50	1.11	98
Rifle - Henry Bldg.	PM_{10}	8	–0.36	–3.22	2.50	99
Carbondale	PM_{10}	6	–3.59	–6.41	–0.77	100
Crested Butte (1)	PM_{10}	8	–1.89	–3.45	–0.33	97
Crested Butte (2)	PM_{10}	4	–1.68	–2.68	–0.68	100
Mt. Crested Butte	PM_{10}	16	–2.47	–3.84	–1.10	98
Durango	PM_{10}	8	–2.37	–4.40	–0.33	85
Ft. Collins - CSU	PM_{10}	8	–1.35	–3.34	0.65	100
GJ - Powell Bldg. (1)	PM_{10}	12	0.79	0.28	1.31	97
GJ - Powell Bldg. (2)	PM_{10}	12	1.09	0.69	1.50	100
Clifton	PM_{10}	8	–0.89	–3.68	1.89	97
Aspen	PM_{10}	6	–2.74	–4.82	–0.66	97
Lamar - Muni.	PM_{10}	16	–0.64	–1.59	0.31	98
Pueblo	PM_{10}	8	0.00	–0.84	0.84	95
Steamboat Springs	PM_{10}	16	–1.47	–2.79	–0.14	94
Telluride	PM_{10}	8	0.28	–1.20	1.76	97
Greeley	PM_{10}	8	0.22	–1.15	1.59	100
Alsup	$PM_{2.5}$	12	0.17	–0.07	0.40	96
Alsup (2)	$PM_{2.5}$	12	–1.26	–1.51	–1.01	100
ACC	$PM_{2.5}$	12	–0.66	–1.07	–0.25	98
Longmont - Muni.	$PM_{2.5}$	12	–1.18	–2.07	–0.29	98
Boulder - COC	$PM_{2.5}$	15	–0.37	–0.91	0.17	100
CAMP (1)	$PM_{2.5}$	12	–0.30	–0.57	–0.03	96
CAMP (2)	$PM_{2.5}$	12	0.41	0.24	0.57	100
CAMP (3)	$PM_{2.5}$	4	–0.87	–6.21	4.47	99
La Casa	$PM_{2.5}$	12	0.00	–0.36	0.36	99
I-25 (1)	$PM_{2.5}$	6	–0.91	–1.01	–0.82	99
I-25 (2)	$PM_{2.5}$	3	–0.62	–9.90	8.67	94
Chatfield	$PM_{2.5}$	12	1.22	0.75	1.70	95
Castlewood Canyon S.P.	$PM_{2.5}$	12	0.22	–0.25	0.68	98
Colorado College	$PM_{2.5}$	12	2.84	1.71	3.96	100
Ft. Collins - CSU	$PM_{2.5}$	12	–0.59	–1.61	0.43	100
GJ - Powell Bldg. (1)	$PM_{2.5}$	12	0.72	0.39	1.06	99
GJ - Powell Bldg. (2)	$PM_{2.5}$	4	–1.80	–4.42	0.81	99
Cortez	$PM_{2.5}$	4	0.71	–0.32	1.75	94
Pueblo	$PM_{2.5}$	12	0.19	–0.23	0.61	92
Greeley	$PM_{2.5}$	12	0.09	–0.44	0.61	95
Platteville	$PM_{2.5}$	12	0.53	0.24	0.82	99

Table 6.7: Summary of precision, accuracy, bias, and completeness for PQAO-level particulate monitoring data.

Parameter	Quarter / Year	Performance Evaluations (Accuracy)		
		Bias (%)	Prob. Limits	
			Lower	Upper
PM_{10}	Q1	–0.70	–1.11	–0.28
PM_{10}	Q2	0.24	–0.09	0.57
PM_{10}	Q3	–2.20	–2.90	–1.50
PM_{10}	Q4	–1.49	–1.98	–1.00
PM_{10}	2014	–1.03	–1.29	–0.77
$PM_{2.5}$	Q1	0.02	–0.39	0.43
$PM_{2.5}$	Q2	0.56	0.30	0.82
$PM_{2.5}$	Q3	–0.51	–0.89	–0.12
$PM_{2.5}$	Q4	0.06	–0.30	0.42
$PM_{2.5}$	2014	0.04	–0.14	0.22

Table 6.8: Collocated QC check statistics for site-level particulate monitoring data.

Site	Parameter	Total Valid Pairs	CV
CAMP	PM_{10}	60	16.19
La Casa	PM_{10}	57	6.97
Longmont	PM_{10}	18	24.70
GJ - Powell Bldg.	PM_{10}	56	6.80
Crested Butte	PM_{10}	59	7.95
Alsup	$PM_{2.5}$	55	8.56
CAMP	$PM_{2.5}$	58	9.89

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Appendix A: Monitoring Site Descriptions

APPENDIX A: MONITORING SITE DESCRIPTIONS

This appendix provides detailed information for all monitoring sites considered in this Network Assessment. Table A-1 summarizes the locations and monitoring parameters of each site currently in operation, by county, alphabetically. The shaded lines in the table list the site AQS identification numbers, address, site start-up date, elevation, and longitude and latitude coordinates. Beneath each site description the table lists each monitoring parameter in operation at that site, the orientation and spatial scale, which national monitoring network it belongs to, the type of monitor in use, and the sampling frequency. The parameter date is the date when valid data were first collected.

Table A-1. (Cont.) Monitoring locations and parameters monitored.

AQS #	*Site Name*	*Address*		*Started*	*Elevation (m)*	*Latitude*	*Longitude*
	Parameter	**POC**	**Started**	**Orient/Scale**	**Monitor**	**Type**	**Sample**
Adams							
08 001 0006	*Alsup Elementary School*	*7101 Birch St.*		*Jan-01*	*1,565*	*39.826007*	*-104.937438*
	PM_{10}	1	Jan-01	P.O. Neigh	Partisol 2025	SLAMS	1 in 1
	$PM_{2.5}$	1	Jan-01	P.O. Neigh	Partisol 2025	SLAMS	1 in 3
	$PM_{2.5}$ Collocated	2	Jan-01	P.O. Neigh	Partisol 2025	SLAMS	1 in 6
	$PM_{2.5}$	3	Jun-03	P.O. Neigh	TEOM-1400ab	SPM	Continuous
	$PM_{2.5}$ Speciation	5	Feb-01	P.O. Neigh	SASS	Trends Spec	1 in 6
	$PM_{2.5}$ Carbon	5	Feb-07	P.O. Neigh	URG 3000N	Trends Spec	1 in 6
	WS/WD/Temp	1	Jun-03	Other	Met - One	Other	Continuous
08 001 3001	*Welby*	*3174 E. 78th Ave.*		*Jul-73*	*1,554*	*39.838119*	*-104.949840*
	CO	1	Jul-73	P.O. Neigh	Thermo 48C	SLAMS	Continuous
	SO_2	2	Jul-73	P.O. Neigh	TAPI 100E	SLAMS	Continuous
	NO	2	Jan-76	P.O. Urban	TAPI 200E	Other	Continuous
	NO_2	1	Jan-76	P.O. Urban	TAPI 200E	SLAMS	Continuous
	O_3	2	Jul-73	P.O. Neigh	TAPI 400E	SLAMS	Continuous
	WS/WD/Temp	1	Jan-75	Other	Met - One	Other	Continuous
	PM_{10}	1	Feb-92	P.O. Neigh	SA/GMW-1200	SLAMS	1 in 6
	PM_{10}	3	Jun-90	P.O. Neigh	TEOM-1400ab	SLAMS	Continuous
Alamosa							
08 003 0001	*Alamosa - ASC*	*208 Edgemont Blvd*		*Jan-70*	*2,302*	*37.469391*	*-105.878691*
	PM_{10}	1	Jul-89	P.O. Neigh	SA/GMW-1200	SLAMS	1 in 1
08 003 0003	*Alamosa - Municipal*	*425 4th St.*		*Apr-02*	*2,301*	*37.469584*	*-105.863175*
	PM_{10}	1	May-02	P.O. Neigh	SA/GMW-1200	SLAMS	1 in 1
Arapahoe							
08 005 0002	*Highland Reservoir*	*8100 S. University Blvd.*		*Jun-78*	*1,747*	*39.567887*	*-104.957193*
	O_3	1	Jun-78	P.O. Neigh	TAPI 400E	SLAMS	Continuous
	WS/WD/Temp	1	Jul-78	Other	Met - One	Other	Continuous

Table A-1. (Cont.) Monitoring locations and parameters monitored.

AQS #	*Site Name*	*Address*		*Started*	*Elevation (m)*	*Latitude*	*Longitude*
	Parameter	**POC**	**Started**	**Orient/Scale**	**Monitor**	**Type**	**Sample**
08 005 0005	*Arapahoe Comm. Coll.*	*6190 S. Santa Fe Dr.*		*Dec-98*	*1,636*	*39.604399*	*-105.019526*
	$PM_{2.5}$	1	Mar-99	P.O. Neigh	Partisol 2025	SLAMS	1 in 3
08 005 0006	*Aurora - East*	*36001 E. Quincy Ave.*		*Apr-11*	*1,552*	*39.638540*	*-104.569130*
	O_3	1	Apr-11	P.O. Region	TAPI 400E	SLAMS	Continuous
	WS/WD/Temp	1	Jun-11	Other	Met - One	Other	Continuous
Archuleta							
08 007 0001	*Pagosa Springs School*	*309 Lewis St.*		*Aug-75*	*2,165*	*37.26842*	*-107.009659*
	PM_{10}	3	Sep-90	P.O. Neigh	SA/GMW-1200	SLAMS	1 in 1
Boulder							
08 013 0003	*Longmont - Municipal*	*350 Kimbark St.*		*Jun-85*	*1,520*	*40.164576*	*-105.100856*
	PM_{10}	2	Sep-85	P.O. Neigh	SA/GMW-1200	SLAMS	1 in 6
	$PM_{2.5}$	1	Jan-99	P.O. Neigh	Partisol 2025	SLAMS	1 in 3
	$PM_{2.5}$	3	Nov-05	P.O. Neigh	TEOM 1400ab	SPM	Continuous
08 013 0011	*South Boulder Creek*	*1405 S. Foothills Pkwy.*		*Jun-94*	*1,669*	*39.957212*	*-105.238458*
	O_3	1	Jun-94	H.C. Urban	TAPI 400E	SLAMS	Continuous
08 013 0012	*Boulder - Chamber*	*2440 Pearl St.*		*Dec-94*	*1,619*	*40.021097*	*-105.263382*
	PM_{10}	1	Oct-94	P.O. Neigh	SA/GMW-1200	SLAMS	1 in 6
	$PM_{2.5}$	1	Jan-99	P.O. Middle[2]	Partisol 2025	SLAMS	1 in 3
Delta							
08 029 0004	*Delta Health Dept*	*560 Dodge St.*		*Aug-93*	*1,511*	*38.739213*	*-108.073118*
	PM_{10}	1	May-93	P.O. Neigh	SA/GMW-1200	SLAMS	1 in 3
Denver							
08 031 0002	*CAMP*	*2105 Broadway St.*		*Jan-65*	*1,593*	*39.751184*	*-104.987625*
	CO	2	Jan-71	P.O. Micro	Thermo 48C	SLAMS	Continuous
	SO_2	1	Jan-67	P.O. Neigh	TAPI 100E	SLAMS	Continuous
	O_3	6	Mar-12	P.O. Neigh	TAPI 400E	SLAMS	Continuous
	NO	1	Jan-73	Other	TAPI 200E	Other	Continuous
	NO_2	1	Jan-73	P.O. Neigh	TAPI 200E	SLAMS	Continuous
	WS/WD/Temp	1	Jan-65	Other	Met - One	Other	Continuous
	PM_{10}	1	Aug-86	P.O. Micro	SA/GMW-1200	SLAMS	1 in 6
	PM_{10} Collocated	2	Dec-87	P.O. Micro	SA/GMW-1200	SLAMS	1 in 6
	PM_{10}	3	Jan-88	P.O. Micro	TEOM-1400ab	SLAMS	Continuous
	$PM_{2.5}$	1	Jan-99	P.O. Micro	Partisol 2025	SLAMS	1 in 1
	$PM_{2.5}$ Collocated	2	Sep-01	P.O. Micro	Partisol 2025	SLAMS	1 in 6
	$PM_{2.5}$	3	Oct-01	P.O. Micro	TEOM FDMS	SPM	Continuous
08 031 0013	*NJH-E*	*14th Ave. & Albion St.*		*Jan-83*	*1,620*	*39.738578*	*-104.939925*
	$PM_{2.5}$	3	Oct-03	P.O. Neigh	TEOM FDMS	SPM	Continuous

Table A-1. (Cont.) Monitoring locations and parameters monitored.

AQS #	*Site Name*	*Address*		*Started*	*Elevation (m)*	*Latitude*	*Longitude*
	Parameter	**POC**	**Started**	**Orient/Scale**	**Monitor**	**Type**	**Sample**
08 031 0017	*Denver Visitor Center*	*225 W. Colfax Ave.*		*Dec-92*	*1,597*	*39.740342*	*-104.991037*
	PM_{10}	1	Dec-92	P.O. Middle	SA/GMW-1200	SLAMS	1 in 1
08 031 0026	*La Casa*	*4587 Navajo St.*		*Jan-13*	*1,594*	*39.779429*	*-105.005174*
	CO (Trace)	1	Jan-12	P.O. Neigh	Thermo 48i-TLE	NCore	Continuous
	SO_2 (Trace)	1	Jan-12	P.O. Neigh	TAPI 100EU	NCore	Continuous
	NO_Y	1	Jan-12	P.O. Neigh	TAPI 200EU	NCore	Continuous
	O_3	1	Jan-12	Neigh/Urban	TAPI 400E	NCore	Continuous
	WS/WD/Temp	1	Jan-12	P.O. Neigh	Met - One	NCore	Continuous
	Relative Humidity	1	Jan-12	P.O. Neigh	Met - One	NCore	Continuous
	Temp (Lower)	2	Jan-12	P.O. Neigh	Met - One	NCore	Continuous
	PM_{10}	1	Jan-12	P.O. Neigh	Partisol 2025	SLAMS	1 in 3
	PM_{10} Collocated/Pb	2	Jan-12	P.O. Neigh	Partisol 2025	SLAMS	1 in 6
	PM_{10}	3	Jan-12	P.O. Neigh	TEOM-1400ab	SLAMS	Continuous
	$PM_{2.5}$	1	Jan-12	P.O. Neigh	Partisol 2025	NCore	1 in 3
	$PM_{2.5}$	3	Jan-12	P.O. Neigh	TEOM FDMS	SPM	Continuous
	$PM_{2.5}$ Speciation	5	Jan-12	P.O. Neigh	SASS	Supplem. Spec.	1 in 3
	$PM_{2.5}$ Carbon	5	Jan-12	P.O. Neigh	URG 3000N	Supplem. Spec.	1 in 3
Douglas							
08 035 0004	*Chatfield State Park*	*11500 N. Roxborough Pk Rd*		*Apr-04*	*1,676*	*39.534488*	*-105.070358*
	O_3	1	May-05	H.C. Urban	TAPI 400E	SLAMS	Continuous
	WS/WD/Temp	1	Apr-04	Other	Met - One	Other	Continuous
	$PM_{2.5}$	1	Jul-05	P.O. Neigh	Partisol 2025	SPM	1 in 3
	$PM_{2.5}$	3	May-04	P.O. Neigh	TEOM FDMS	SPM	Continuous
El Paso							
08 041 0013	*U. S. Air Force Academy*	*USAFA Rd. 640*		*May-96*	*1,971*	*39.958341*	*-104.817215*
	O_3	1	Jun-96	P.O. Urban	TAPI 400E	SLAMS	Continuous
08 041 0015	*Highway 24*	*690 W. Hwy. 24*		*Nov-98*	*1,824*	*39.830895*	*-104.839243*
	CO	1	Nov-98	P.O. Micro	Thermo 48i-TLE	SLAMS	Continuous
	SO_2	1	Jan-13	P.O. Micro	TAPI 100T	SLAMS	Continuous
08 041 0016	*Manitou Springs*	*101 Banks Pl.*		*Apr-04*	*1,955*	*38.853097*	*-104.901289*
	O_3	1	Apr-04	P.O. Neigh	TAPI 400E	SLAMS	Continuous
08 041 0017	*Colorado College*	*130 W. Cache La Poudre*		*Dec-07*	*1,832*	*38.848014*	*-104.828564*
	PM_{10}	1	Dec-07	P.O. Neigh	Partisol 2000	SLAMS	1 in 6
	$PM_{2.5}$	1	Dec-07	P.O. Neigh	Partisol 2025	SLAMS	1 in 3
	$PM_{2.5}$	3	Jan-08	P.O. Neigh	TEOM FDMS	SLAMS	Continuous

Table A-1. (Cont.) Monitoring locations and parameters monitored.

AQS #	*Site Name*	*Address*		*Started*	*Elevation (m)*	*Latitude*	*Longitude*
	Parameter	**POC**	**Started**	**Orient/Scale**	**Monitor**	**Type**	**Sample**
Fremont							
08 043 0003	*Cañon City - City Hall*	*128 Main St.*		*Oct-04*	*1,626*	*38.438290*	*-105.245040*
	PM_{10}	1	Oct-04	P.O. Neigh	SA/GMW-1200	SLAMS	1 in 6
Garfield							
08 045 0005	*Parachute*	*100 E. 2nd St.*		*Jan-82*	*1,557*	*38.453654*	*-108.053269*
	PM_{10}	1	May-00	P.O. Neigh	SA/GMW-1200	SLAMS	1 in 3
	WS/WD/Temp	1	Mar-11	Other	RM Young /Vaisala	Other	Continuous
08 045 0007	*Rifle - Henry Bldg*	*144 3rd St.*		*May-05*	*1,627*	*39.531813*	*-107.782298*
	PM_{10}	1	May-05	P.O. Neigh	SA/GMW-1200	SPM	1 in 3
	$PM_{2.5}$	3	Sep-08	P.O. Neigh	Thermo 1405 DF	SPM	Continuous
	PM_{10}	3	Sep-08	P.O. Neigh	Thermo 1405 DF	SPM	Continuous
	$PM_{10-2.5}$	3	Sep-08	P.O. Neigh	Thermo 1405 DF	SPM	Continuous
	WS/WD/Temp	1	Sep-08	Other	RM Young /Vaisala	Other	Continuous
08 045 0012	*Rifle - Health Dept*	*195 W. 14th Ave.*		*Jun-08*	*1,629*	*39.541820*	*-107.784125*
	O_3	1	Jun-08	P.O. Neigh	TAPI 400E	SLAMS	Continuous
08 045 0018	*Carbondale*	*1493 County Road 106*		*May-12*	*1868*	*39.412240*	*-107.230413*
	PM_{10}	1	Aug-12	P.O. Neigh	SA/GMW-1200	SLAMS	1 in 3
Gunnison							
08 051 0004	*Crested Butte*	*603 6th St.*		*Sep-82*	*2,714*	*38.867595*	*-106.981436*
	PM_{10}	2	Mar-97	P.O. Neigh	SA/GMW-1200	SLAMS	1 in 3
	PM_{10} Collocated	3	Oct-08	P.O. Neigh	SA/GMW-1200	SLAMS	1 in 6
08 051 0007	*Mt. Crested Butte*	*19 Emmons Rd.*		*Jul-05*	*2,866*	*38.900392*	*-106.966104*
	PM_{10}	1	Jul-05	P.O. Neigh	SA/GMW-1200	SLAMS	1 in 1
Jefferson							
08 059 0005	*Welch*	*12400 W. Hwy. 285*		*Aug-91*	*1,742*	*39.638781*	*-105.139480*
	O_3	1	Aug-91	P.O. Urban	TAPI 400E	SLAMS	Continuous
	WS/WD/Temp	1	Nov-91	Other	Met - One	Other	Continuous
08 059 0006	*Rocky Flats - N*	*16600 W. Hwy. 128*		*Jun-92*	*1,802*	*39.912799*	*-105.188587*
	O_3	1	Sep-92	H.C. Urban	TAPI 400E	SLAMS	Continuous
	WS/WD/Temp	1	Sep-92	Other	Met - One	Other	Continuous
08 059 0011	*NREL*	*2054 Quaker St.*		*Jun-94*	*1,832*	*39.743724*	*-105.177989*
	O_3	1	Jun-94	H.C. Urban	TAPI 400E	SLAMS	Continuous
08 059 0013	*Aspen Park*	*26137 Conifer Rd.*		*Apr-11*	*2,467*	*39.540321*	*-105.296512*
	O_3	1	Apr-11	P.O. Neigh	TAPI 400E	SLAMS	Continuous
	WS/WD/Temp	1	Jun-11	Other	Met - One	Other	Continuous

Table A-1. (Cont.) Monitoring locations and parameters monitored.

AQS #	*Site Name*	*Address*		*Started*	*Elevation (m)*	*Latitude*	*Longitude*
	Parameter	**POC**	**Started**	**Orient/Scale**	**Monitor**	**Type**	**Sample**
La Plata							
08 067 0004	*Durango*	*1235 Camino del Rio*		*Sep-85*	*1,988*	*37.277798*	*-107.880928*
	PM_{10}	1	Dec-02	P.O. Neigh	SA/GMW-1200	SLAMS	1 in 3
Larimer							
08 069 0009	*Fort Collins - CSU*	*251 Edison Dr.*		*Dec-98*	*1,524*	*40.571288*	*-105.079693*
	PM_{10}	1	Jul-99	P.O. Neigh	SA/GMW-1200	SLAMS	1 in 3
	PM_{10}	3	Jun-11	P.O. Neigh	Thermo 1405 DF	SPM	Continuous
	$PM_{2.5}$	1	Jul-99	P.O. Neigh	Partisol 2025	SLAMS	1 in 3
	$PM_{2.5}$	3	Jun-11	P.O. Neigh	Thermo 1405 DF	SPM	Continuous
	$PM_{10-2.5}$	3	Jun-11	P.O. Neigh	Thermo 1405 DF	SPM	Continuous
08 069 0011	*Fort Collins - West*	*3416 La Porte Ave.*		*May-06*	*1,571*	*40.592543*	*-105.141122*
	O_3	1	May-06	H.C. Urban	TAPI 400E	SLAMS	Continuous
08 069 1004	*Fort Collins - Mason*	*708 S. Mason St.*		*Dec-80*	*1,524*	*40.577470*	*-105.078920*
	CO	1	Dec-80	P.O. Neigh	Thermo 48C	SLAMS	Continuous
	O_3	1	Dec-80	P.O. Neigh	TAPI 400E	SLAMS	Continuous
	WS/WD/Temp	1	Jan-81	Other	Met - One	Other	Continuous
Mesa							
08 077 0017	*Grand Junction - Powell*	*650 South Ave.*		*Feb-02*	*1,398*	*39.063798*	*-108.561173*
	PM_{10} & NATTS Toxics	3	Jan-05	P.O. Neigh	Partisol 2025	SLAMS	1 in 3
	PM_{10} Collocated & NATTS	4	Mar-05	P.O. Neigh	Partisol 2000	SLAMS	1 in 6
	$PM_{2.5}$	1	Nov-02	P.O. Neigh	Partisol 2025	SLAMS	1 in 3
	PM_{10}	3	Jul-11	P.O. Neigh	Thermo 1405 DF	SPM	Continuous
	$PM_{2.5}$	3	Jan-05	P.O. Neigh	Thermo 1405 DF	SPM	Continuous
	$PM_{10-2.5}$	3	Jul-11	P.O. Neigh	Thermo 1405 DF	SPM	Continuous
08 077 0018	*Grand Junction - Pitkin*	*645 Pitkin Ave.*		*Jan-04*	*1,398*	*39.064289*	*-108.56155*
	CO	1	Jan-04	P.O. Micro	Thermo 48C	SLAMS	Continuous
	WS/WD/Temp	1	Jan-04	Other	Met - One	Other	Continuous
	Relative Humidity	1	Jan-04	Other	Rotronic	Other	Continuous
08 077 0020	*Palisade Water Treatment*	*Rapid Creek Rd.*		*May-08*	*1,512*	*39.130575*	*-108.313853*
	O_3	1	Apr-08	P.O. Urban	TAPI 400E	SLAMS	Continuous
	WS/WD/Temp	1	Apr-08	Other	RM Young	Other	Continuous
Montezuma							
08 083 0006	*Cortez - Health Dept.*	*106 W. North St.*		*Jun-06*	*1,890*	*37.350054*	*-108.592337*
	O_3	1	Jun-08	P.O. Urban	TAPI 400E	SLAMS	Continuous
	$PM_{2.5}$	1	Jun-08	P.O Region	Partisol 2000	SPM	1 in 6

Table A-1. (Cont.) Monitoring locations and parameters monitored.

AQS #	*Site Name*	*Address*		*Started*	*Elevation (m)*	*Latitude*	*Longitude*
	Parameter	**POC**	**Started**	**Orient/Scale**	**Monitor**	**Type**	**Sample**
Pitkin							
08 097 0006	*Aspen - Library*	*120 Mill St.*		*May-02*	*2,408*	*39.191040*	*-106.818864*
	PM_{10}	1	May-02	P.O. Neigh	SA/GWM 1200	SLAMS	1 in 3
Prowers							
08 099 0002	*Lamar Municipal*	*104 E. Parmenter St.*		*Dec-76*	*1,107*	*38.084688*	*-102.618641*
	PM_{10}	2	Mar-87	P.O. Neigh	SA/GMW-1200	SLAMS	1 in 1
Pueblo							
08 101 0015	*Pueblo - Fountain School*	*925 N. Glendale Ave.*		*Jun-11*	*1,433*	*38.276099*	*-104.597613*
	PM_{10}	1	Apr-11	P.O. Neigh	SA/GMW-1200	SLAMS	1 in 3
	$PM_{2.5}$	1	Apr-11	P.O. Neigh	Partisol 2025	SLAMS	1 in 3
Routt							
08 107 0003	*Steamboat Springs*	*136 6th St.*		*Sep-75*	*2,054*	*40.485201*	*-106.831625*
	PM_{10}	2	Mar-87	P.O. Neigh	SA/GMW-1200	SLAMS	1 in 1
San Miguel							
08 113 0004	*Telluride*	*333 W. Colorado Ave.*		*Mar-90*	*2,684*	*37.937872*	*-107.813061*
	PM_{10}	1	Mar-90	P.O. Neigh	SA/GMW-1200	SLAMS	1 in 3
Weld							
08 123 0006	*Greeley-Hospital*	*1516 Hospital Rd.*		*Apr-67*	*1,441*	*40.414877*	*-104.706930*
	PM_{10}	2	Mar-87	P.O. Neigh	SA/GMW-1200	SLAMS	1 in 3
	$PM_{2.5}$	1	Feb-99	P.O. Neigh	Partisol 2025	SLAMS	1 in 3
	$PM_{2.5}$	3	Feb-99	P.O. Neigh	TEOM – 1400ab	SPM	Continuous
08 123 0008	*Platteville Middle School*	*1004 Main St.*		*Dec-98*	*1,469*	*40.209387*	*-104.824050*
	$PM_{2.5}$	1	Aug-99	P.O. Region	Partisol 2025	SLAMS	1 in 3
	$PM_{2.5}$ Speciation	5	Aug-99	P.O. Region	SASS	Spec Trends	1 in 6
	$PM_{2.5}$ Carbon	5	Apr-11	P.O. Neigh	URG 3000N	Spec Trends	1 in 6
08 123 0009	*Greeley - County Tower*	*3101 35th Ave.*		*Jun-02*	*1,484*	*40.386368*	*-104.737440*
	O_3	1	Jun-02	P.O. Neigh	TAPI 400E	SLAMS	Continuous
	WS/WD/Temp	1	Feb-12	Other	Met - One	Other	Continuous
08 123 0010	*Greeley - West Annex*	*905 10th Ave.*		*Dec-03*	*1,421*	*40.423432*	*-104.694790*
	CO	1	Dec-03	P.O. Neigh	Thermo 48C	SLAMS	Continuous

Alsup Elementary School (Commerce City), 7101 Birch Street (08 001 0006):

The Alsup Elementary School site is located in a predominantly residential area with a large commercial and industrial district. It is located north of the Denver Central Business District (CBD) near the Platte River Valley, downstream from the Denver urban air mass. There are two schools in addition to the Alsup Elementary School in the immediate vicinity, a middle school to the north, and a high school to the southeast. There is a large industrial area to the south and east and gravel pits about a kilometer to the west and northwest.

PM_{10} and $PM_{2.5}$ monitoring began in January 2001 and continues to this day. There are a collocated set of monitors, along with a continuous monitor, a trends speciation monitor, and a $PM_{2.5}$ carbon monitor all in operation.

Meteorological monitoring began in June of 2003.

Welby, 3174 E. 78th Avenue (08 001 3001):

Located 13 km north-northeast of the Denver Central Business District (CBD) on the bank of the South Platte River, this site is ideally located to measure nighttime drainage of the air mass from the Denver metropolitan area and the thermally driven, daytime upriver flows. Monitoring data suggests that elevated CO concentrations are associated with winds from the south-southwest. While this is the direction of five of the six major sources in the area, it is also the direction of the primary drainage winds along the South Platte River. This monitor is a population-oriented, neighborhood scale SLAMS monitor.

CO monitoring began in 1973 and continued through the spring of 1980. Monitoring was stopped from the spring of 1980 until October 1986 when it began again as a special study. Welby has not recorded an exceedance of either the one-hour or eight-hour CO standard since January 1988. In the last few years, its primary value has been as an indicator of changes in the air quality index (AQI).

O_3 monitoring began at Welby in July of 1973. The Welby monitor has not recorded an exceedance of the old one-hour O_3 standard since 1998. However, the trend in the 3-year average of the 4th maximum eight-hour average has been increasing since 2002.

The Welby NO_2 monitor began operation in July 1976. The site's location provides an indication of possible exceedance events before they impact the Denver metro area. The site serves as a good drainage location, but it may be a target for deletion or relocation farther down the South Platte River Valley from Denver.

The Welby SO_2 monitor began operation in July of 1973.

PM_{10} monitoring began at Welby in June and July of 1990. The continuous monitor began operation in June, while the high volume monitor began operation in July.

Meteorological monitoring began in January of 1975.

Alamosa – Adams State College, 208 Edgemont Boulevard (08 003 0001):

The Alamosa – Adams State College site is located on the science building of Adams State College in a principally residential area. The only significant traffic is along US 160 through the center of town. The site is adjacent to this highway but far enough away to limit direct impacts on PM_{10} levels. Meteorological data are not available from the area. The city has a population of 8,780 (2010 Census data). This is an increase of 10.3% from the 2000 census. The major particulate source is wind-blown dust. This site began operation in 1973 as a TSP monitor and was changed to a PM_{10} monitor in June 1990. This is a population-oriented, neighborhood scale SLAMS monitor on a daily sampling schedule.

Alamosa - Municipal, 425 4th Street (08 003 0003):

The Alamosa 425 4th St. site was started in May 2002. The site was established closer to the center of the city to be more representative of the population exposure in the area. This is a population-oriented, neighborhood scale SLAMS monitor on a daily sampling schedule.

Highland Reservoir, 8100 S. University Boulevard (08 005 0002):

The Highlands site began operation in June of 1978. It was intended to be a background location. However, with urban growth and the construction of C-470, it has become a long-term trend site that monitors changes in the air quality of the area. It is currently believed to be near the southern edge of the high urban O_3 concentration zone although it may not be in the area of maximum concentrations. This is a population-oriented, neighborhood scale SLAMS monitor.

Meteorological monitoring began in July of 1978.

In September of 2010 the site and meteorological tower were relocated to the east by approximately 30 meters to allow for the construction of an emergency generator system. This emergency generator system is located approximately 20 meters northwest of the new site location.

The site was closed temporarily in October of 2013 due to the disturbances associated with the construction of new water storage tanks at the site. The site was reopened in September of 2015.

Arapahoe Community College (ACC), 6190 S. Santa Fe Drive (08 005 0005):

The ACC site is located in south suburban metropolitan Denver. It is located on the south side of the Arapahoe Community College campus in a distant parking lot. The site is near the bottom of the Platte River Valley along Santa Fe Drive (Hwy. 85) in the city of Littleton. It is also near the city of Englewood. There is a large residential area located to the east across the railroad and Light Rail tracks. The $PM_{2.5}$ monitor is located on a mobile shelter in the rarely used South parking lot. Located at 6190 S. Santa Fe Drive, this small trailer is close to the Platte River and the monitor has excellent 360° exposure. Based on the topography and meteorology of the area, ACC is in an area where $PM_{2.5}$ emissions may accumulate. This location may capture high concentrations during periods of upslope flow and temperature inversion in the valley. However, since it is further south in a more sparsely populated area, the concentrations are usually not as high as other Denver locations.

Winds are predominately out of the south-southwest and south, with secondary winds out of the north and north-northeast (upslope). Observed distances and traffic estimates easily fall into the neighborhood scale in accordance with federal guidelines found in the 40 CFR, Part 58, Appendix D. The site meets all other neighborhood scale criteria, making the monitor a population oriented neighborhood scale SLAMS monitor operating on a 1 in 3 day sampling schedule.

Aurora – East, 36001 Quincy Ave (08 005 0006):

The Aurora - East site began operation in June 2009. It is intended to act as a regional site and an aid in the determination of the easternmost extent of the high urban O_3 concentration zone. It is located along the eastern edge of the former Lowry bombing range, on a flat, grassy plains area. This site is currently outside of the rapid urban growth area taking place around Aurora Reservoir. This was a special projects monitor (SPM) for a regional scale and became a SLAMS monitor in 2013.

Pagosa Springs School, 309 Lewis Street (08 007 0001):

The Pagosa Springs School site was located on the roof of the Town Hall from April 24, 2000 through May 2001. When the Town Hall building was planned to be demolished, the PM_{10} monitor was relocated to the Pagosa Springs Middle School and the first sample was collected on June 7, 2001.

The Pagosa Springs School site is located next to Highway 160 near the center of town. Pagosa Springs is a small town spread over a large area. The San Juan River runs through the south side of town. The town sits in a small bowl-like setting with hills all around. A small commercial strip area along Highway 160 and single-family homes surround this location. It is representative of residential neighborhood exposure. Pagosa Springs was a PM_{10} nonattainment area and a SIP was implemented for this area. PM_{10} concentrations were exceeded a few times in the late 1990s.

Winds in this area are predominantly northerly, with secondary winds from the north-northwest and the south. The predominant wind directions closely follow the valley topography in this rugged terrain. McCabe Creek, which is very near the meteorological station that was on the Town Hall building, runs north-south through this area. However, the highest wind gusts come from the west and southwest during regional dust storms. This is a population-oriented, neighborhood scale SLAMS monitor operated on a daily sampling schedule.

Longmont – Municipal Bldg., 350 Kimbark Street (08 013 0003):

The town of Longmont is a growing, medium sized Front Range community. Longmont is located between the Denver/Boulder metro area and Fort Collins. Longmont is both suburban and rural in nature. The town of Longmont is located approximately 50 km north of Denver along the St. Vrain Creek and is about 10 km east of the foothills. Longmont is partly a bedroom community for the Denver-Boulder area. The elevation is 517 meters. The Front Range peaks rise to an elevation of 4300 meters just to the west of Longmont. In general, the area experiences low relative humidity, light precipitation and abundant sunshine.

The station began operation in 1985 with the installation of a PM_{10} monitor and $PM_{2.5}$ monitors were added in 1999.

Longmont's predominant wind direction is from the north through the west due to winds draining from the St. Vrain Creek Canyon. The PM_{10} site is near the center of the city near both commercial and residential areas. This location provides the best available monitoring for population exposure to particulate matter. The distance and traffic estimates for the controlling streets easily fall into the neighborhood scale in accordance with federal guidelines found in 40 CFR, Part 58, and Appendix D. This is a population oriented neighborhood scale SLAMS monitor operated on a 1 in 6 day sampling schedule.

South Boulder Creek, 1405½ S. Foothills Parkway (08 013 0011):

The city of Boulder is located about 50 km to the northwest of Denver. The Boulder Foothills, South Boulder Creek site was established as a special-purpose O_3 monitor within the framework of the "summer 1993 Denver O_3 Study." In 1994, the monitor was converted from an SPM to a seasonal SLAMS monitor. In 1995 it was converted to a year-round O_3 monitoring site when the instruments were moved into a new shelter.

This is a highest concentration-oriented urban scale SLAMS monitor.

Boulder Chamber of Commerce, 2440 Pearl Street (08 013 0012):

The city of Boulder is located on the eastern edge of the Rocky Mountain foothills. Most of the city sits on rolling plains. The Boulder $PM_{2.5}$ site is approximately 2,134 meters east of the base of the Front Range foothills and about 15 meters south of a small branch of Boulder Creek, the major creek that runs through Boulder.

PM_{10} monitoring began at this site in December of 1994 and $PM_{2.5}$ monitoring began in January of 1999.

The predominant wind direction at the Division's closest meteorological site (Rocky Flats – North) is from the west with secondary maximum frequencies from the west-northwest and west-southwest. The distance and traffic estimate for Pearl Street and Folsom Street falls into the middle scale, but the site has been justified to represent a neighborhood scale site in accordance with federal guidelines found in 40 CFR, Part 58 and Appendix D. This is a population-oriented, neighborhood scale SLAMS monitoring site operated on a 1 in 6 day sampling schedule.

Delta - Health Department, 560 Dodge Street (08 029 0004):

Delta is a small agricultural community midway between Grand Junction and Montrose. The topography in and around Delta is relatively flat as it sits in the broad Uncompaghre River Valley surrounded by high mesas and mountains. Delta sits in a large bowl-shaped basin that can effectively trap air pollution, especially during persistent temperature inversions.

The Delta County Health Department site was chosen because it is a one story building near the downtown area. The site began operation in August 1993, and is representative of the large basin with the potential for high PM_{10} due to agricultural burning and automobile traffic. This is a population-oriented, neighborhood scale SLAMS monitor operated on a 1 in 3 day sampling schedule.

CAMP, 2105 Broadway (08 031 0002):

The City and County of Denver is located approximately 50 km east of the foothills of the Rocky Mountains. Denver sits in a basin, and the terrain of the city is characterized by gently rolling hills, with the Platte River running from southwest to northeast just west of the downtown area. The CAMP site is located in downtown Denver.

CO monitoring began in February 1965 as a part of the Federal Continuous Air Monitoring Program. It was established as a maximum concentration (micro-scale), population-oriented monitor. The CAMP site measures the exposure of the people who work or reside in the central business district (CBD). Its location in a high traffic street canyon causes this site to record most of the high pollution episodes in the metro area. The street canyon effect at CAMP results in variable wind directions for high CO levels and as a result wind direction is less relevant to high concentrations than wind speed. Wind speeds less than 1 mph, especially up-valley, combined with temperature inversions trap the pollution in the area. Sampling for all parameters at the site was discontinued from June of 1999 to July of 2000 for the construction of a new building.

The NO_2 monitor began operation in January 1973 at this location.

The SO_2 monitor began operation in January 1967.

O_3 monitoring began originally in 1972 and has been intermittently conducted to this day. The current O_3 monitor began operation in February 2012.

The PM_{10} monitoring began in 1986 with the installation of collocated monitors, and was furthered by the addition of a continuous monitor in 1988.

The $PM_{2.5}$ monitoring began in 1999 with a continuous and an FEM monitor, and was furthered by the addition of a collocated FEM monitor in 2001.

Meteorological monitoring began at this site in January of 1965.

NJH-E, 14th Avenue & Albion Street (08 031 0013):

This site is located 5 km east of the Denver CBD, close to a very busy intersection (Colorado Boulevard and Colfax Avenue). The current site began operations in 1982 as a CO monitor. Two previous sites were located just west of the current location. The first operated for only a few months before it was moved to a new site in the corner of the laboratory building at the corner of Colorado Boulevard and Colfax Avenue. With the decline in CO concentrations, CO monitoring was terminated and NJH became a particulate monitoring site. Data from this continuous TEOM monitor is not compared with the NAAQS. It is used for short term forecasting and public notifications. The monitor here is a population-oriented middle scale special project monitor.

Denver Visitor Center, 225 W. Colfax Avenue (08 031 0017):

The Denver Visitor Center site is located near the corner of Colfax Avenue and Tremont Street. It began operation on December 28, 1992. In 1993, this site, along with the Denver CAMP and Gates monitors, recorded the first exceedances of the 24-hour PM_{10} standard in the Denver metropolitan area since 1987. Since then, high values have been observed, but have been below the NAAQS of 150 $\mu g\ m^{-3}$. In the past ten years, the 24-hour maximum levels have trended downward. This is a population-oriented middle scale SLAMS monitor operating on a daily sampling schedule.

La Casa, 4587 Navajo Street (08 031 0026):

The La Casa site was established in January of 2013 as a replacement for the Denver Municipal Animal Shelter (DMAS) site when a land use change forced the relocation of the site. The La Casa location has been established as the NCore site for the Denver Metropolitan area. In late 2012, the DMAS site was decommissioned and moved to La Casa in northwest Denver. It includes a trace gas/precursor-level CO analyzer and a NO_y analyzer, in addition to the trace level SO_2, O_3, meteorology, and particulate monitors. La Casa was certified in 2013 as an NCore compliant site by the EPA. The site represents a population-oriented neighborhood scale monitoring area.

The trace level SO_2, CO, and NO_y analyzers began operation in January 2013.

The meteorological monitoring began at La Casa in January 2013.

PM_{10} monitoring began at La Casa in January 2013. Currently, there is a pair of collocated high volume samplers, and a Lo-Vol PM_{10} on the shelter roof. These concurrent PM_{10} measurements will be compared prior to removing the Hi-Vol PM_{10} monitors. The Lo-Vol PM_{10} concentrations are more useful as they can be used with the $PM_{2.5}$ measurements to calculate $PM_{10\text{-}2.5}$ or coarse PM.

$PM_{2.5}$ monitoring began at La Casa in January 2013 with an FRM monitor, a continuous TEOM/FDMS FEM instrument, a supplemental $PM_{2.5}$ speciation monitor, and a carbon speciation monitor. PM_{10}/lead (Pb-TSP) monitoring began in January 2013.

<u>Chatfield State Park, 11500 N. Roxborough Park Road (08 035 0004):</u>

The Chatfield State Park location was established as the result of the 1993 Summer O_3 Study. The original permanent site was located at the campground office. This site was later relocated on the south side of Chatfield State Park at the park offices. This location was selected over the Corps of Engineers Visitor Center across the reservoir because it was more removed from the influence of traffic along C-470. Located in the South Platte River drainage, this location is well suited for monitoring southwesterly O_3 formation in the Denver metro area.

$PM_{2.5}$ monitoring began at this site in 2004 with the installation of a continuous monitor, and was furthered by the addition of an FEM monitor in 2005.

Meteorological monitoring began in April of 2004.

<u>United States Air Force Academy, USAFA Road 640 (08 041 0013):</u>

The United States Air Force Academy site was installed as a replacement maximum concentration O_3 monitor for the Chestnut Street (08 041 0012) site. Modeling in the Colorado Springs area indicates that high O_3 concentrations should generally be found along either the Monument Creek drainage to the north of the Colorado Springs central business district (CBD), or to a lesser extent along the Fountain Creek drainage to the west of the CBD. The decision was made to locate this site near the Monument Creek drainage, approximately 15 km north of the CBD. This location is near the south entrance of the Academy approximately ¾ mile from I-25. This is a population-oriented urban scale SLAMS monitor.

<u>Colorado Springs Hwy-24, 690 W. Highway 24 (08 041 0015):</u>

The Highway 24 site is located just to the west of I-25 and just to the east of the intersection of U.S. Highway 24 and 8th Street, approximately 1 km to the west of the Colorado Springs CBD. Commencing operation in November 1998, this site is a replacement for the Tejon Street (08 041 0004) CO monitor. The site is located in the Fountain Creek drainage and is in one of the busiest traffic areas of Colorado Springs. Additionally, traffic is prone to back-up along Highway 24 due to a traffic light at 8th Street. Thus, this site is well suited for the SLAMS network to monitor maximum concentrations of CO in the area both from automotive sources and also from nearby industry, which includes a power plant. It also provides a micro-scale setting for the Colorado Springs area, which has not been possible in the past. In January of 2013, an SO_2 monitor was added to the Highway 24 due to an increased population found during the 2010 census.

<u>Manitou Springs, 101 Banks Place (08 041 0016):</u>

Manitou Springs is a located 6 km west of Colorado Springs. The station was established due to concerns that the high O_3 concentrations associated with the Colorado Springs urban area was traveling farther up the Fountain Creek drainage and that the current monitoring network was not adequate to capture this effect. The Manitou Springs monitor began operations in April 2004. It is located in the foothills above Colorado Springs in the back of the city maintenance facility. It has not recorded any levels greater than the current standard. This is a population-oriented neighborhood scale SLAMS monitor.

Colorado College, 130 W. Cache la Poudre Street (08 041 0017):

The Colorado College monitoring site was established in January 2007 after the revised particulate regulations required that Colorado Springs have a continuous $PM_{2.5}$ monitor. The Division elected to collocate the new $PM_{2.5}$ monitor with the corresponding filter based monitors from the RBD site at the Colorado College location, which included a FRM $PM_{2.5}$ monitor and added a low volume FEM PM_{10} monitor in November 2007. The continuous monitor began operation in April of 2008.

The nearest representative meteorological site is located at the Colorado Springs Airport. Wind flows at the Colorado College site are affected by its proximity to Fountain Creek, so light drainage winds will follow the creek in a north/south direction. The three monitoring sites here are population-oriented neighborhood scale monitors, two on the SLAMS network (PM_{10} and $PM_{2.5}$) and one that is a special projects monitor ($PM_{2.5}$ continuous).

Cañon City - City Hall, 128 Main Street (08 043 0003):

Cañon City is located 63 km west of Pueblo. Particulate monitoring began on January 2, 1969 with the operation of a TSP monitor located on the roof of the courthouse building at 7th Avenue and Macon Street. The Macon Street site was relocated to the City Hall in October of 2004.

The Cañon City PM_{10} site began operation in December 1987. On May 6, 1988, the Macon Street monitor recorded a PM_{10} concentration of 172 $\mu g/m^3$. This is the only exceedance of either the 24-hour or annual NAAQS since PM_{10} monitoring was established at Cañon City. This is a population-oriented neighborhood scale SLAMS monitor on a 1 in 6 day sampling schedule.

Parachute – Elementary School, 100 E. 2nd Street (08 045 0005):

The Parachute site began operation in May 2000 with the installation of a PM_{10} monitor at the high school. This is a population-oriented neighborhood scale SLAMS monitor on a 1 in 3 day sampling schedule.

Rifle - Henry Building, 144 3rd Street (08 045 0007):

The first Rifle site began monitoring for particulates in June 1985 and ended operation in May 1986. The next site began operation in December 1987 and continued until 2001. The levels at that site, with the exception of the March 31, 1999 high wind event, were always less than one half of both the annual and the 24-hour standards. The current location at the Henry Building began operation in May of 2005 with the installation of a PM_{10} monitor as a part of the Garfield County study. There are now two population-oriented neighborhood scale special project PM_{10} monitoring sites: one on a 1 in 3 day sampling schedule, and one that is continuous. There is also a continuous monitor measuring $PM_{2.5}$ and PM_{10}, as well as meteorological monitors.

Rifle - Health Dept., 195 14th Ave (08 045 0012):

The Rifle Health Department site is located at the Garfield County Health Department building. The site is 1 km to the north of the downtown area and next to the Garfield County fairgrounds. The site is uphill from the downtown area. A small residential area is to the north and a commercial area to the east. This site was established to measure O_3 in Rifle, which is the largest population center in the oil and gas impacted area of the Grand Valley. Monitoring commenced in June 2008. This is a SLAMS monitor with a neighborhood scale.

Rocky Mountain School (Carbondale), 1493 County Road 106 (08 045 0018):

Carbondale is in the fairly narrow Roaring Fork valley between Aspen and Glenwood Springs. The Carbondale site is located just south of the confluence of the Crystal and Roaring Fork rivers and was established to monitor PM_{10} in January of 2013. This is a population-oriented neighborhood scale special project monitoring site.

Crested Butte, 603 6th Street (08 051 0004):

The Crested Butte PM_{10} site began operation in June 1985. Crested Butte is a high mountain ski town. The monitor is at the east end of town near the highway and in the central business district. Any wood burning from the residential area to the west directly affects this location. The physical setting of the town, near the end of a steep mountain valley, makes wood burning, street sanding, and wintertime inversions a major concern. The town is attempting to regulate the number of wood burning appliances, since this is a major source of wintertime PM_{10}.

There are two population oriented neighborhood scale monitors here, one in the SLAMS network (1 in 3 day sampling schedule) and one that is a continuous monitor.

Mt. Crested Butte, 19 Emmons Road (08 051 0007):

Mount Crested Butte is located at an elevation of 2,725 m at the base of the Crested Butte Mountain Resort ski area. Mount Crested Butte is a unique location for high particulate matter concentrations because it is located on the side of a mountain (Crested Butte, 3,707 m), not in a bowl, valley, or other topographic feature that would normally trap air pollutants. There is not a representative meteorological station in or near Mt. Crested Butte.

The location for the Mt. Crested Butte site was selected because it had an existing PM_{10} site that had several high PM_{10} concentrations including five exceedances of the 24-hour standard in 1997 and one in 1998. Mt. Crested Butte also exceeded the PM_{10} annual average standard in 2011. A CMB source apportionment from 10 PM_{10} filters identified crustal material as the mostly likely source (91%) of PM_{10}. Carbon, which is most likely from residential wood smoke, made up 8% of the statistically composite sample and secondary species made up the remaining one percent. The Mt. Crested Butte site was also selected because it is an area representative of the residential impact of PM_{10}. This is a population-oriented neighborhood scale SLAMS monitor on a daily sampling schedule.

Welch, 12400 W. Highway 285 (08 059 0005):

The Division conducted a short-term O_3 study on the grounds of Chatfield High School from June 14, 1989 until September 28, 1989. The Chatfield High School location was chosen because it sits on a ridge southwest of the Denver CBD. Wind pattern studies showed a potential for elevated O_3 levels in the area on mid to late afternoon summer days. There were no exceedances of the NAAQS recorded at the Chatfield High School site, but the levels were frequently higher than those recorded at the other monitoring sites south of the metro area.

One finding of the study was the need for a new, permanent site further north of the Chatfield High School location. As with most Denver locations, the predominant wind pattern is north/south. The southern flow occurs during the upslope, daytime warming period. The northern flow occurs during late afternoon and nighttime when drainage is caused by cooling and settling. The major drainages of Bear Creek and Turkey Creek were selected as target downwind transport corridors. These are the first major topographical features north of the Chatfield High School site. A point midway between the valley floor

(Englewood site) and the foothill's hogback ridge was modeled to be the best estimate of the maximum downwind daytime transport area. These criteria were used to evaluate available locations. The Welch site best met these conditions. This site is located off State Highway 285 between Kipling Street and C-470. This is a population-oriented urban scale SLAMS monitor.

Rocky Flats - N, 16600 W. Highway 128 (08 059 0006):

The Rocky Flats - North site is located north-northeast of the plant on the south side of Colorado Highway 128, approximately 2 km to the west of Indiana Street. The site began operation in June 1992 with the installation of an O_3 monitor and meteorological monitors as a part of the first phase of the APCD's monitoring effort around the Rocky Flats Environmental Technology Site.

O_3 monitoring began as a part of the Summer 1993 Ozone Study. The monitor recorded some of the highest O_3 levels of any of the sites during that study. Therefore, it was included as a regular part of the APCD O_3 monitoring network. The Rocky Flats - North monitor frequently exceeds the current standard. This is a highest concentration oriented urban scale SLAMS monitor.

NREL Solar Radiation Research Laboratory, 2054 Quaker Street (08 059 0011):

The National Renewable Energy Laboratory (NREL) site is located on the south rim of South Table Mountain, near Golden, and was part of the Summer 1993 Ozone Study. Based on the elevated concentrations found at this location, it was made a permanent monitoring site in 1994. This site typically records some of the higher eight-hour O_3 concentrations in the Denver area, frequently exceeding the current standard. This is a highest concentration oriented urban scale SLAMS monitor.

Aspen Park, 26137 Conifer Road (08 059 0013):

The Aspen Park site began operation in May 2009. It is intended to verify/refute model predictions of above normal O_3 levels. In addition, passive O_3 monitors used in the area in a 2007 study indicated the possibility of higher O_3 levels. The monitor is located in an urban setting at a Park and Ride facility off of Highway 285, at an elevation of just over 2,500 meters. Because the site is nearly 1,000 meters higher than the average metro area elevation, it should see O_3 levels that are larger than those seen in the metro area, as O_3 concentrations increase with increasing elevation. Whether or not the increased concentrations will be a health concern will be determined with the data gathered from this monitor. This is a SLAMS neighborhood scale monitor.

Durango - River City Hall, 1235 Camino del Rio (08 067 0004):

Durango is the second largest city on the western slope. The town is situated in the Animas River Valley in southwestern Colorado. Its elevation is approximately 1,981 meters above mean sea level. The Animas valley through Durango is steep and narrow. Even though little meteorological information is available for the area, the microclimate of Colorado mountain communities is typically characterized by cold air subsidence, or drainage flows during the evening and early morning hours and up valley flows during afternoon and early evening hours when solar heating is highest. Temperature inversions that trap air pollutants near the surface are common during night and early morning hours. This is a population-oriented neighborhood scale SLAMS monitor that samples continuously.

Fort Collins – CSU – Edison, 251 Edison Street (08 069 0009):

Fort Collins does not have the population to require a particulate monitor under Federal regulations. However, it is one of the largest cities along the Front Range. There are two population oriented neighborhood scale SLAMS monitors, a PM_{10} and a $PM_{2.5}$, that sample on a 1 in 3 day sampling schedule. There is also continuous monitor measuring PM_{10} and $PM_{2.5}$.

<u>Fort Collins - West, 3416 W. La Porte Avenue (08 069 0011):</u>

The Fort Collins - West monitor began operation in May of 2006. The location was established based on modeling and to satisfy permit conditions for a major source in the Fort Collins area. The levels recorded for the first season of operation showed consistently higher concentrations than the 708 S. Mason Street monitor. This is a highest concentration oriented urban scale SLAMS monitor.

<u>Fort Collins- Mason, 708 S. Mason Street (08 069 1004):</u>

The 708 S. Mason Street site began operation in December 1980 and is located one block west of College Avenue in the Central Business District. The one-hour CO standard of 35 ppm as a one-hour average has only been exceeded on December 1, 1983, at 4:00 P.M. and again at 5:00 P.M. The values reported were 43.9 ppm and 43.2 ppm respectively. The eight-hour standard of 9 ppm was exceeded one or more times a year from 1980 through 1989. The last exceedances were in 1991 on January 31 and December 6 when values of 9.8 ppm and 10.0 ppm, respectively, were recorded.

Fort Collins does not have the population to require a CO monitor under Federal regulation. However, it is one of the largest cities along the Front Range and was declared in nonattainment for CO in the mid-1970s after exceeding the eight-hour standard in both 1974 and 1975. The current level of monitoring is in part a function of the resulting CO State Maintenance Plan (SMP) for the area. This is a population-oriented neighborhood scale SLAMS monitor.

O_3 monitoring began in 1980 and continues today.

In March 2012, the meteorological tower was relocated from a freestanding tower on the west side of the shelter to a shelter mounted tower on the south side of the shelter due to the Mason Street Redevelopment Project.

<u>Grand Junction - Powell, 650 South Avenue (08 077 0017):</u>

Grand Junction is the largest city on the western slope in the broad valley of the Colorado River. The monitors are on county owned buildings in the south side of the city. The site is on the southern end of the central business district and close to the industrial area along the train tracks. It is about a 1 km north of the river and about 0.5 km east of the railroad yard. This site monitors for 24-hour and hourly PM_{10} as well as for 24-hour and hourly $PM_{2.5}$.

<u>Grand Junction - Pitkin, 645¼ Pitkin Avenue (08 077 0018):</u>

The Grand Junction-Pitkin CO monitor began operation in January 2004. This monitor replaced the site at the Stocker Stadium. The Stocker Stadium location had become less than ideal with the growth of the trees surrounding the park and the Division felt that a location nearer to the CBD would provide a better representation of CO concentration values for the city. The CO concentrations at the Stocker Stadium site had been declining from an eight-hour maximum in 1991 of 7.8 ppm to 3.3 ppm in 2003. This is a population-oriented, micro-scale SLAMS monitor.

Meteorological monitors were installed in 2004, and include wind speed, wind direction, temperature and relative humidity sensors.

Palisade Water Treatment, Rapid Creek Rd (08 077 0020):

The Palisade site is located at the Palisade Water Treatment Plant. The site is 4 km to the east-northeast of downtown Palisade, just into the De Beque Canyon area. The site is remote from any significant population and was established to measure maximum concentrations of O_3 that may result from summertime up-flow conditions into a topographical trap. Monitoring commenced in May 2008. This is an urban scale special purpose monitor.

Cortez, 106 W. North St (08 083 0006):

The Cortez site is located in downtown Cortez at the Montezuma County Health Department building. Cortez is the largest population center in Montezuma County in the southwest corner of Colorado. Currently, there are O_3 and $PM_{2.5}$ monitors in operation at this site.

The O_3 site was established to address community concerns of possible high O_3 from oil and gas and power plant emissions in the area. Many of these sources are in New Mexico. Monitoring commenced in May 2008. This is an urban scale SLAMS monitor.

Aspen - Library, 120 Mill Street (08 097 0006):

Aspen is at the upper end of a steep mountain valley. Aspen does not have an interstate running through it. Aspen was classified as nonattainment for PM_{10}, but it is now under an attainment/maintenance plan. The valley is more restricted at the lower end, and thus forms a tighter trap for pollutants. The transient population due to winter skiing and summer mountain activities greatly increases the population and traffic during these seasons. There is also a large down valley population that commutes to work each day from as far away as the Glenwood Springs area, which is 66 km to the northeast.

The population-oriented neighborhood scale SLAMS monitor is operating on a 1 in 3 sampling schedule.

Lamar - Municipal Building, 104 Parmenter Street (08 099 0002):

The Lamar Municipal site was established in January of 1996 as a more population-oriented location than the Power Plant. The Power Plant site was located on the northern edge of town (until it was decommissioned in 2012), while the Municipal site is near the center of the town. Both sites have recorded exceedances of the 24-hour PM_{10} standard of 150 µg m^{-3}, and both sites regularly record values above 100 µg m^{-3} as a 24-hour average. This is a population-oriented neighborhood scale SLAMS monitor on a daily sampling schedule.

Pueblo – Fountain School, 925 N. Glendale Ave (08 101 0015):

Pueblo is the third largest city in the state, not counting communities that are part of Metropolitan Denver. Pueblo is principally characterized by rolling plains and moderate slopes with elevations ranging from 1,364 to 1,467 meters. The Rocky Mountain Front Range is about 40 km west and Pikes Peak is easily visible on a clear day.

Meteorologically, Pueblo can be described as having mild weather with an average of about 300 days of sunshine per year. Generally, wind blows up valley from the southeast during the day and down valley from the west at night. Pueblo's average wind speed ranges from 11 km per hour in the fall and early winter to 18 km per hour in the spring.

This site was formerly located on the roof of the Public Works Building at 211 E. D St., in a relatively flat area two blocks northeast of the Arkansas River. At the end of June in 2011 the Public Works site was shut down and moved to the Magnet School site as the construction of a new multi-story building caused a major change in the flow dynamics of the site. The new site began operations in 2011. The distance and traffic estimate for the surrounding streets falls into the middle scale in accordance with federal guidelines found in 40 CFR, Part 58, and Appendix D.

Steamboat Springs, 136 6th Street (08 107 0003):

Like other ski towns, Steamboat Springs has problems with wintertime inversions, high traffic density, wood smoke, and street sand. These problems are exacerbated by temperature inversions that trap the pollution in the valleys.

The first site began operation in Steamboat Springs in June 1985 at 929 Lincoln Avenue. It was moved to the current location in October 1986. The 136 6th Street location not only provides a good indication of population exposure, since it is more centrally located, but it has better accessibility than the previous location. This is a population-oriented neighborhood scale SLAMS monitor on a daily sampling schedule.

Telluride, 333 W. Colorado Avenue (08 117 0002):

Telluride is a high mountain ski town in a narrow box end valley. The San Miguel River runs through the south end of town and the town is only about 1 km wide from north to south. The topography of this mountain valley regime creates temperature inversions that can last for several days during the winter. Temperature inversions can trap air pollution close to the ground. Telluride sits in a valley that trends mainly east to west, which can trap air pollutants more effectively since the prevailing winds at this latitude are the westerly and the San Miguel River Valley is closed off on the east end. This is a population-oriented neighborhood scale SLAMS monitor on a 1 in 3 day sampling schedule.

Greeley - Hospital, 1516 Hospital Road (08 123 0006):

The Greeley PM_{10} monitor is on the roof of a hospital office building at 1516 Hospital Road. Greeley Central High School is located immediately to the east of the monitoring site. Overall, this is in an area of mixed residential and commercial development that makes it a good population exposure, neighborhood scale monitor. The distance and traffic estimates for the most controlling street easily falls into the neighborhood scale in accordance with federal guidelines found in 40 CFR, Part 58. This is a population-oriented neighborhood scale SLAMS monitor on a 1 in 3 day sampling schedule.

Winds in this area are primarily out of the northwest, with dominant wind speeds less than 5 mph. Secondary winds are from the north, north-northwest and east-southeast, with the most frequent wind speeds also being less than 5 mph. The most recent available wind data for this station is for the period December 1986 to November 1987. Predominant residential growth patterns are to the west and north with large industrial growth expected to the west. There are two feedlots located about 18 km east of the town. There was a closer feedlot on the east edge of town, but it was shut down in early 1999, after the town of Greeley purchased the land in 1997.

Platteville, 1004 Main Street (08 123 0008):

Platteville is located immediately west of Highway 85 along the Platte River valley bottom approximately 8 km east of I -25, at an elevation of 1,470 meters. The area is characterized by relatively flat terrain and is located about 2 km east of the South Platte. The National Oceanic and Atmospheric Administration (NOAA) operated the Prototype Regional Observational Forecasting System Mesonet network of meteorological monitors from the early 1990s through the mid 1990s in the northern Colorado Front Range area. Based on this data, the area around Platteville is one of the last places in the wintertime that the cold pool of air that is formed by temperature inversions will burn off. This is due to solar heating. The upslope/down slope Platte River Valley drainage and wind flows between Denver and Greeley make Platteville a good place to monitor $PM_{2.5}$. These characteristics also make it an ideal location for chemical speciation sampling, which began at the end of 2001.

The Platteville site is located at 1004 Main Street at the South Valley Middle School, located on the south side of town on Main Street. The school is a one-story building and it has a roof hatch from a locked interior room providing easy access to its large flat roof. There is a 2-story gym attached to the building approximately 28 meters to the Northwest of the monitor. The location of the Platteville monitor falls into the regional transport scale in accordance with federal guidelines found in 40 CFR, Part 58, and Appendix D. There are three monitors here. Two are population oriented regional scale monitors, one of which is on the SLAMS network and the other is for supplemental speciation. The SLAMS monitor is operating on a 1 in 3 day sampling schedule, while the speciation monitor is operating on a 1 in 6 day schedule. The remaining monitor is a population oriented neighborhood scale supplemental speciation monitor on a 1 in 6 day sampling schedule.

Greeley - Weld County Tower, 3101 35th Avenue (08 123 0009):

The Weld County Tower O_3 monitor began operation in June 2002. The site was established after the 811 15th Street building was sold and was scheduled for conversion to other uses. The Weld County Tower site has generally recorded levels greater than the old site. This is a population-oriented neighborhood scale SLAMS monitor.

Meteorological monitoring began in February of 2012.

Greeley West Annex Bldg, 905 10th Avenue (08 123 0010):

Greeley does not have the population to require a CO monitor under Federal regulations. However, it is one of the larger cities along the Front Range and was declared in nonattainment for CO in the late-1970s after exceeding the eight-hour standard in 1976 and 1977. The first Greeley monitor operated from December 1976 to December 1980. It was located at 15th Street and 16th Avenue and exceeded the eight-hour standard numerous times from 1976 through 1980. The monitor is a population-oriented neighborhood scale SLAMS monitor.

The 811 15th Street location began operation in November 1981 and was discontinued in 2002. The current monitor is located in the Weld County West Annex building, and began operations in December 2003. This location is in the Greeley CBD. The levels recorded at this site are comparable but slightly lower than those at the former 811 15th Street site, about a quarter of the eight-hour standard.