COLORADO

Air Pollution Control Division

Department of Public Health & Environment

Technical Services Program

2018 Air Quality Data Report

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COLORADO
AIR QUALITY
DATA REPORT
2018

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Glossary of Terms

APCD	Air Pollution Control Division
AQS	Air Quality System (EPA database)
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
DQO	Data Quality Objective
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	Oxides of nitrogen
NO_y	Total reactive nitrogen
NPS	National Park Service
O_3	Ozone
Pb	Lead
$PM_{2.5}$	Particulate matter with an equivalent diameter less than or equal to 2.5 micrometers
PM_{10}	Particulate matter with an equivalent diameter less than or equal to 10 micrometers
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 Particulates
µg	Microgram (10^{-6} grams)
USFS	U.S. Forest Service
VOC	Volatile Organic Compound

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Introduction

The Air Pollution Control Division (APCD) of the Colorado Department of Public Health and Environment (CDPHE) has prepared the 2018 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 APCD in 2018. 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

APCD conducted air quality and meteorological monitoring operations at 51 locations statewide throughout 2018. Ozone (O_3) and particulate matter (PM) monitors, including those for particulate matter less than 10 μm in diameter (PM_{10}) and particulate matter less than 2.5 μm in diameter ($PM_{2.5}$), are the most abundant and widespread monitors in the network. During 2018, there were PM_{10} monitors at 24 locations, $PM_{2.5}$ monitors at 16 locations, O_3 monitors at 21 locations, carbon monoxide (CO) monitors at eight locations, nitrogen dioxide (NO_2) monitors at five locations, and sulfur dioxide (SO_2) monitors at four locations. APCD also operated 21 meteorological sites statewide for the continuous measurement of wind speed, wind direction, and temperature.

A map of APCD air quality stations is shown in Figure 1.2 and the parameters monitored at each location are given in Table 1.1.

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 monitoring station in downtown Denver at the intersection of 21st Street and Broadway, which was the area that was thought at the time to represent the best site 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 were 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.

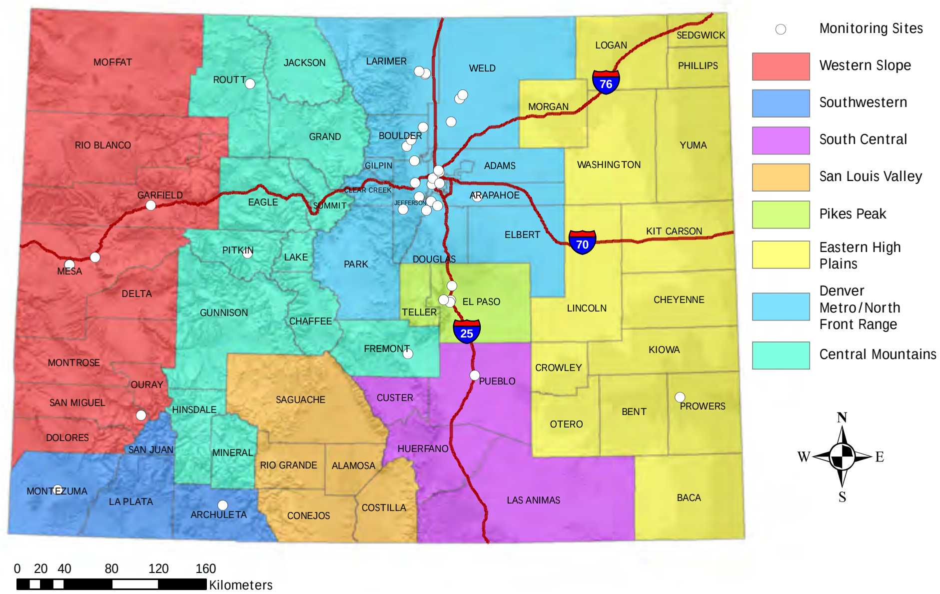

Figure 1.1: Counties and multi-county monitoring regions discussed in this report.

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 approximately 241,531, according to the 2010 U.S. Census. Skiing, tourism, ranching, mining, and correctional facilities are the primary industries. The Black Canyon of the Gunnison National Park is located in this region.

The primary monitoring concern in this region is centered around particulate pollution from wood burning and road dust. During 2018, there were five particulate monitoring sites operated by APCD in the Central Mountains region. APCD did not operate any gaseous monitors in this region during 2018. All of this region complies with federal air quality standards.

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. This 13 county region comprises the largest population base in the state of Colorado with approximately 3,943,779 people living in the area, according to the 2010 U.S. Census. This region includes Rocky Mountain National Park and several other wilderness areas. Since 2002, the region has complied with all National Ambient Air Quality Standards, except for ozone. The area has been exceeding the EPA's 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 2015, the EPA reviewed criteria for ozone and related photochemical oxidants and revised the primary and secondary 8 hour ozone standards further downward to a level of 0.070 parts per million (ppm).

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 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.

During 2018, there were 49 air quality and meteorological monitors at 24 individual sites in the Northern Front Range Region. There were six CO monitors, 14 O_3 monitors, five NO_2 monitors, three SO_2 monitors, as well as eight PM_{10} monitors, 13 $PM_{2.5}$ monitors, and 15 meteorological towers. There were also 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 fifteen counties on the plains of eastern Colorado. The area is semiarid and often windy. The area's population is approximately 134,472, according to the 2010 U.S. Census. 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.

Historically, there have been a number of communities in the Eastern High Plains Region 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 through early 1990s after a review showed that the concentrations were well below the standards and trending downward. The only sampling sites left in operation in this region are located in Lamar where a meteorological monitoring site and a particulate monitoring site are located.

1.1.2.4 Pikes Peak Region

The Pikes Peak region includes El Paso and Teller counties. The area has a population of approximately 737,782, 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, which are 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, two exceedances of the level of the SO_2 standard were observed at the Highway 24 site during 2014-2015. These elevated values have not resulted in a violation of the NAAQS and SO_2 concentrations have been trending downward at the Highway 24 site since 2016 (see subsection 4.4.4).

During 2018, there was one CO monitor, one SO_2 monitor, and two O_3 monitors in the Pikes Peak region, as well as one PM_{10} monitor and one $PM_{2.5}$ monitor.

1.1.2.5 San Luis Valley Region

Colorado's San Luis Valley region is located 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 of this area is approximately 46,271, according to the 2010 U.S. Census. 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.

During 2018, there was one PM_{10} monitoring site in the region.

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 194,302, 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 APCD has conducted particulate monitoring in both Walsenburg and Trinidad, but that monitoring was discontinued in 1979 and 1985, respectively, due to low concentrations.

During 2018, there were two particulate monitors (one PM_{10} monitor and one $PM_{2.5}$ monitor) operated in the South Central Region, both at a site located in the city of 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 approximately 100,480, 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.

During 2018, there was one O_3 monitor in Cortez and two PM_{10} monitors, one located in Pagosa Springs and another in Durango.

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 approximately 323,997, 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 complied with federal air quality standards during 2018.

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
08-001-0008	Tri County Health (TCH)	Adams					X	X	
08-001-3001	Welby	Adams	X	X	X	X	X		X
08-003-0003	Alamosa - Municipal Bldg.	Alamosa					X		
08-005-0002	Highland Reservoir	Arapahoe	X						X
08-005-0005	Arapaho Community College (ACC)	Arapahoe						X	
08-005-0006	Aurora - East	Arapahoe	X						X
08-007-0001	Pagosa Springs School	Archuleta					X		
08-013-0003	Longmont - Municipal Bldg.	Boulder					X	X	
08-013-0012	Boulder Chamber of Commerce (CC)	Boulder					X	X	
08-013-0014	Boulder Reservoir	Boulder	X						X
08-013-1001	Boulder - CU Athens	Boulder						X	
08-029-0004	Delta Health Dept.	Delta					X		
08-031-0002	CAMP	Denver	X	X	X	X	X	X	X
08-031-0013	National Jewish Health (NJH)	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
08-031-0028	I-25: Globeville	Denver			X			X	X
08-035-0004	Chatfield State Park	Douglas	X					X	X
08-041-0013	U.S. Air Force Academy (USAFA)	El Paso	X						
08-041-0015	Highway 24	El Paso		X		X			X
08-041-0016	Manitou Springs	El Paso	X						
08-041-0017	Colorado College	El Paso					X	X	
08-043-0003	Cañon City - City Hall	Fremont					X		
08-045-0005	Parachute - Elementary School	Garfield					X		
08-045-0012	Rifle - Health Dept.	Garfield	X						
08-045-0023	Rifle - Garfield County Library	Garfield					X		
08-051-0004	Crested Butte	Gunnison					X		
08-051-0007	Mt. Crested Butte	Gunnison					X		
08-059-0002	Arvada	Jefferson							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 - River City Hall	La Plata					X		
08-069-0009	Fort Collins - CSU	Larimer					X	X	
08-069-0011	Fort Collins - West	Larimer	X						
08-069-1004	Fort 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 Water Treatment	Mesa	X						X
08-081-0003	Elk Springs	Moffat	X						X
08-083-0006	Cortez - Health Dept.	Montezuma	X						
08-085-0005	Paradox	Montrose	X						X
08-097-0008	Aspen	Pitkin					X		
08-099-0002	Lamar - Municipal Bldg.	Prowers					X		
08-099-0003	Lamar Port of Entry	Prowers							X
08-101-0015	Pueblo - Fountain School	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 - Middle School	Weld						X	
08-123-0009	Greeley - County Tower	Weld	X	X					X

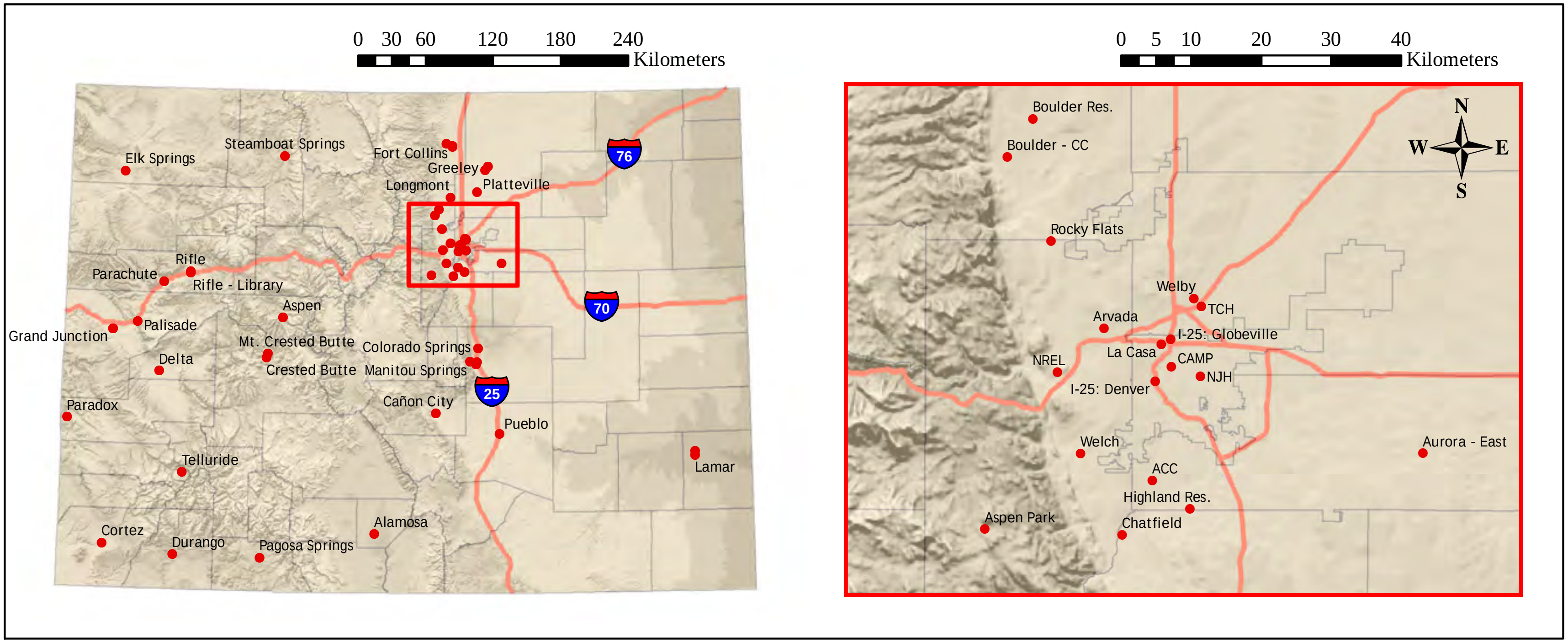

Figure 1.2: Map of Colorado with an inset map of the Denver metropolitan area showing the location of all monitoring sites operated by APCD and listed in Table 1.1. For the purpose of improving the readability of the map, labels for monitoring sites in Fort Collins, Grand Junction, Colorado Springs, Lamar, and Rifle have been combined under a single label. 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, and particulate matter, which is currently split into PM_{10} and $PM_{2.5}$ size fractions. 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 are 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.

In 2015, based on an EPA review of O_3 health effects studies, EPA revised the level of both the primary and secondary standards. EPA revised the primary and secondary ozone standard levels to 0.070 parts per million (ppm), and retained their forms (fourth-highest daily maximum, averaged across three consecutive years) and averaging times (eight hours). The final rule making was effective on October 26^{th} 2015.

Due to low measured concentrations over the last decade, APCD no longer operates lead monitors. Historic trends data are available in data reports from previous years [1].

2.1 Summary of Exceedances

Table 2.2 is a summary of those 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.

[1] http://www.colorado.gov/airquality/tech_doc_repository.aspx

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	98^{th} percentile of 1-hour daily maximum concentrations, averaged over three years
	Primary and Secondary	Annual	53 ppb	Annual mean
Sulfur Dioxide (SO_2)	Primary	1-hr	75 ppb	99^{th} percentile of 1-hour daily maximum concentrations, averaged over three years
	Secondary	3-hr	0.5 ppm	Not to be exceeded more than once per year
Ozone (O_3)	Primary and Secondary	8-hr	0.070 ppm	Annual fourth-highest daily maximum 8-hr concentration, averaged over three years
PM_{10}	Primary and Secondary	24-hr	150 µg m^{-3}	Not to be exceeded more than once per year on average over three years
$PM_{2.5}$	Primary	Annual	12 µg m^{-3}	Annual mean, averaged over three years
	Secondary	Annual	15 µg m^{-3}	Annual mean, averaged over three years
	Primary and Secondary	24-hr	35 µg m^{-3}	98^{th} percentile, averaged over three years

Table 2.2: Exceedance summary table for APCD monitoring sites showing the number of days in exceedance for O_3, PM_{10}, and $PM_{2.5}$ in 2017 and 2018. Numbers in parenthesis are additional exceedance events 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**	**2017**			**2018**		
		O_3	PM_{10}	$PM_{2.5}$	O_3	PM_{10}	$PM_{2.5}$
08-001-0008	Tri County Health (TCH)			2		1	1
08-003-0003	Alamosa - Municipal Bldg.					1	
08-005-0002	Highland Reservoir	2			7		
08-005-0005	Arapaho Community College (ACC)			1			
08-005-0006	Aurora - East	1			3		
08-013-0003	Longmont - Municipal Bldg.			1			2
08-013-0012	Boulder Chamber of Commerce (CC)			1			
08-013-0014	Boulder Reservoir	1			5		
08-031-0002	CAMP			4	1		5
08-031-0013	National Jewish Health (NJH)						1
08-031-0026	La Casa			2	1		1
08-031-0027	I-25: Denver			2			1
08-031-0028	I-25: Globeville			1			1
08-035-0004	Chatfield State Park	2		2	10		3
08-041-0013	U.S. Air Force Academy (USAFA)				2		
08-041-0016	Manitou Springs				1		
08-041-0017	Colorado College			1			1
08-045-0012	Rifle - Health Dept.				1		
08-059-0006	Rocky Flats - N.	3			16		
08-059-0011	NREL	5			10		
08-069-0009	Fort Collins - CSU			1			1
08-069-0011	Fort Collins - West	3			8		
08-069-1004	Fort Collins - Mason				1		
08-077-0020	Palisade Water Treatment				1		
08-085-0005	Paradox				1		
08-099-0002	Lamar - Municipal Bldg.					1	
08-101-0015	Pueblo - Fountain School		1	1		1	
08-123-0006	Greeley - Hospital			2			2
08-123-0008	Platteville - Middle School			1			1
08-123-0009	Greeley - County Tower	1			2		

2.2 General Statistics for Criteria Pollutants

In this section, historical trends in ambient pollutant concentrations are illustrated using NAAQS standard values measured throughout Colorado in each year. This comparison is for reference only as the NAAQS apply only over the averaging periods shown in Table 2.1 (typically a three-year period). Subsequent sections of this report include an evaluation of the concentrations of each pollutant 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.[2]

The National Emissions Inventory[3] estimates that 31% 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 22% of emissions, making transportation approximately 53% of the total CO emissions nationwide. Figure 2.1 illustrates the trend of national CO emissions from 1970 through 2018.

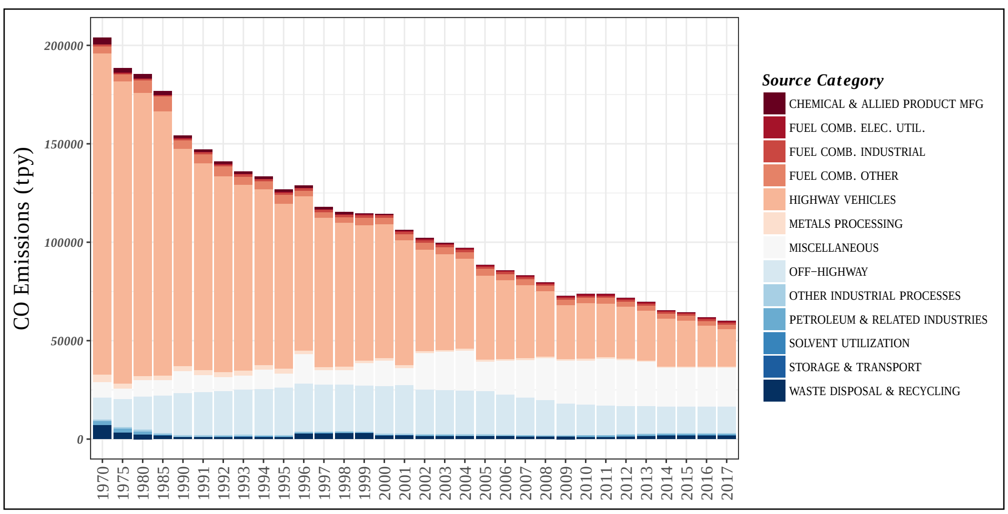

Figure 2.1: Trends in national carbon monoxide emissions from 1970 to 2018.

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 eight-hour primary standard at 9 parts per million (ppm) and a one-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.

The one-hour and eight-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 one-hour or eight-hour standard in the same calendar year. An EPA directive states that the comparison with the CO standards will be made in integers. Fractions

[2]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

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

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 eight-hour and one-hour standards, respectively.

The eight CO monitors currently operated by 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. Monitors have been installed at two near roadway NO_2 sites (I-25 Denver and I-25 Globeville) 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 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 eight-hour standard. In 1975, 9 of 11 (81%) state-operated monitors exceeded the eight-hour standard. In 1980, 13 of 17 (77%) state-operated monitors exceeded the eight-hour standard. Since 1996, no state-operated monitors have recorded a violation of the eight-hour standard. In 2018, the highest statewide second maximum eight-hour concentration was 2.9 ppm as recorded at the I-25 Denver station. Historical trends in CO NAAQS values for the CAMP and Welby stations are shown in Figure 2.2 and Figure 2.3 for illustration purposes.

Figure 2.4 shows the trend in maximum one-hour CO values recorded statewide between 1965 and 2018. The highest one-hour concentration ever recorded at any of the state-operated monitors was 79.0 ppm, which was recorded at the Denver CAMP monitor in 1968. In 2018 the highest one-hour concentration was 4.5 ppm, also recorded at the Denver CAMP station. The one-hour annual maximum concentrations have declined from more than twice the standard in the late 1960s to about one quarter of the standard today. Table 2.3 presents the historical maximum values recorded in Colorado.

Spatial trends in maximum one-hour CO across the continental U.S. are shown in Figure 2.5. National and statewide maximum CO values for 2018 are presented in Table 2.4.

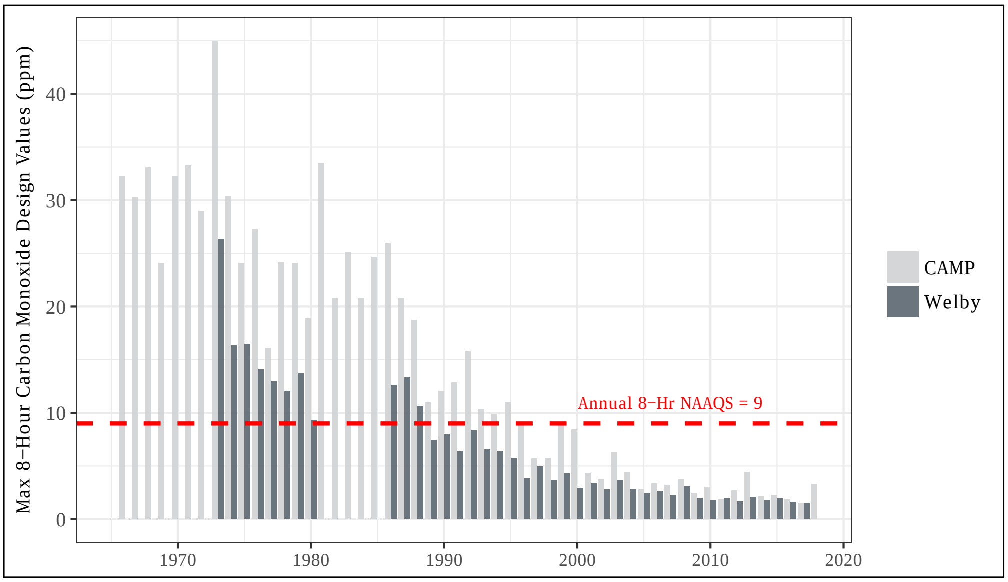

Figure 2.2: Historical record of maximum eight-hour carbon monoxide values at the CAMP and Welby stations.

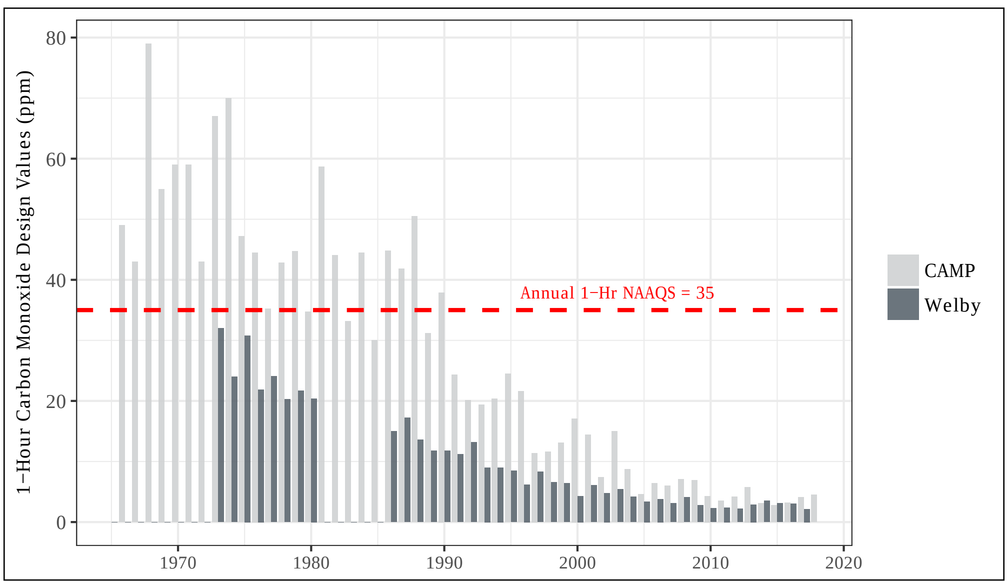

Figure 2.3: Historical record of maximum one-hour carbon monoxide values at the CAMP and Welby stations.

Table 2.3: Historical maximum one-hour CO concentrations in Colorado

Site	Max 1-Hour CO (ppm)	Year
CAMP	79.0	1968
CAMP	70.0	1974
CAMP	67.0	1973
Denver	64.9	1979
CAMP	59	1970
2018 Maximum		
CAMP	4.5	2018

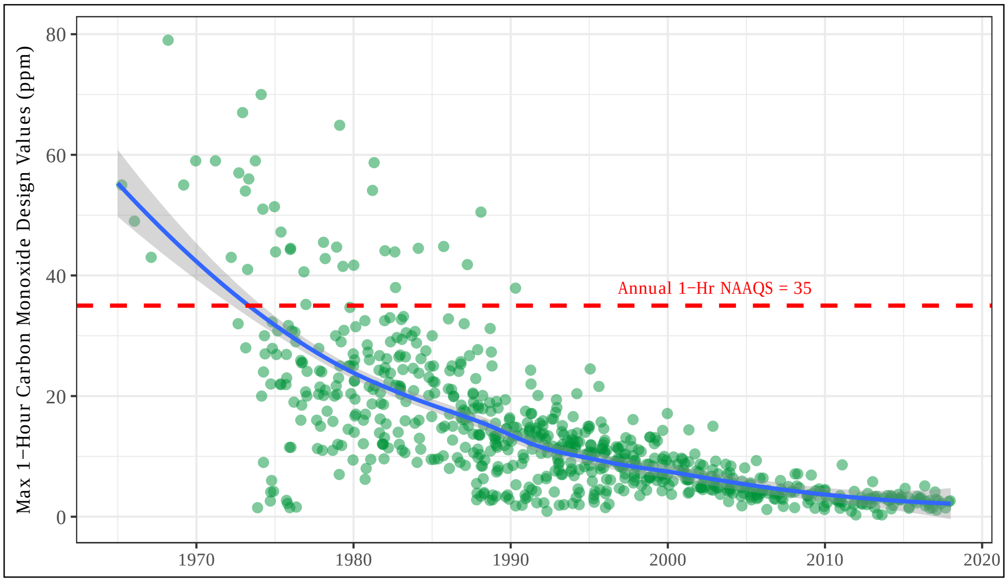

Figure 2.4: Statewide historical record of maximum one-hour carbon monoxide values. The mean trend obtained using a generalized additive model is shown as a blue line.

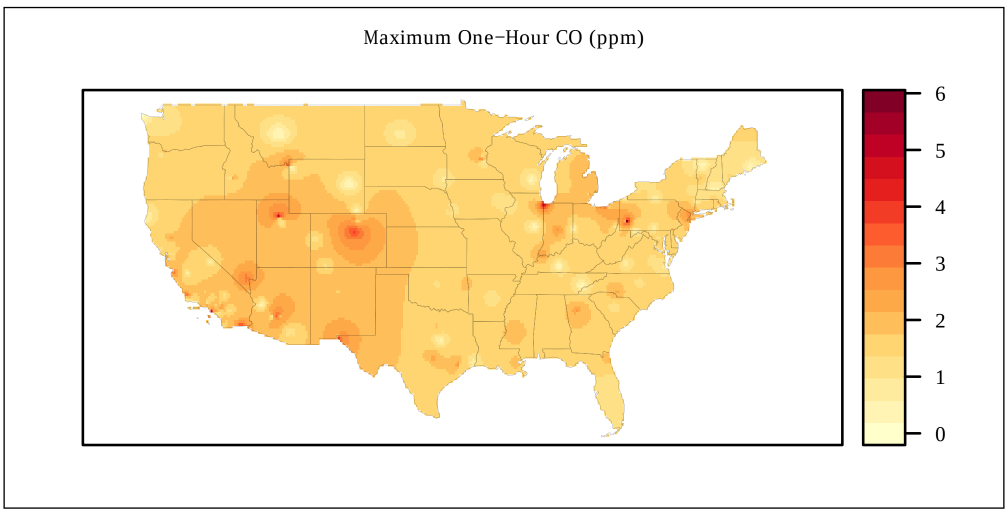

Figure 2.5: Interpolation map of maximum one-hour CO values for air quality monitoring stations in the continental U.S. during 2018

Table 2.4: National (left) and statewide (right) rankings of CO monitors by maximum one-hour concentration in 2018

Nationwide (275 Monitors)					Colorado (eight Monitors)			
Rank	**City**	**State**	**CO (ppm)**	**Exceedances**	**Rank**	**Site**	**CO (ppm)**	**Exceedances**
1	Wilkinsburg	PA	7.4	0	9	CAMP	4.5	0
2	Salt Lake City	UT	5.9	0	13	I-25: Denver	4.0	0
3	Cleveland	OH	5.4	0	22	La Casa	3.8	0
4	El Paso	TX	5.2	0	27	Highway 24	2.8	0
5	Jersey City	NJ	5.1	0	33	Fort Collins	2.6	0

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 2.6. 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.[4] 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.

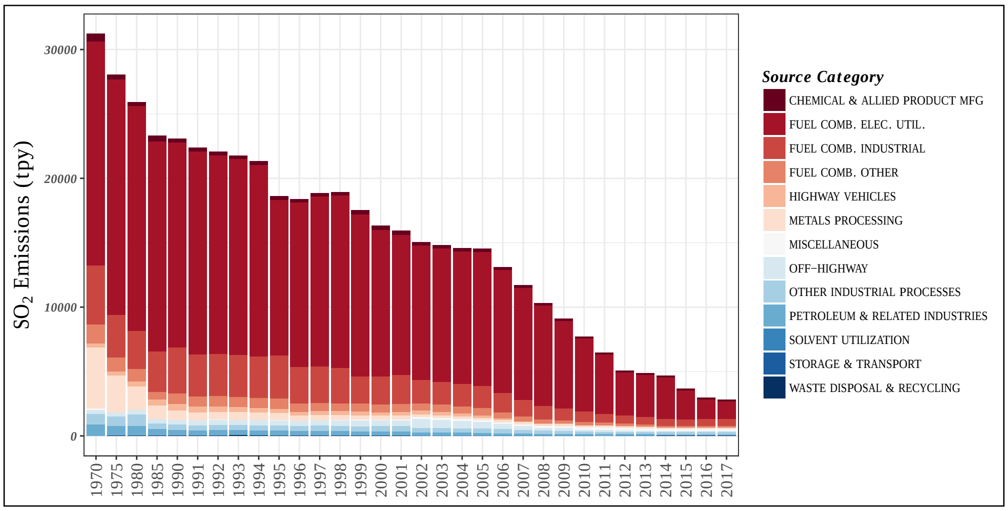

Figure 2.6: Trends in national sulfur dioxide emissions from 1970 to 2018.

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 three-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 one-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 one-hour standard at 75 ppb.

APCD has monitored SO_2 at eight locations in Colorado in the past. Currently, there are four SO_2 monitoring sites in operation. No area of the country has been found to be out of compliance with the current SO_2 standards. There were two exceedances of the one-hour standard at the Highway 24 (Colorado Springs) site during the 2014-2015 period (see Table 2.2); however, there was no exceedance recorded at any site in 2018.

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.

[4] 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

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. Ambient SO_2 levels have decreased significantly in the past forty years, with one-hour SO_2 annual 99^{th} percentile values at the CAMP station having declined from greater than 200 ppb in the late 1960s and early 1970s to 7.9 ppb in 2018, as shown in Figure 2.7. Figure 2.8 shows the declining trend in sulfur dioxide readings over the last several decades, with relatively low concentrations of sulfur dioxide recorded at APCD monitors. This same trend is evident, although not as pronounced, in the three-hour and 24-hour averages. Table 2.5 presents the historical maximum one-hour concentrations recorded in Colorado. National and statewide maximum values for 2018 are presented in Table 2.6.

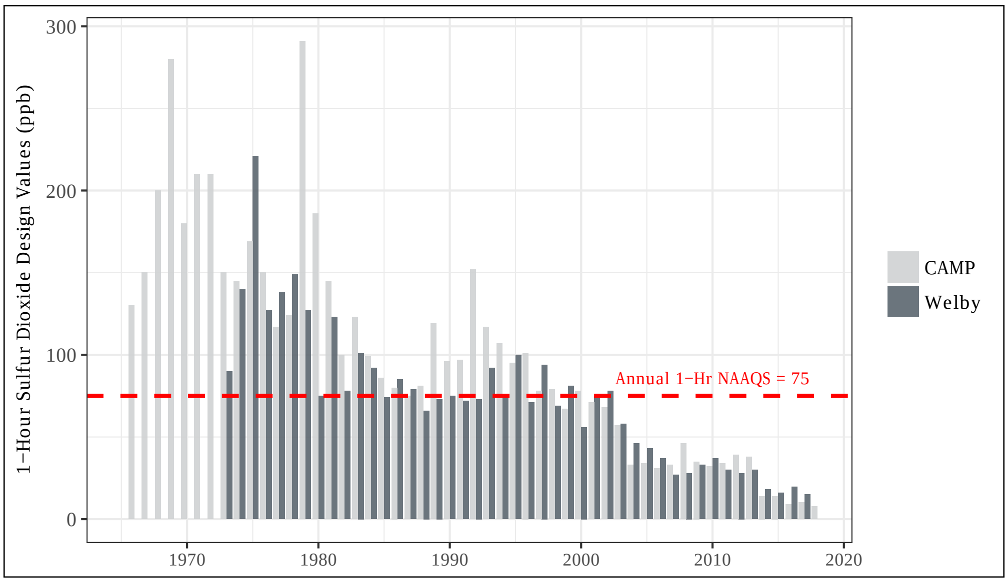

Figure 2.7: Historical record of one-hour sulfur dioxide annual 99^{th} percentile values at the CAMP and Welby stations.

Table 2.5: Historical maximum one-hour SO_2 concentrations in Colorado

Site	Max 1-Hour SO_2 (ppb)	Year
Rio Blanco	733	1976
Denver	550	1974
CAMP	490	1969
CAMP	360	1965
Denver	328	1976
2018 Maximum		
Highway 24	16	2018

Table 2.6: National (left) and statewide (right) rankings of SO_2 monitors by maximum one-hour concentration in 2018

Nationwide (467 Monitors)					Colorado (four Monitors)			
Rank	**City**	**State**	**SO_2 (ppb)**	**Exceedances**	**Rank**	**Site**	**SO_2 (ppb)**	**Exceedances**
1	Keyser	WV	531	5	203	Highway 24	16	0
2	Big Spring	TX	460	74	230	La Casa	13	0
3	Westernport	MD	323	114	238	CAMP	13	0
4	West Canton	NC	302	36	331	Welby	6	0
5	Hayden	AZ	265	16				

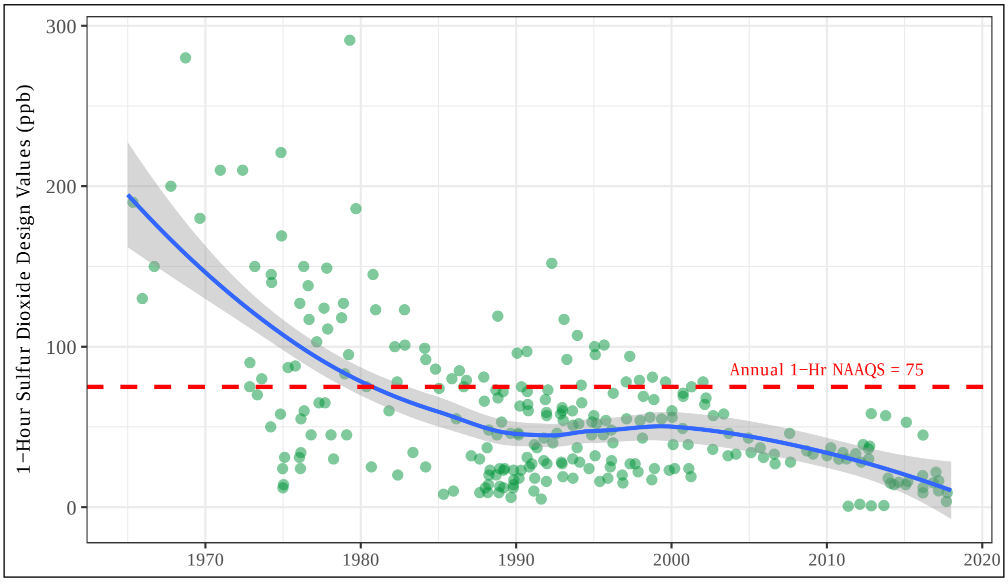

Figure 2.8: Statewide historical record of one-hour sulfur dioxide annual 99th percentile values. The mean trend obtained using a generalized additive model is shown as a blue line.

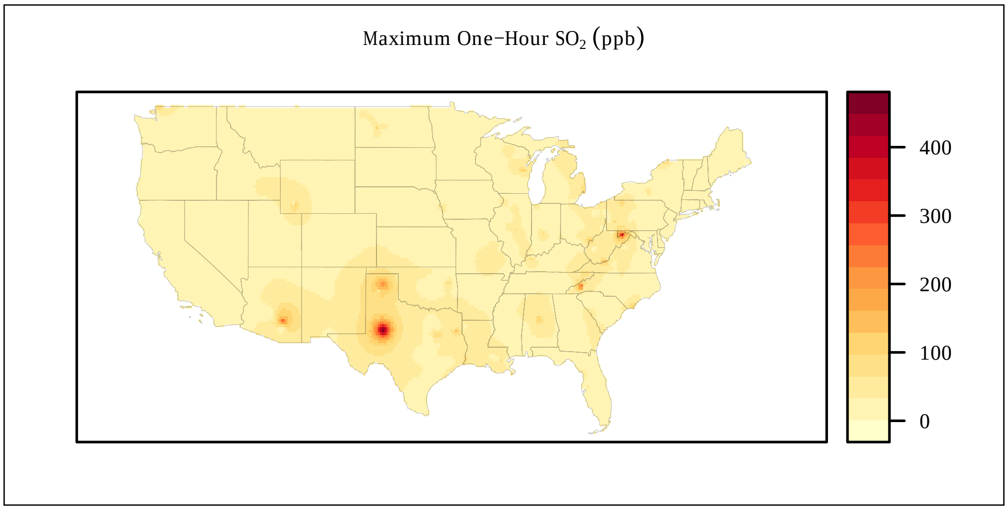

Figure 2.9: Interpolation map of maximum one-hour SO_2 values for air quality monitoring stations in the continental U.S. during 2018

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, and chemical solvents are some of the major sources of NO_x and VOCs (see Figure 2.10 and Figure 2.13). 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.[5] 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 miles away from their original source regions.

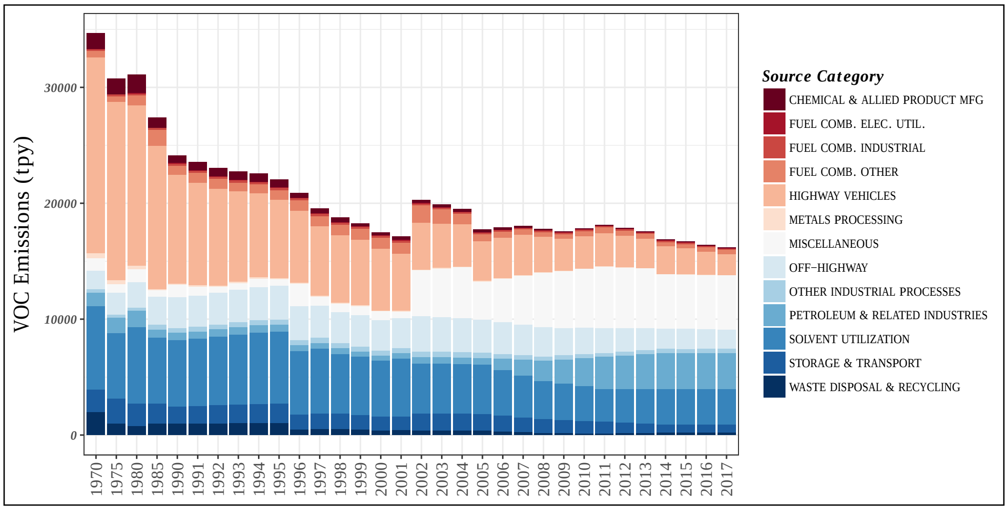

Figure 2.10: Trends in national VOC emissions from 1970 to 2018.

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 and typically reaches maximum concentrations 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. can be 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.[6]

2.2.3.1 Standards

In 1971, the EPA promulgated the first NAAQS for photochemical oxidants, setting a one-hour primary standard at 80 ppb (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 eight-hour standard of 75 ppb. On November 26, 2014, the EPA again proposed lowering the O_3 NAAQS standard from 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. To ensure compliance with the 2008 and 2015 O_3 standards, the EPA has extended the O_3 monitoring requirements for Colorado

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

[6]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

by 5 months, essentially redefining Colorado's ozone season as January through December. In 2018, six of 21 O_3 sites operated by APCD had three-year NAAQS values in excess of the current eight-hour O_3 standard of 70 ppb.

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.[7] 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)[8]. 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.

2.2.3.3 Statewide Summaries

As illustrated in Figure 2.11, statewide average O_3 values have historically fluctuated around the standard. In recent years, the trend has been downward, but the averages seem to fluctuate within the amount of variance seen for the last several years.

Ozone monitoring began in 1972 at the Denver CAMP station, and eight exceedances of the then-applicable one-hour standard were recorded that year. Table 2.7 lists the five highest eight-hour concentrations recorded in Colorado. Note that all five maximum historical values were recorded within the first three years of ozone monitoring. National and statewide maximum eight-hour values for 2018 are presented in Table 2.8.

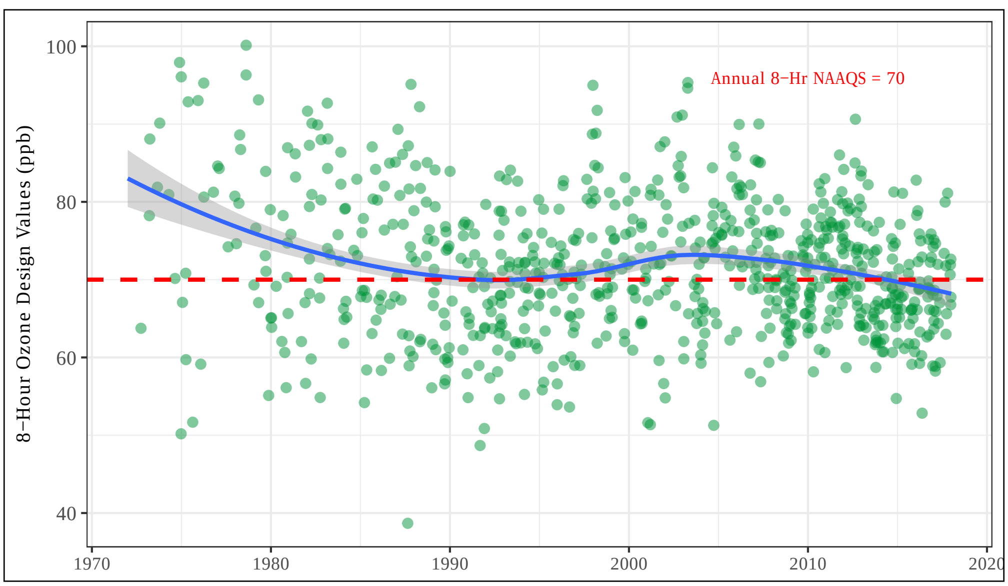

Figure 2.11: Statewide historical record of eight-hour ozone NAAQS values. The mean trend obtained using a generalized additive model is shown as a blue line.

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

Table 2.7: Historical maximum eight-hour O_3 concentrations in Colorado

Site	Max 8-Hour O_3 (ppb)	Year
CAMP	310	1972
CAMP	264	1973
Arvada	198	1973
Denver	194	1973
Welby	156	1974
2018 Maximum		
Boulder	89	2018

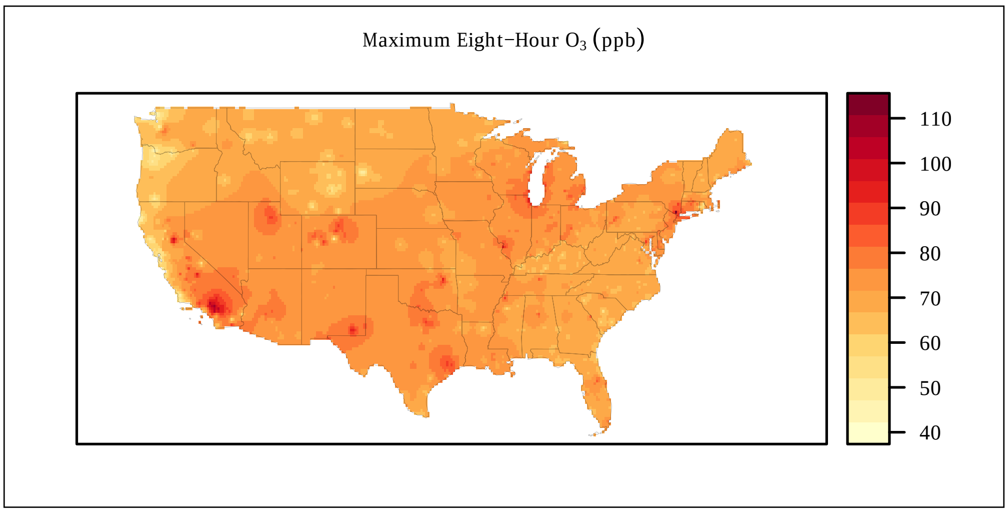

Figure 2.12: Interpolation map of maximum eight-hour O_3 values for air quality monitoring stations in the continental U.S. during 2018

Table 2.8: National (left) and statewide (right) rankings of O_3 monitors by maximum eight-hour concentration in 2018

Nationwide (1,236 Monitors)					Colorado (21 Monitors)			
Rank	**City**	**State**	**O_3 (ppb)**	**Exceedances**	**Rank**	**Site**	**O_3 (ppb)**	**Exceedances**
1	Crestline	CA	125	43	60	Boulder	89	29
2	San Bernardino	CA	116	33	68	Highland Reservoir	88	13
3	Auburn	CA	115	30	69	Chatfield SP	88	24
4	Mt. Ivy	NY	115	6	71	Fort Collins	88	25
5	Colfax	CA	114	27	87	Rifle	86	1

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.[9]

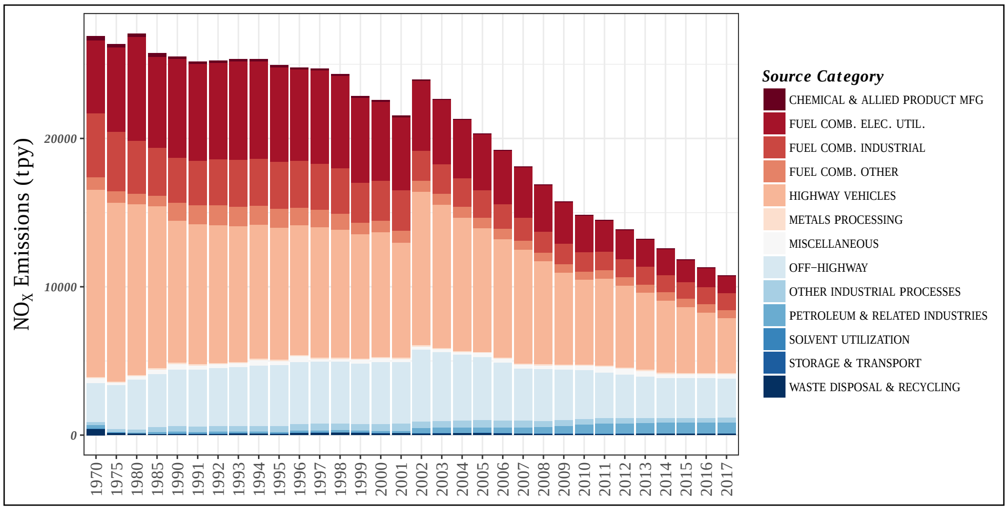

Figure 2.13: Trends in national NO_x emissions from 1970 to 2018.

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 1,000,000 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 (installed in 2013) and I-25 Globeville (installed in 2015) sites. 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 site satisfies this requirement. Additionally, the Welby monitoring location serves as a an EPA Regional Administrated NO_2 site targeted at the characterization of NO_2 exposure for susceptible and vulnerable populations.

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

[9]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.

aerosols, which result from NO and NO_2 combining with water vapor in the air, have been consistently linked to Denver's visibility problems.[10]

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 2.14 and Figure 2.15 show that levels have declined minimally but remained below the NAAQS at both the Welby and CAMP monitors over the past ten years in terms of both the annual mean and one-hour NAAQS values. The statewide historical trend is summarized in Figure 2.16. Table 2.9 presents the historical maximum one-hour NO_2 values recorded in Colorado. National and statewide maximum values for 2018 are presented in Table 2.10.

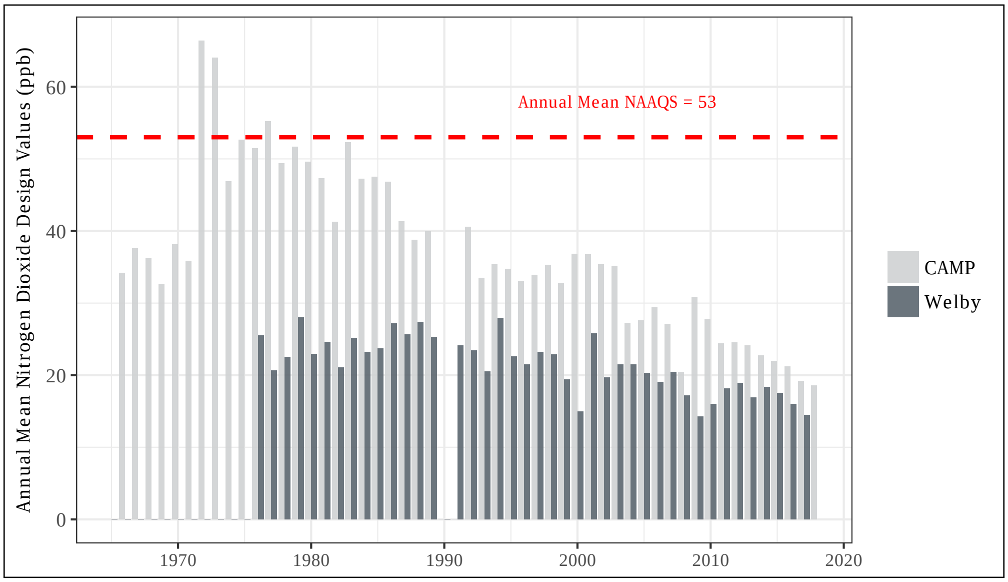

Figure 2.14: Historical record of annual mean nitrogen dioxide NAAQS values at the CAMP and Welby stations.

Table 2.9: Historical maximum one-hour NO_2 concentrations in Colorado

Site	Max 1-Hour NO_2 (ppb)	Year
Denver	639	1983
CAMP	620	1973
CAMP	462	1989
CAMP	448	1983
CAMP	420	1974
2018 Maximum		
I-25: Globeville	103	2018

[10]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.

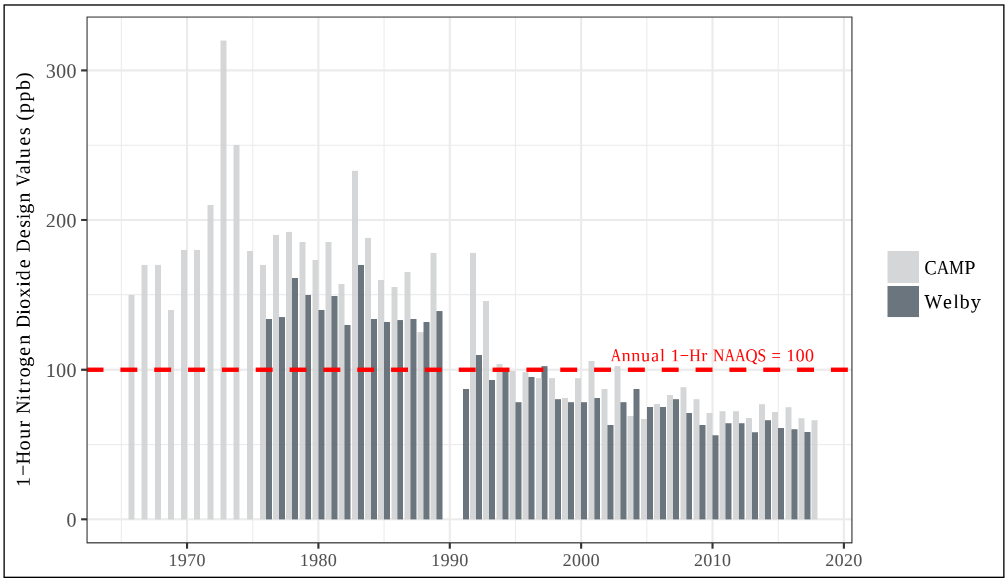

Figure 2.15: Historical record of one-hour nitrogen dioxide NAAQS values at the CAMP and Welby stations.

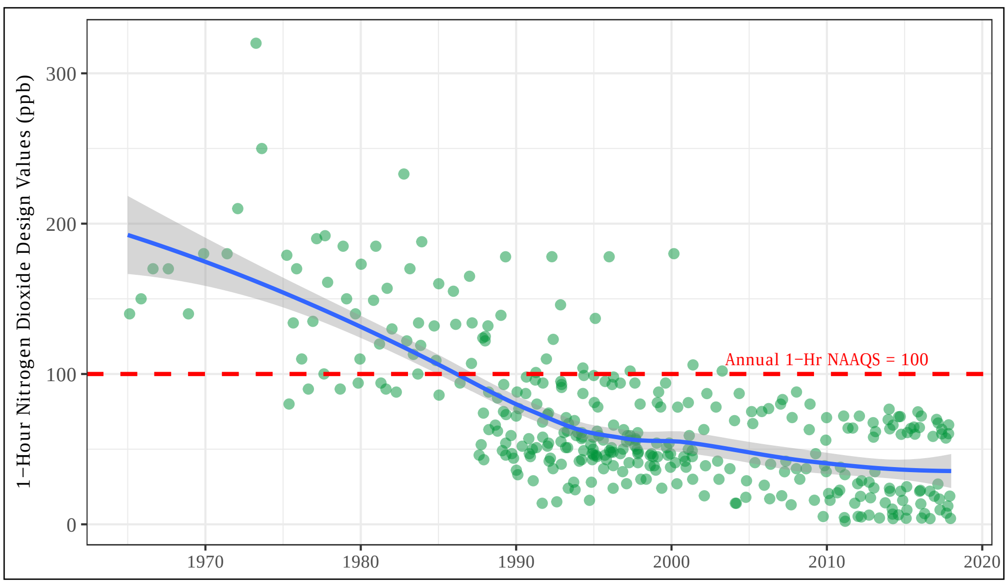

Figure 2.16: Statewide historical record of one-hour nitrogen dioxide NAAQS values. The mean trend obtained using a generalized additive model is shown as a blue line.

Table 2.10: National (left) and statewide (right) rankings of NO_2 monitors by maximum one-hour concentration in 2018

Nationwide (445 Monitors)					Colorado (five Monitors)			
Rank	City	State	NO_2 (ppb)	Exceedances	Rank	Site	NO_2 (ppb)	Exceedances
1	Anacortes	WA	229	2	5	I-25: Globeville	103	1
2	Brigham City	UT	174	1	6	CAMP	103	1
3	Fort Lee	NJ	131	1	9	I-25: Denver	86	0
4	East Hartford	CT	119	1	18	Welby	78	0
5	Denver	CO	103	1	50	La Casa	64	0

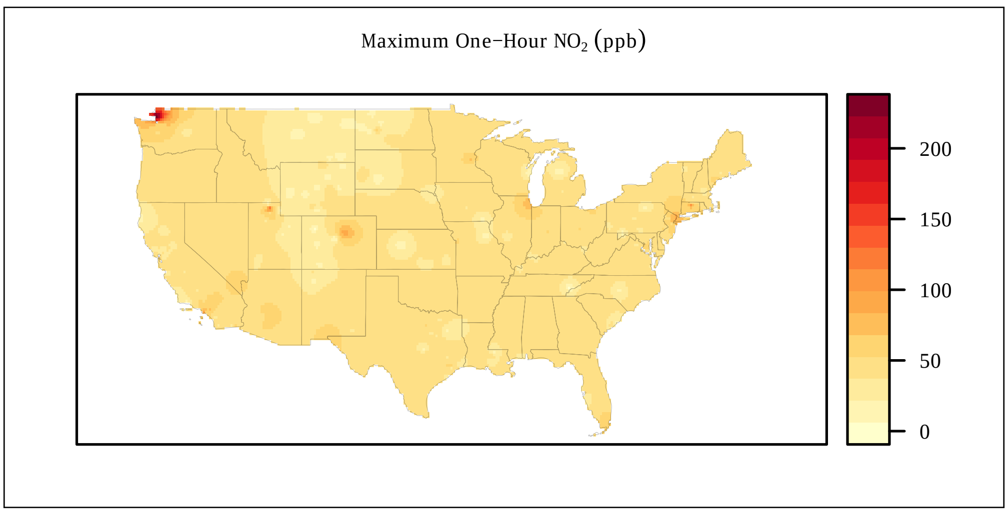

Figure 2.17: Interpolation map of maximum one-hour NO_2 values for air quality monitoring stations in the continental U.S. during 2018

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 (e.g., 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 in the lungs, 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 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 gases 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 the 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 trend in national PM emissions from 1990 to 2018 is shown in Figure 2.19 for illustration purposes.

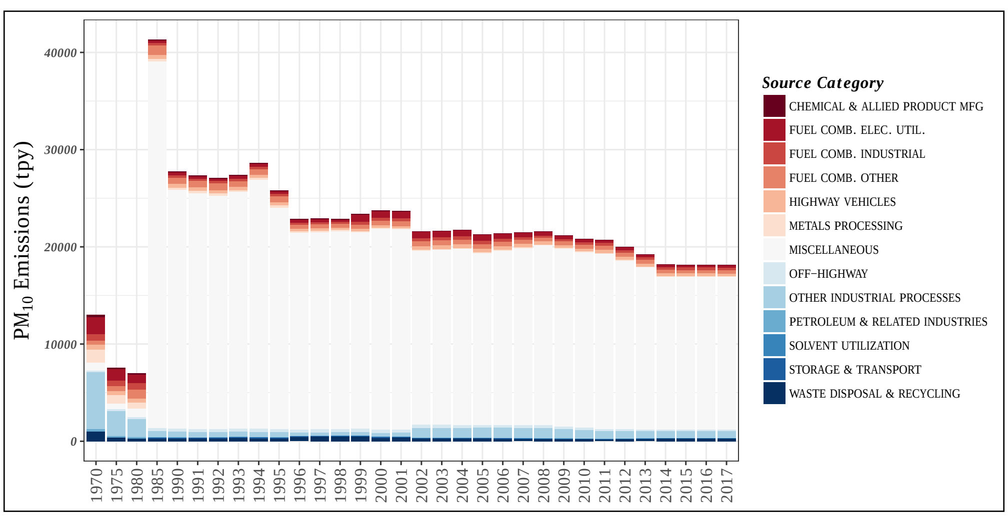

Figure 2.18: Trends in national PM_{10} emissions from 1970 to 2018.

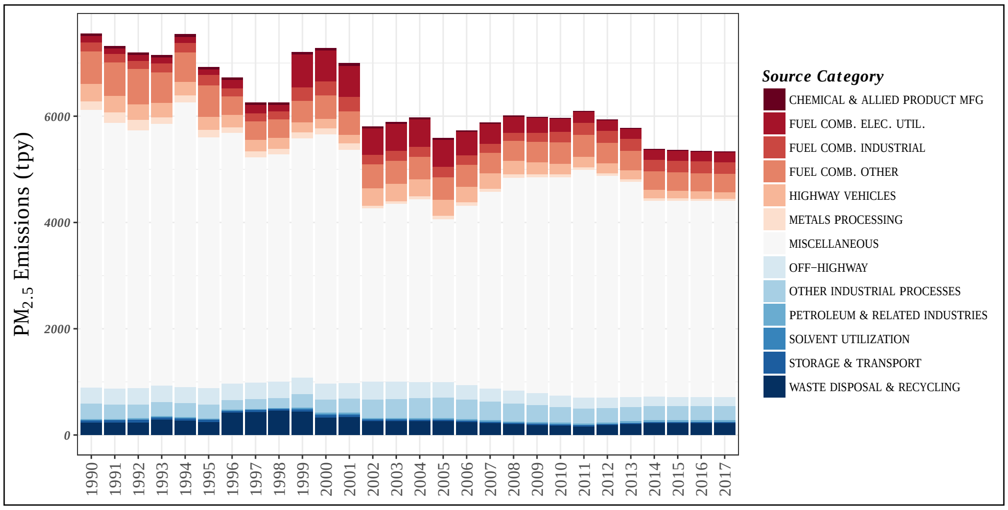

Figure 2.19: Trends in national $PM_{2.5}$ emissions from 1990 to 2018.

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 $PM_{10\text{-}2.5}$ 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 98^{th} 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 three 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 98^{th} 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 APCD flags and documents as exceptional events in the EPA's AQS database. The Exceptional Events Rule was revised in 2016, with an effective date of September 30, 2016. 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.

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, statewide values have been summarized in a box plot in Figure 2.20 for illustration purposes. The box plot shows the median PM_{10} NAAQS value statewide for each year as a horizontal black bar, as well as the first quartile (Q1, box bottom), the third quartile (Q3, box top), and the minimum and maximum values, which are represented by vertical black tick marks. For each year, outliers are considered to be those points with values greater than Q3 + 1.5*(Q3 - Q1) or less than Q1 - 1.5*(Q3 - Q1), and are represented by black points. Maximum historical values greater than 500 µg m^{-3} are labeled in in Figure 2.20 with the name of the city where those values were measured.

The data shown in Figure 2.20 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 1987, including the maximum 24-hour PM_{10} concentration of 1220 µg m^{-3} recorded in Lamar in 2013 and the 635 µg m^{-3} value recorded in Alamosa in 2011. Table 2.11 presents the historical maximum 24-hour PM_{10} concentrations recorded in Colorado.

National and statewide maximum 24-hour PM_{10} concentrations for 2018 are presented in Table 2.12. In the past several years the top five locations on the list have generally included Keeler, CA, sites around Owens Lake, CA, and sites around Mono Lake, CA. All of these levels are associated with hot dry winds. The levels around Owens Lake are associated with high winds that blow across a large dry lake bed. In the past, several monitors in that area have recorded levels in excess of 20,000 µg m^{-3} as a 24-hour average. Exceedances in Colorado are mainly due to large regional dust storms that usually begin in desert areas to the south and west of the state. These are natural or exceptional events for which the Division is currently analyzing the scientific data and documenting as high wind/blown dust exceptional events.

Spatial trends in median 24-hour PM_{10} across the continental U.S. are shown in Figure 2.21. By plotting the median instead of maximum values, the effect of exceptional event data is effectively removed from this plot.

Table 2.11: Historical maximum 24-hour PM_{10} concentrations in Colorado

Site	Max 24-Hour PM_{10} (µg m^{-3})	Year
Lamar	1,220	2013
Alamosa	635	2011
Denver	532	1985
Alamosa	494	2007
Montrose	491	1999
	2018 Maximum	
Alamosa	379	2018

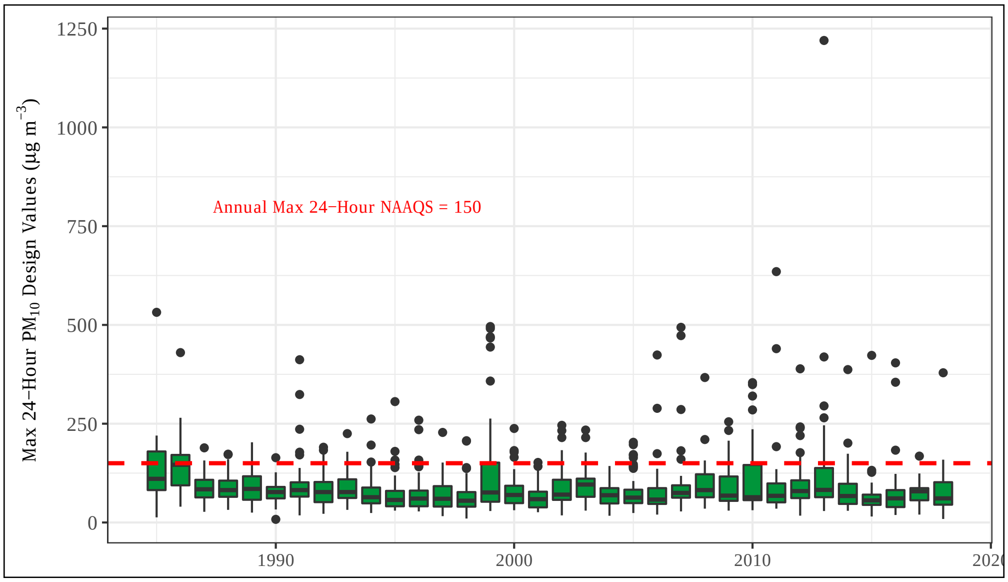

Figure 2.20: Statewide historical record of annual maximum 24-hour PM_{10} values. The box plot shows the median PM_{10} NAAQS value statewide for each year, as well as the interquartile range (box) of values observed at monitoring sites throughout the state and the minimum and maximum values. Outliers are indicated by black points.

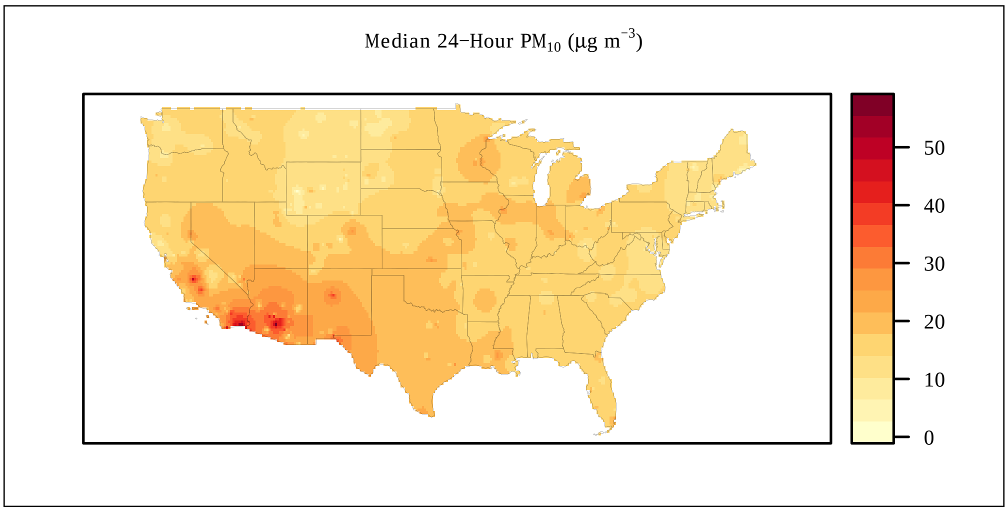

Figure 2.21: Interpolation map of median 24-hour PM_{10} values for air quality monitoring stations in the continental U.S. during 2018

Table 2.12: National (left) and statewide (right) rankings of PM_{10} monitors by maximum 24-hour concentration in 2018

Nationwide (708 Monitors)					Colorado (24 Monitors)			
Rank	**City**	**State**	**PM_{10} (μg m^{-3})**	**Exceedances**	**Rank**	**Site**	**PM_{10} (μg m^{-3})**	**Exceedances**
1	Stanfield	AZ	1,100	5	15	Alamosa	379	1
2	Mono Lake	CA	1,098	5	83	Lamar	159	1
3	Casa Grande	AZ	780	5	84	TCH	158	1
4	Keeler	CA	728	2	88	Pueblo	155	1
5	Aberdeen	SD	533	1	97	CAMP	149	0

$PM_{2.5}$ 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. A majority of the SPM sites were removed as of December 31, 2006 due to low concentrations and a lack of funding.

Figure 2.22 and Figure 2.23 show the historical trends in annual mean and 24-hour maximum $PM_{2.5}$ NAAQS values, respectively. Although data has only been collected for the past 12 years, the trend in the average levels of $PM_{2.5}$ appears to be essentially flat. Since the 35 μg m^{-3} standard is based on a three-year average of the 98^{th} percentile, the 24-hour standard has not been violated at any site, nor has the three-year average annual standard of 12 μg m^{-3}. Table 2.13 presents the historical maximum 24-hour $PM_{2.5}$ concentrations recorded in Colorado. National and statewide maximum 24-hour $PM_{2.5}$ concentrations for 2018 are presented in Table 2.6.

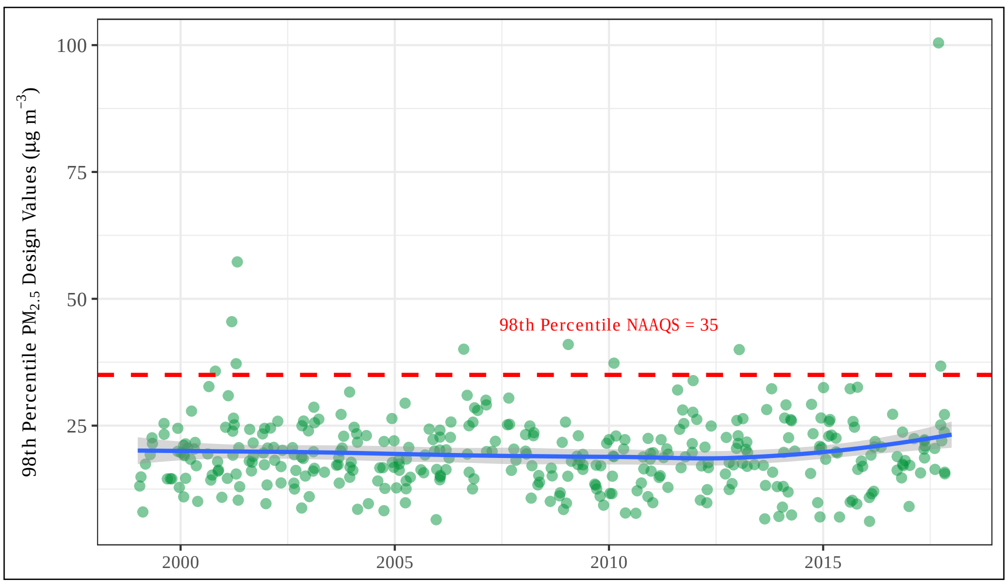

Figure 2.22: Statewide historical record of 24-hour $PM_{2.5}$ 98^{th} percentile values. The mean trend obtained using a generalized additive model is shown as a blue line.

Table 2.13: Historical maximum 24-hour $PM_{2.5}$ concentrations in Colorado

Site	Max 24-Hour $PM_{2.5}$ (μg m^{-3})	Year
Arapahoe Community College (ACC)	140	1999
Fort Collins - CSU	75	2015
CAMP	68	2001
Chatfield State Park	62	2017
Greeley	62	2017
2018 Maximum		
I-25: Globeville	55	2018

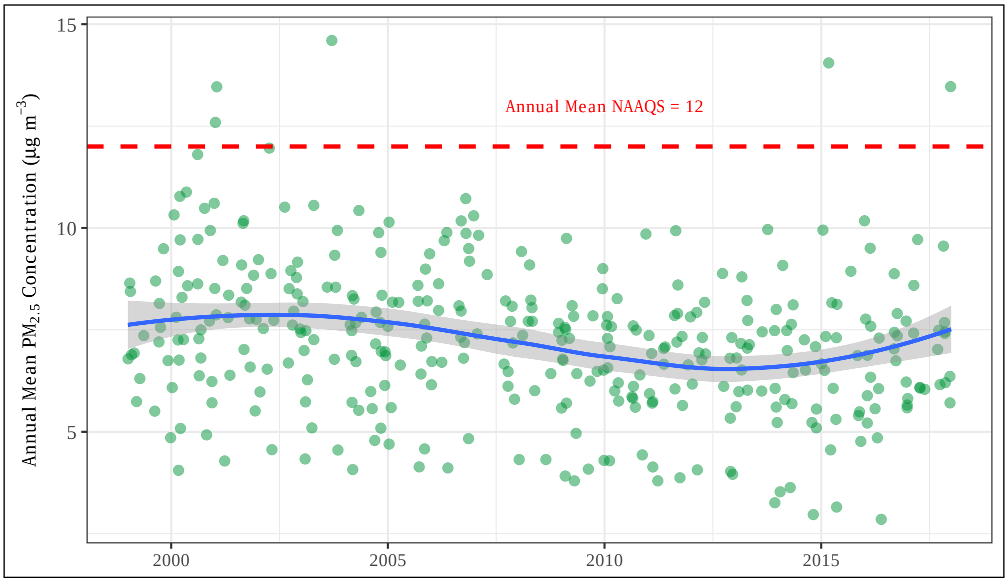

Figure 2.23: Statewide historical record of annual mean $PM_{2.5}$ values. The mean trend obtained using a generalized additive model is shown as a blue line.

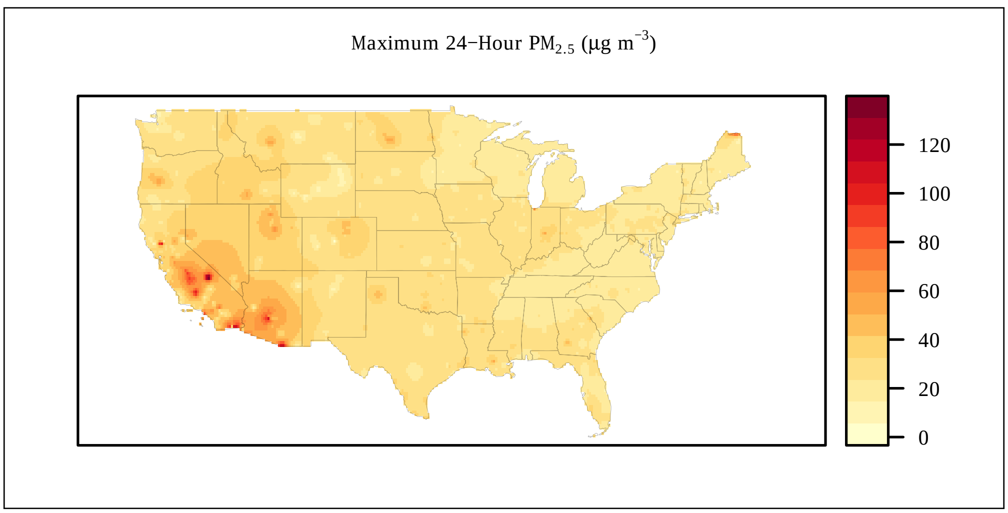

Figure 2.24: Interpolation map of maximum 24-hour $PM_{2.5}$ values for air quality monitoring stations in the continental U.S. during 2018

Table 2.14: National (left) and statewide (right) rankings of $PM_{2.5}$ monitors by maximum 24-hour concentration in 2018

Nationwide (960 Monitors)					Colorado (16 Monitors)			
Rank	**City**	**State**	**$PM_{2.5}$ (µg m^{-3})**	**Exceedances**	**Rank**	**Site**	**$PM_{2.5}$ (µg m^{-3})**	**Exceedances**
1	Phoenix	AZ	199	1	48	I-25: Globeville	55	1
2	Keeler	CA	156	2	57	Longmont	53	2
3	Cortina	CA	118	17	64	Ft. Collins	50	1
4	Nogales	AZ	117	1	70	Greeley	48	1
5	Long Beach	CA	111	5	73	TCH	47	1

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 $PM_{2.5}$.

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, 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 in 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.

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

[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 (1984-2012), 114(D2)

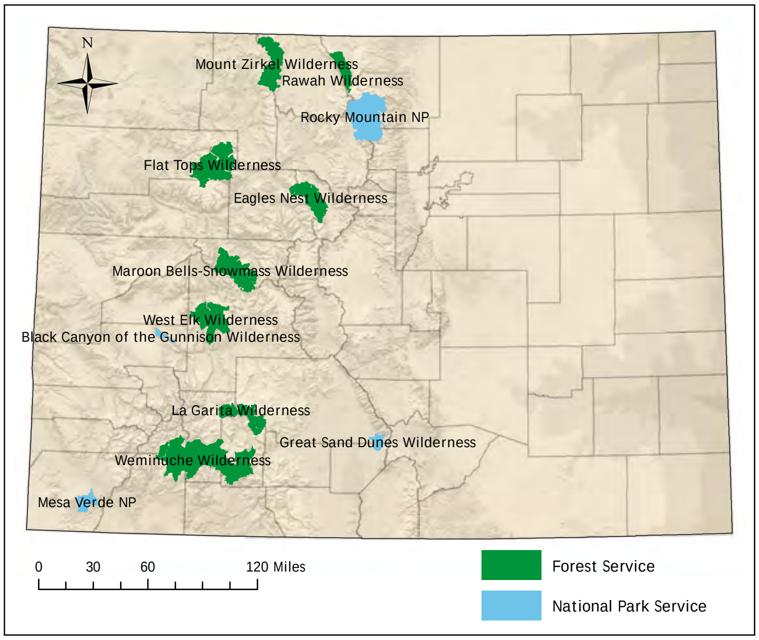

Figure 3.1: Class I areas in Colorado shown in green and blue. Blue indicates a National Park or Preserve, and green indicates a federally-protected wilderness area.

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. 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. 13^{th} 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.

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

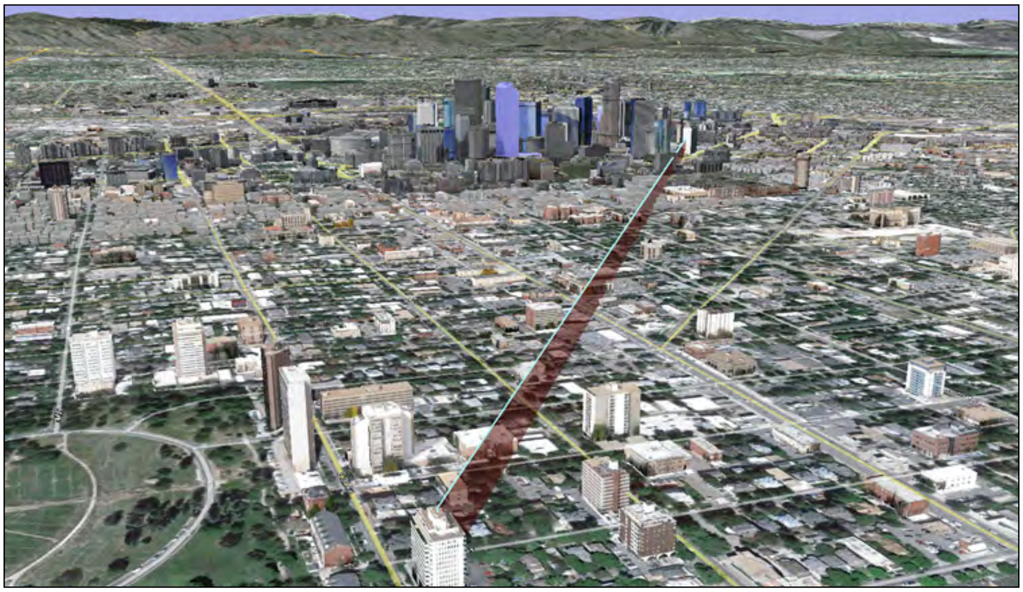

Figure 3.2: Denver transmissometer path (for illustration purposes only).

3.1.6 Denver Camera

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 one of the worst days for the year, January 23rd and September 4th, respectively.

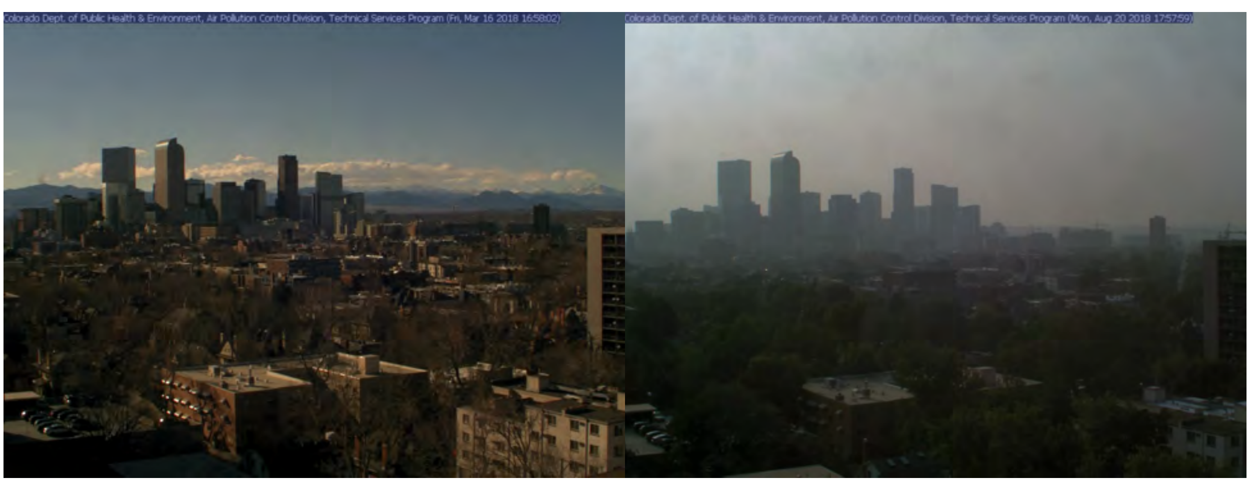

Figure 3.3: Denver Camera images of the best (left) and worst (right) visibility days in Denver during 2018.

These two pictures are images made by the web camera at the visibility monitor located at 1901 E. 13th 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 at 4 P.M. for March 20, 2018 (best day) and January 10, 2018 (worst day) were 0.013 and 0.273 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, I-25 Globeville, and I-25 Denver sites. Table 3.1 shows the maximum and average NO concentrations measured in Colorado in 2018. Without national standards with which to compare these numbers, they are presented here for informational purposes only, and are considered by 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 average and maximum one-hour nitric oxide values measured at APCD monitoring sites in 2018.

Site Name	County	NO (ppb)	
		Annual Average	Maximum Value
Welby	Adams	14.1	333
CAMP	Denver	13.5	494
La Casa	Denver	10.7	424
I-25 Globeville	Denver	36.3	623
I-25 Denver	Denver	27.6	442

3.3 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.

Since 2004, APCD has monitored 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, 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`.

3.4 Meteorology

APCD takes a limited set of meteorological measurements at 21 locations around the state. These measurements include wind speed, wind direction, temperature, standard deviation of horizontal wind direction, and select monitoring of relative humidity and solar radiation. 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 0-2 ms^{-1}, 2-4 ms^{-1}, 4-6 ms^{-1}, 6-8 ms^{-1}, 8-10 ms^{-1}, and greater than 10 ms^{-1}. 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.

3.5 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 redevelopment of the property 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 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 fifteen years are summarized for each air quality monitor in the APCD network, which are grouped below by monitoring region and pollutant. The plots in this section show annual means and one-hour, eight-hour, or 24-hour values in the form of the NAAQS standards. The values recorded at individual sites are compared to statewide averages, which are shown in light blue in all plots. 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 for a description of exceptional events.

Table 4.1: Summary of PM_{10} values recorded at monitoring stations in the Central Mountains region during 2018.

Site Name	County	PM_{10} (µg m^{-3})		
		Annual Average	24-Hr Max	3-Year Exceedances
Cañon City	Fremont	12.7	39	0
Crested Butte	Gunnison	24.4	63	0
Aspen	Pitkin	15.4	45	0
Steamboat Springs	Routt	18.1	56	0

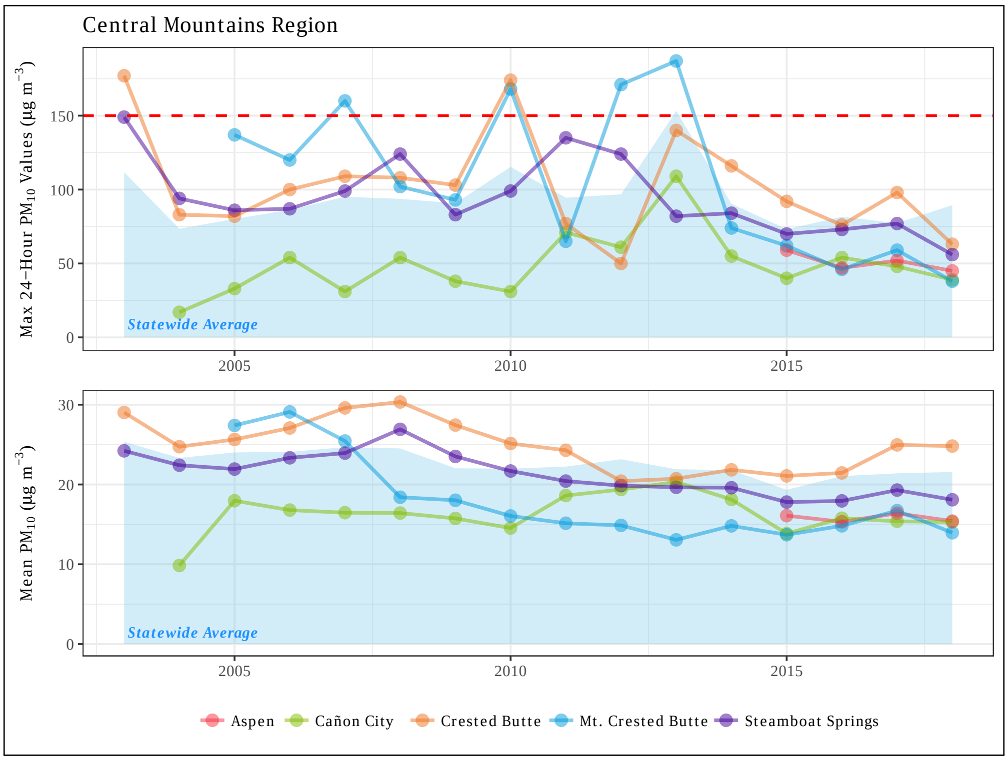

Figure 4.1: Fifteen-year trend in maximum 24-hour PM_{10} values (top) and annual mean concentrations (bottom) for monitoring sites in the Central Mountains region. The 24-hour NAAQS (150 µg m^{-3}) is shown as a dashed red line.

4.2 Denver Metro / North Front Range Region

4.2.1 Particulate Matter

There were no violations of the PM_{10} or $PM_{2.5}$ NAAQS in the Denver Metro / Northern Front Range counties in 2018. The Tri-County Health station has not yet been in operation for three years, being established in July 2016; therefore, while the 2018 98th percentile $PM_{2.5}$ value is reported, the primary $PM_{2.5}$ standard of the 98th percentile averaged over three years cannot yet be calculated for this site. The $PM_{2.5}$ plots below show the 98th percentile of the data collected during each year rather than the three-year average.

Table 4.2: Summary of PM_{10} values recorded at monitoring stations in the Denver Metro/Northern Front Range region during 2018.

Site Name	County	PM_{10} (µg m^{-3})		
		Annual Average	24-Hr Max	3-Year Exceedances
Tri-County	Adams	35.9	158	-
Welby	Adams	32.7	106	0
Longmont	Boulder	20.0	63	0
Boulder Chamber of Comm.	Boulder	20.3	57	0
CAMP	Denver	29.4	147	0
La Casa	Denver	22.6	102	0
Fort Collins - CSU	Larimer	19.7	59	0
Greeley - Hospital	Weld	22.8	54	0

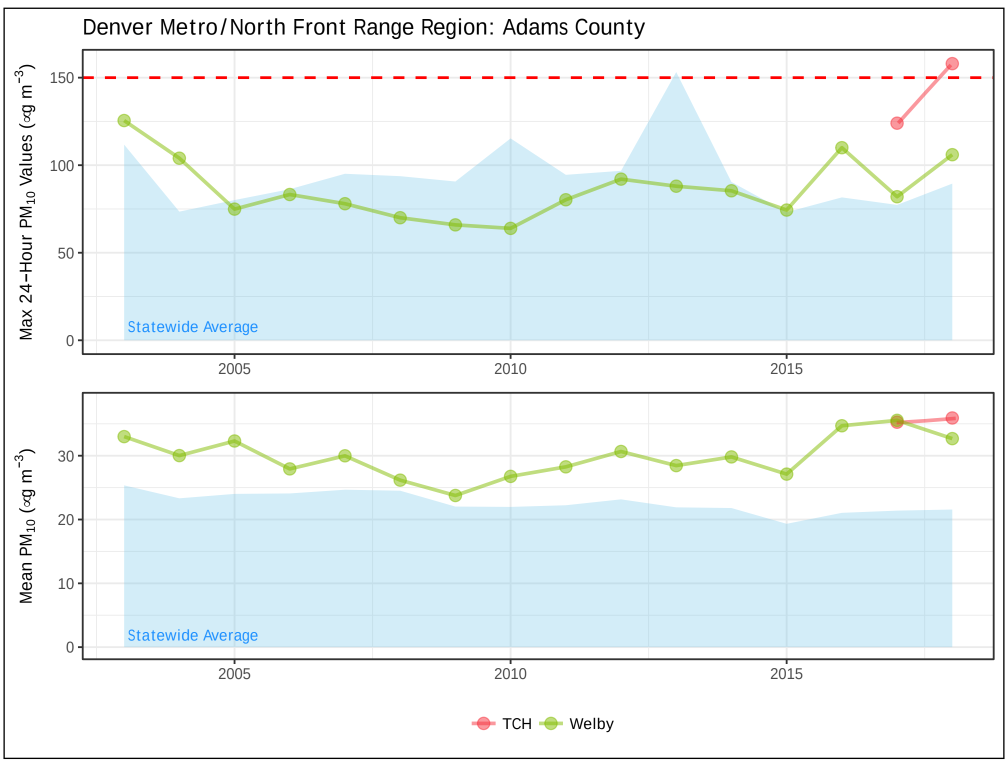

Figure 4.2: Fifteen-year trend in maximum 24-hour PM_{10} values (top) and annual mean concentrations (bottom) for monitoring sites in Adams County. The 24-hour NAAQS (150 µg m^{-3}) is shown as a dashed red line.

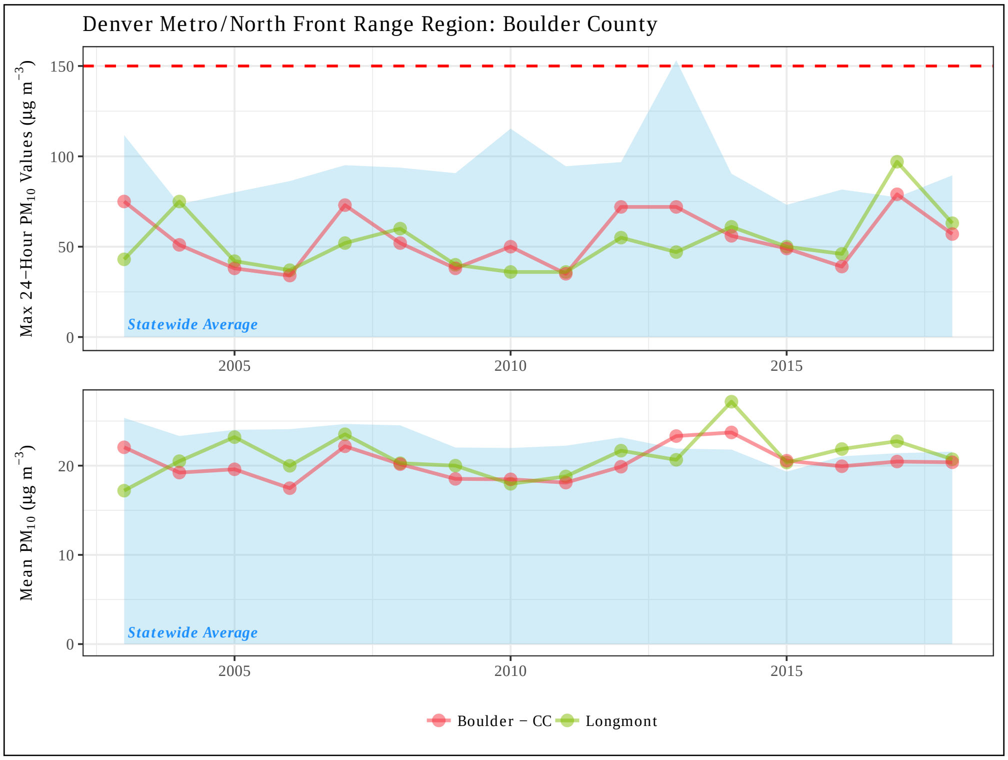

Figure 4.3: Fifteen-year trend in maximum 24-hour PM_{10} values (top) and annual mean concentrations (bottom) for monitoring sites in Boulder County. The 24-hour NAAQS (150 µg m^{-3}) is shown as a dashed red line.

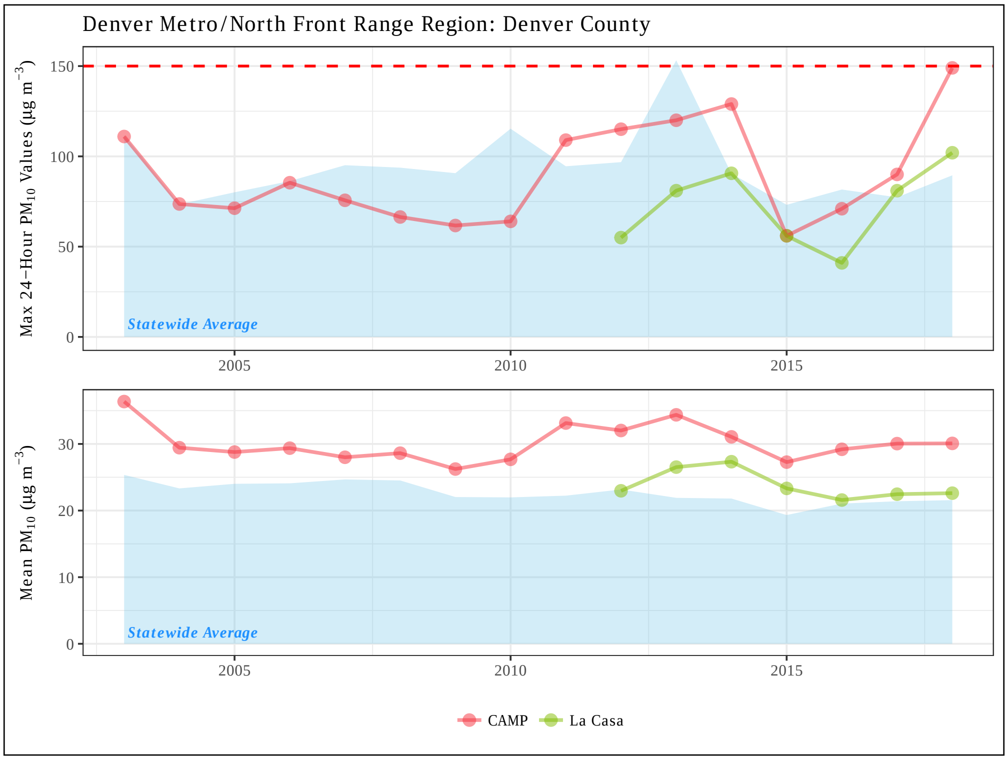

Figure 4.4: Fifteen-year trend in maximum 24-hour PM_{10} values (top) and annual mean concentrations (bottom) for monitoring sites in Denver County. The 24-hour NAAQS (150 µg m^{-3}) is shown as a dashed red line.

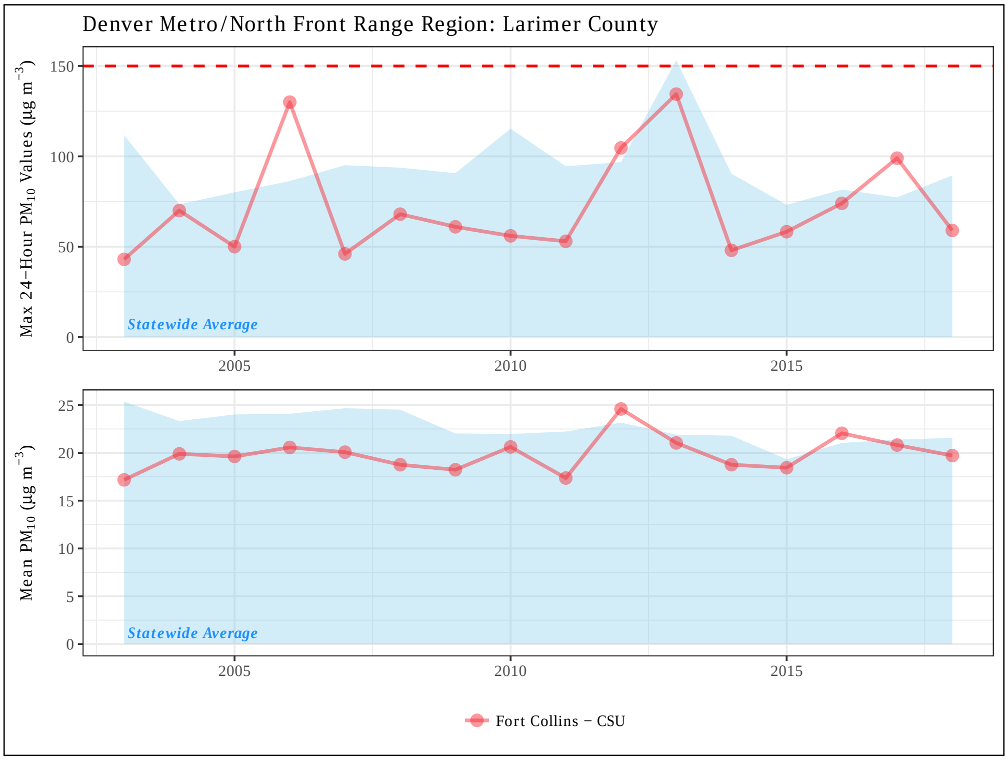

Figure 4.5: Fifteen-year trend in maximum 24-hour PM_{10} values (top) and annual mean concentrations (bottom) for monitoring sites in Larimer County. The 24-hour NAAQS (150 μg m^{-3}) is shown as a dashed red line.

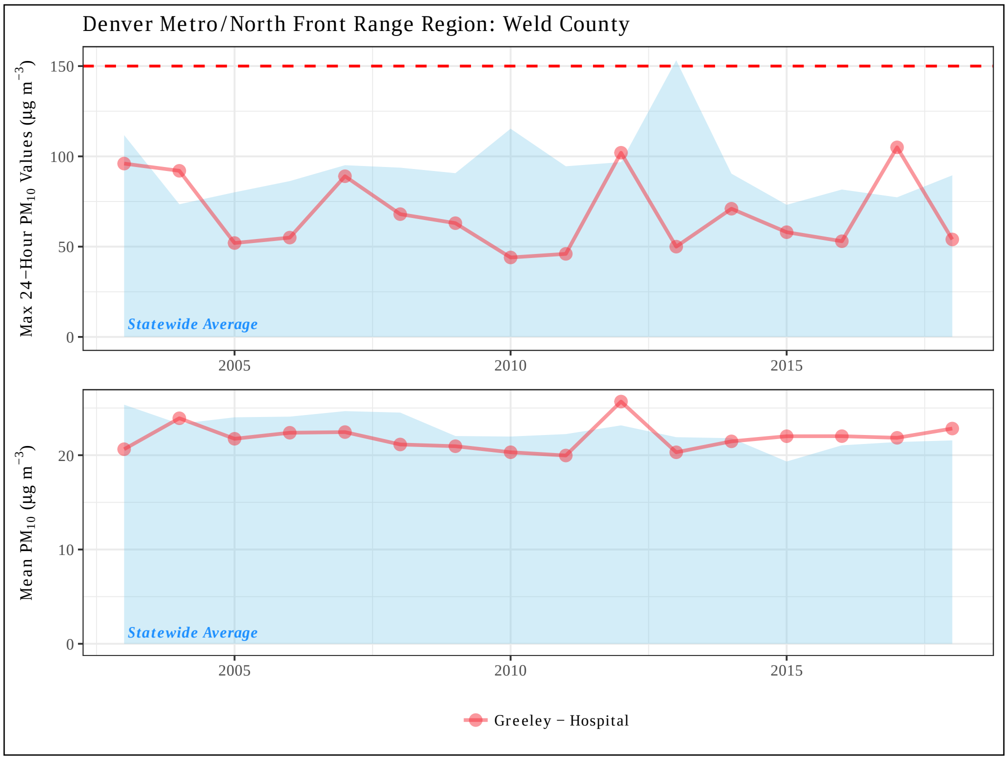

Figure 4.6: Fifteen-year trend in maximum 24-hour PM_{10} values (top) and annual mean concentrations (bottom) for monitoring sites in Weld County. The 24-hour NAAQS (150 μg m^{-3}) is shown as a dashed red line.

Table 4.3: Summary of $PM_{2.5}$ values recorded at monitoring stations in the Denver Metro/Northern Front Range region during 2018.

Site Name	County	$PM_{2.5}$ (µg m^{-3})		
		Annual Average	Annual 98^{th} Percentile	3-Year Ave. of 98^{th} Percentile
Tri-County	Adams	10.2	27.2	-
Arapaho Comm. College	Arapahoe	6.3	20.1	17
Longmont	Boulder	6.8	20.8	25
Boulder Chamber of Comm.	Boulder	6.4	22.0	19
CAMP	Denver	8.4	24.5	20
National Jewish Health	Denver	7.0	21.3	-
La Casa	Denver	7.7	22.9	19
I-25 Denver	Denver	8.2	23.7	22
I-25 Globeville	Denver	9.2	25.1	24
Chatfield State Park	Douglas	7.5	36.7	25
Fort Collins - CSU	Larimer	7.7	20.4	19
Greeley - Hospital	Weld	9.6	23.6	24
Platteville	Weld	8.0	20.5	23

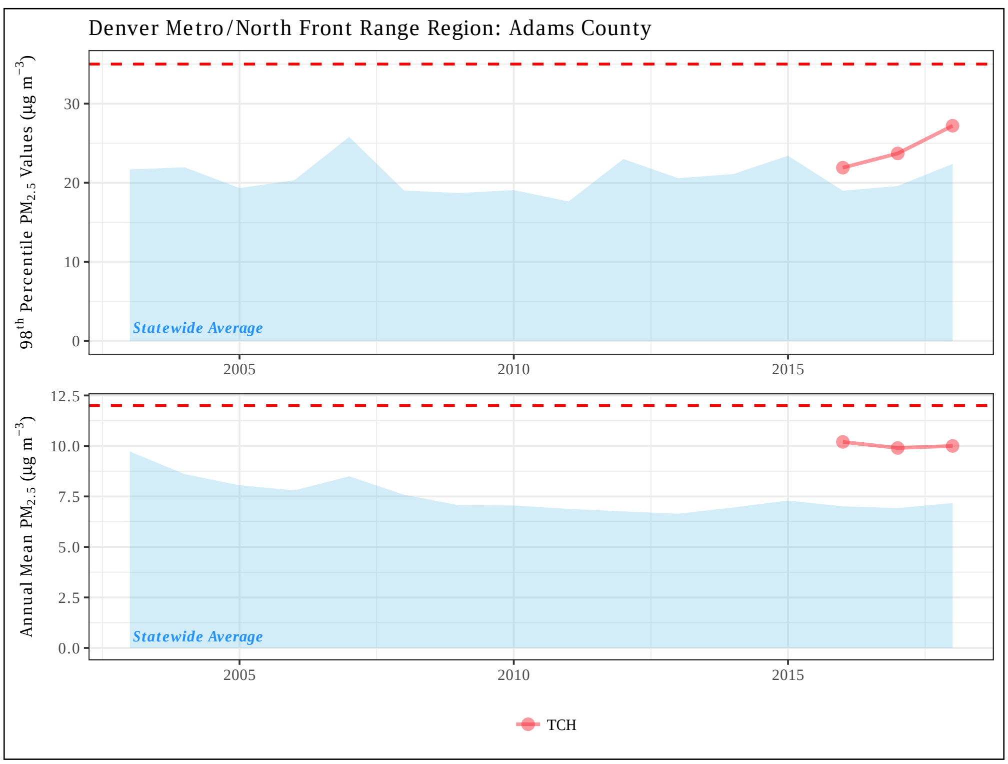

Figure 4.7: Fifteen-year trend in 24-hour $PM_{2.5}$ annual 98^{th} percentile values (top) and annual mean concentrations (bottom) for monitoring sites in Adams County. The 24-hour and annual mean NAAQS (35 µg m^{-3} and 12 µg m^{-3}, respectively) are shown as dashed red lines.

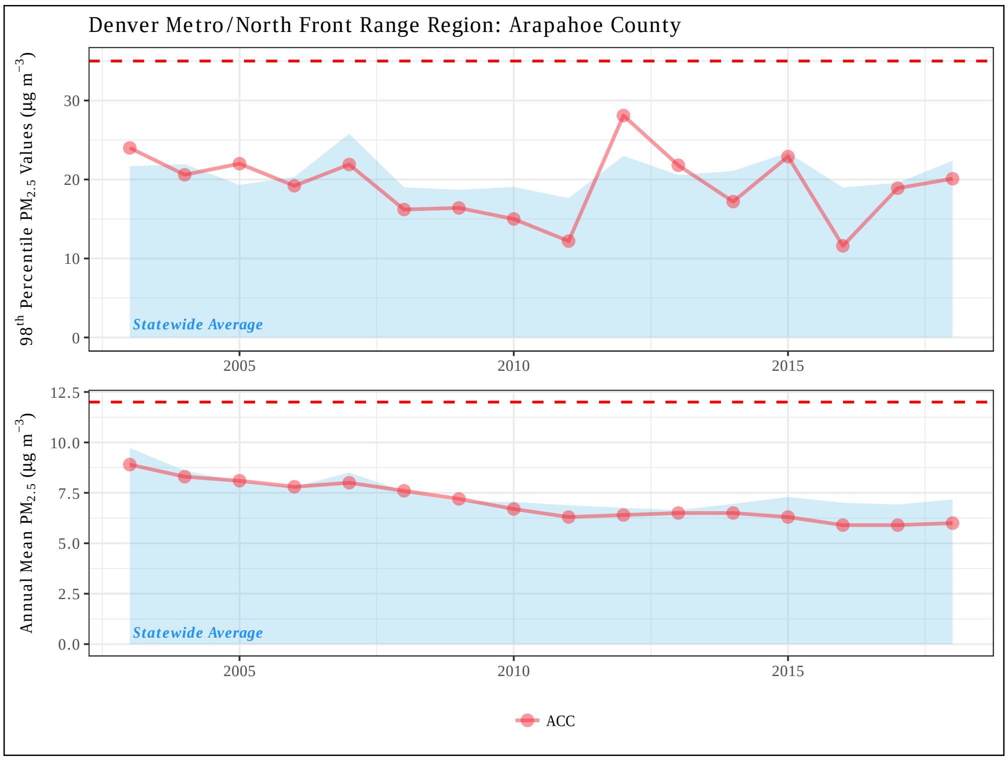

Figure 4.8: Fifteen-year trend in 24-hour $PM_{2.5}$ annual 98^{th} percentile values (top) and annual mean concentrations (bottom) for monitoring sites in Arapahoe County. The 24-hour and annual mean NAAQS (35 µg m^{-3} and 12 µg m^{-3}, respectively) are shown as dashed red lines.

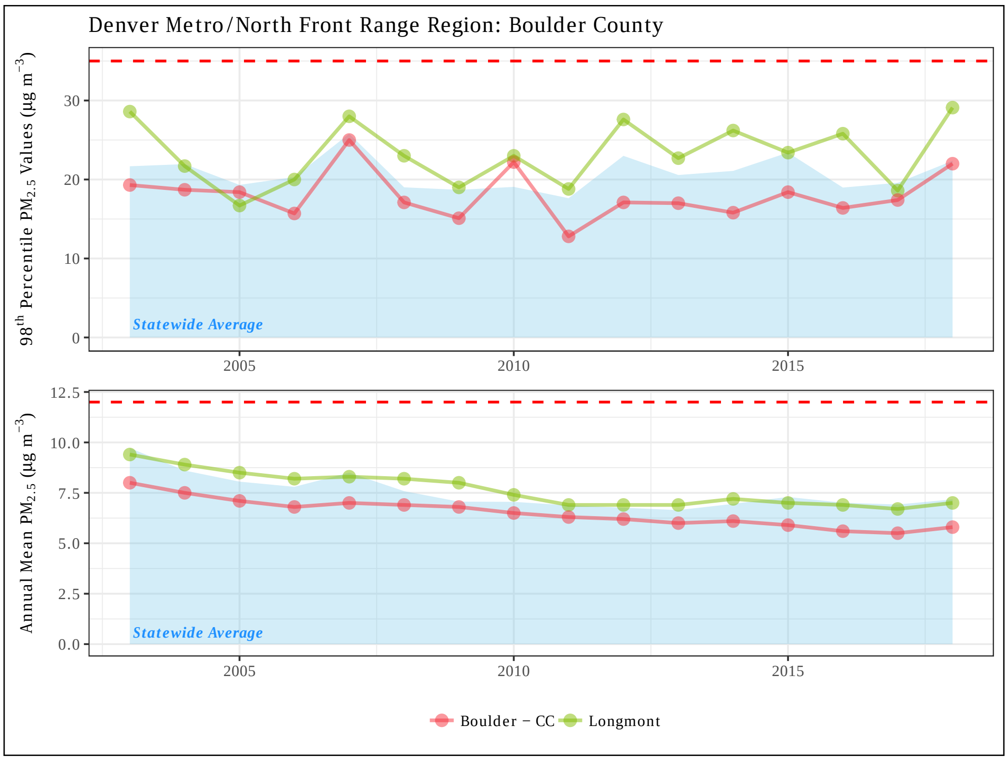

Figure 4.9: Fifteen-year trend in 24-hour $PM_{2.5}$ annual 98^{th} percentile values (top) and annual mean concentrations (bottom) for monitoring sites in Boulder County. The 24-hour and annual mean NAAQS (35 µg m^{-3} and 12 µg m^{-3}, respectively) are shown as dashed red lines.

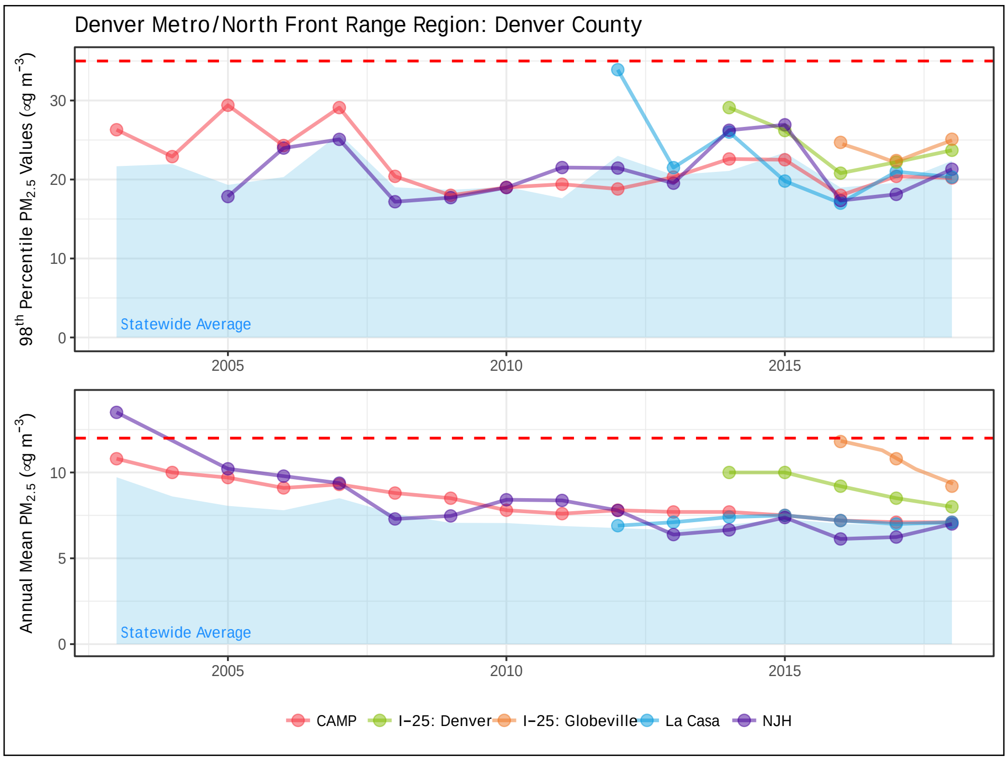

Figure 4.10: Fifteen-year trend in 24-hour $PM_{2.5}$ annual 98^{th} percentile values (top) and annual mean concentrations (bottom) for monitoring sites in Denver County. The 24-hour and annual mean NAAQS (35 µg m^{-3} and 12 µg m^{-3}, respectively) are shown as dashed red lines.

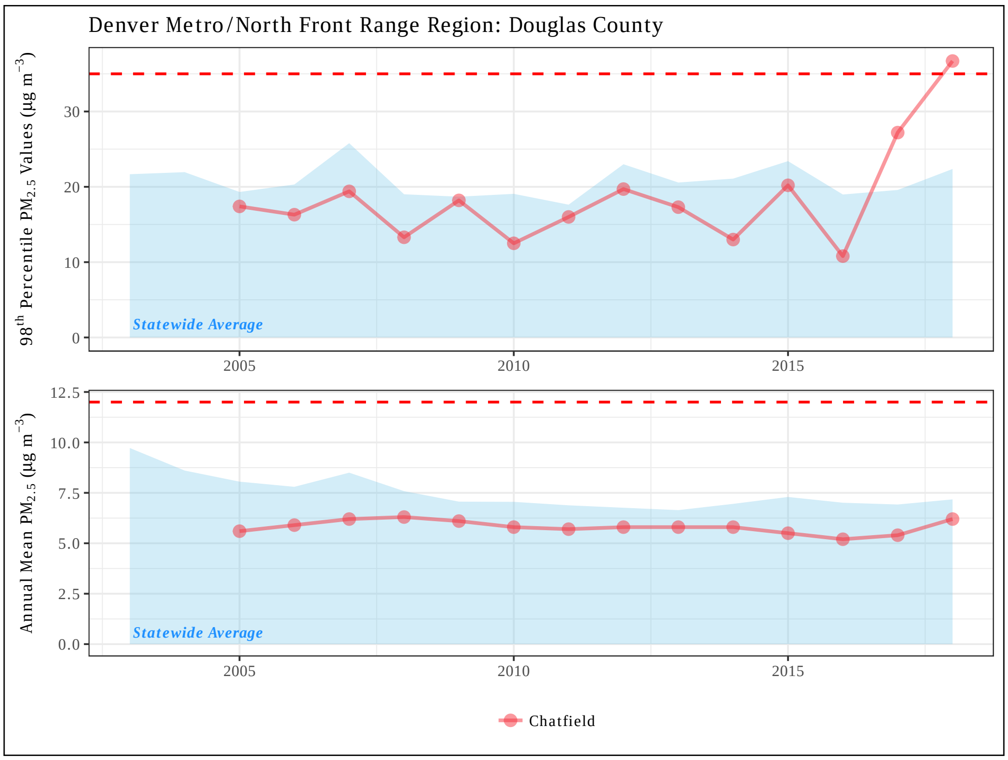

Figure 4.11: Fifteen-year trend in 24-hour $PM_{2.5}$ annual 98^{th} percentile values (top) and annual mean concentrations (bottom) for monitoring sites in Douglas County. The 24-hour and annual mean NAAQS (35 µg m^{-3} and 12 µg m^{-3}, respectively) are shown as dashed red lines.

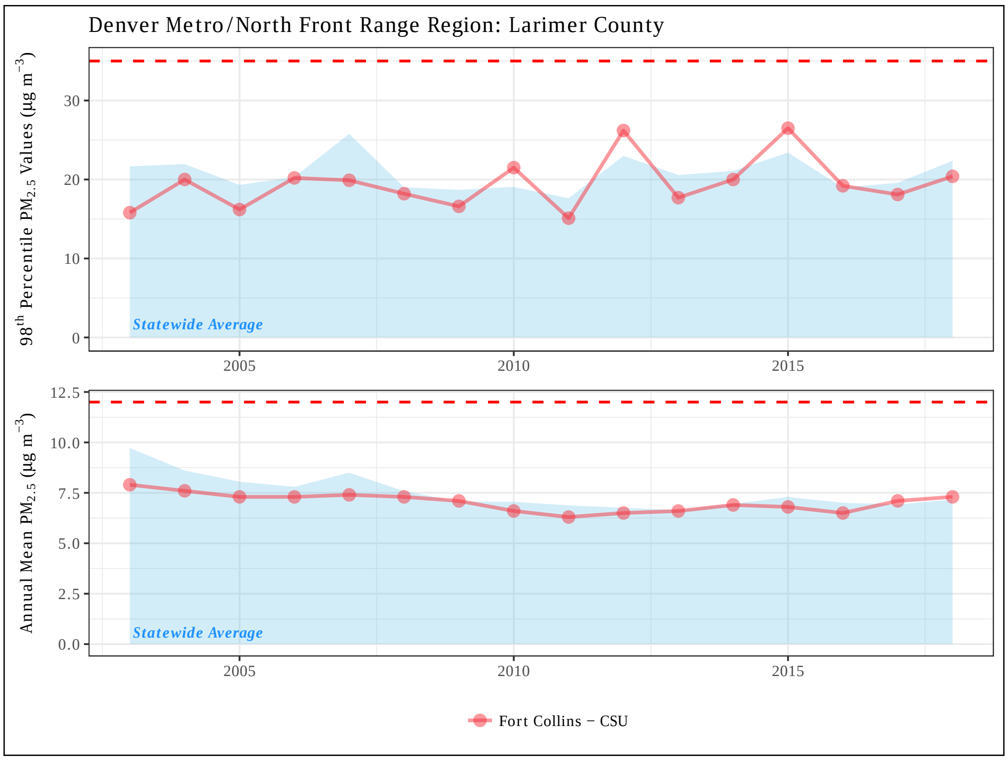

Figure 4.12: Fifteen-year trend in 24-hour $PM_{2.5}$ annual 98^{th} percentile values (top) and annual mean concentrations (bottom) for monitoring sites in Larimer County. The 24-hour and annual mean NAAQS (35 µg m^{-3} and 12 µg m^{-3}, respectively) are shown as dashed red lines.

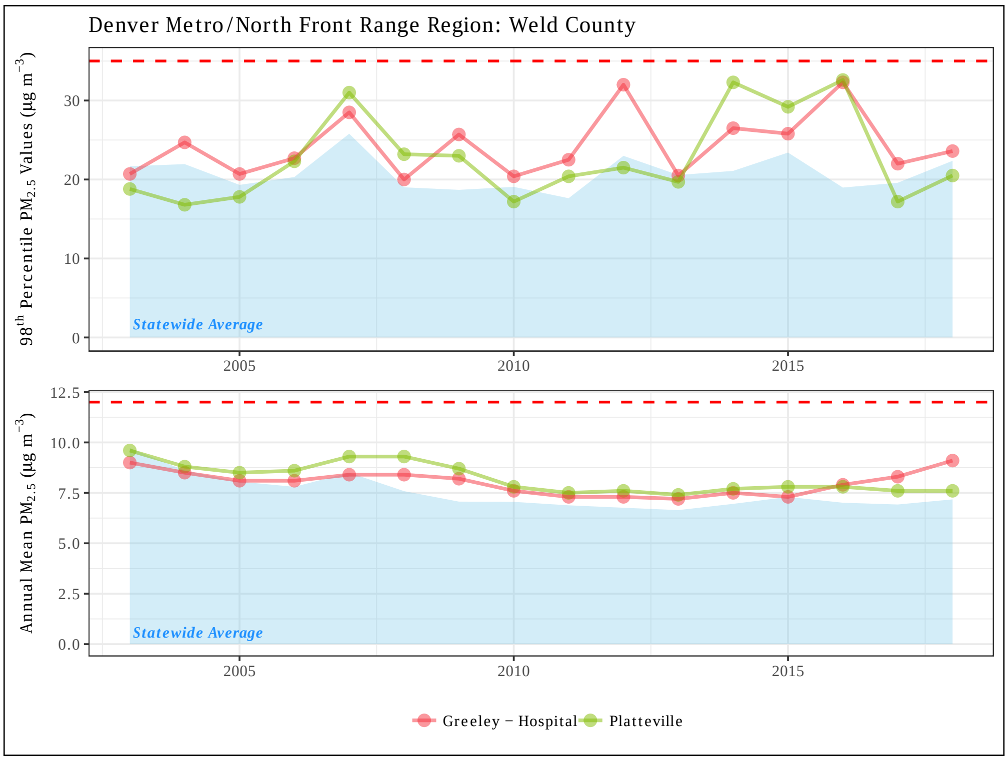

Figure 4.13: Fifteen-year trend in 24-hour $PM_{2.5}$ annual 98^{th} percentile values (top) and annual mean concentrations (bottom) for monitoring sites in Weld County. The 24-hour and annual mean NAAQS (35 µg m^{-3} and 12 µg m^{-3}, respectively) are shown as dashed red lines.

4.2.2 Carbon Monoxide

Table 4.4: Summary of CO values recorded at monitoring stations in the Denver Metro / Northern Front Range region during 2018.

Site Name	County	CO 1-Hour Average (ppm)		CO 8-Hour Average (ppm)	
		1st Max.	2nd Max.	1st Max.	2nd Max.
Welby	Adams	2.5	2.5	2.1	1.7
CAMP	Denver	4.5	4.0	3.3	2.5
La Casa	Denver	3.8	3.2	2.8	2.1
I-25 Denver	Denver	4.0	4.0	3.7	2.9
Fort Collins - Mason	Larimer	2.6	2.3	1.6	1.6
Greeley - County Tower	Weld	1.5	1.3	1.0	1.0

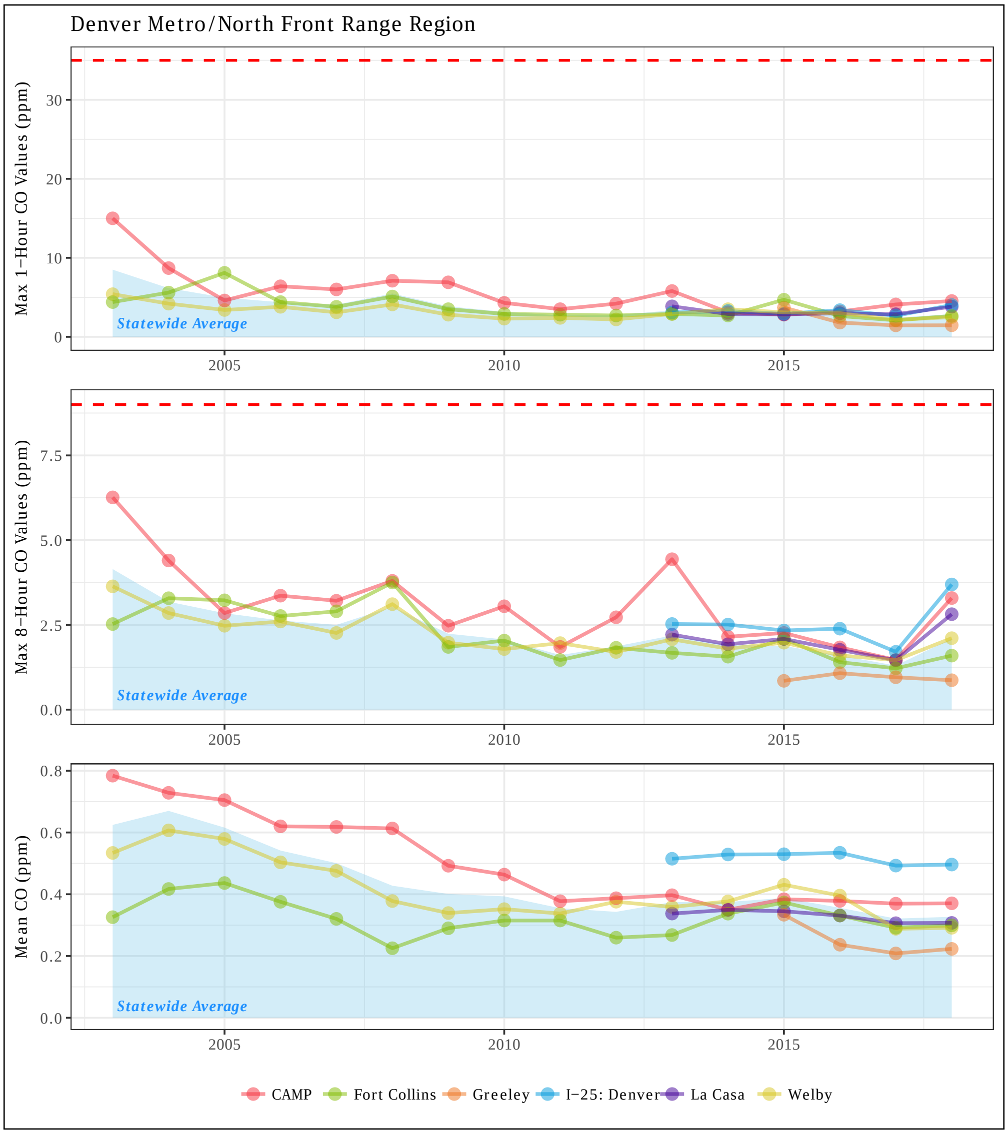

Figure 4.14: Fifteen-year trend in annual maximum one-hour (top) and eight-hour (center) CO values and annual mean eight-hour CO concentrations (bottom) for monitoring sites in the Denver Metro/Northern Front Range region. The one-hour and eight-hour NAAQS (35 ppm and 9 ppm, respectively) are shown as dashed red lines.

4.2.3 Ozone

The Boulder Reservoir site has only been in operation since September 2016, so three-year NAAQS values are not valid for this site.

Table 4.5: Summary of O_3 values recorded at monitoring stations in the Denver Metro / Northern Front Range region during 2018. Sites having three-year NAAQS values in excess of 70 ppb are indicated by asterisks.

Site Name	County	Ozone 8-Hour Average (ppm)		
		1^{st} Max.	4^{th} Max.	3-Year Ave. of 4^{th} Max.
Welby	Adams	73	69	67
Highlands	Arapahoe	88	77	73*
Aurora East	Arapahoe	78	72	69
Boulder Reservior	Boulder	89	77	-
CAMP	Denver	79	71	69
La Casa	Denver	78	72	69
Chatfield State Park	Douglas	88	83	78*
Welch	Jefferson	72	66	72*
Rocky Flats - N.	Jefferson	86	81	78*
NREL	Jefferson	86	80	79*
Aspen Park	Jefferson	74	71	70
Fort Collins - West	Larimer	88	81	77*
Fort Collins - Mason	Larimer	79	72	69
Greeley - County Tower	Weld	77	73	70

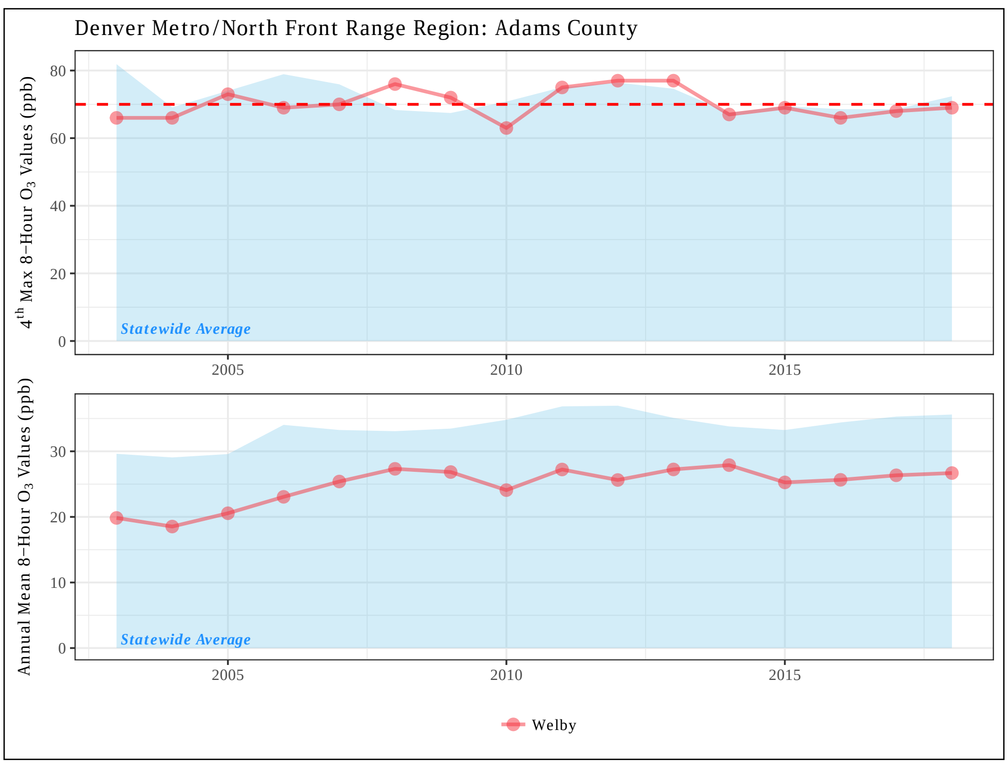

Figure 4.15: Fifteen-year trend in ozone eight-hour NAAQS value (top) and annual mean 8-hour concentration (bottom) for monitoring sites in Adams County. The 8-hour NAAQS (70 ppb) is shown as a dashed red line.

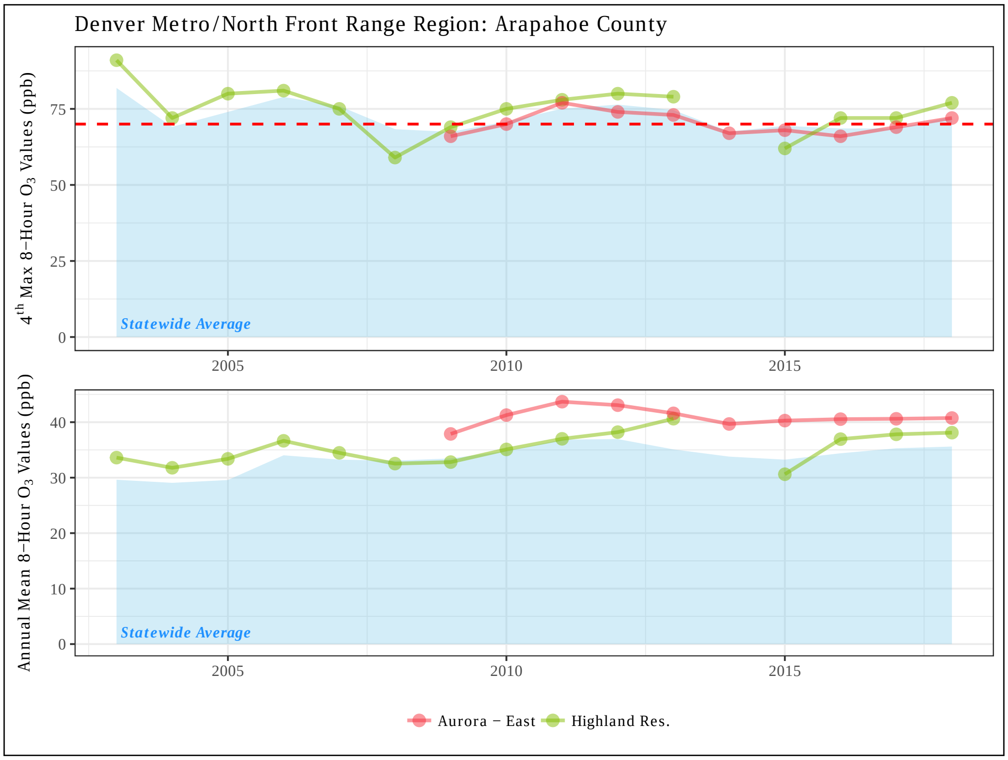

Figure 4.16: Fifteen-year trend in ozone eight-hour NAAQS values (top) and annual mean eight-hour concentrations (bottom) for monitoring sites in Arapahoe County. The 8-hour NAAQS (70 ppb) is shown as a dashed red line.

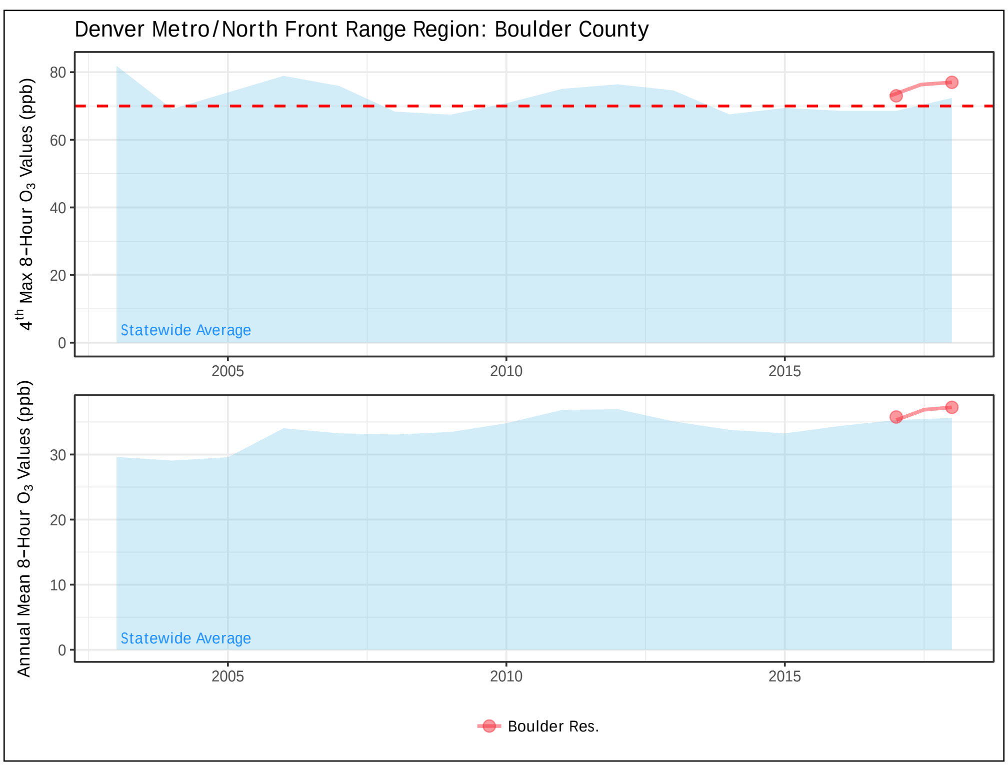

Figure 4.17: Fifteen-year trend in ozone eight-hour NAAQS values (top) and annual mean eight-hour concentrations (bottom) for monitoring sites in Boulder County. The eight-hour NAAQS (70 ppb) is shown as a dashed red line.

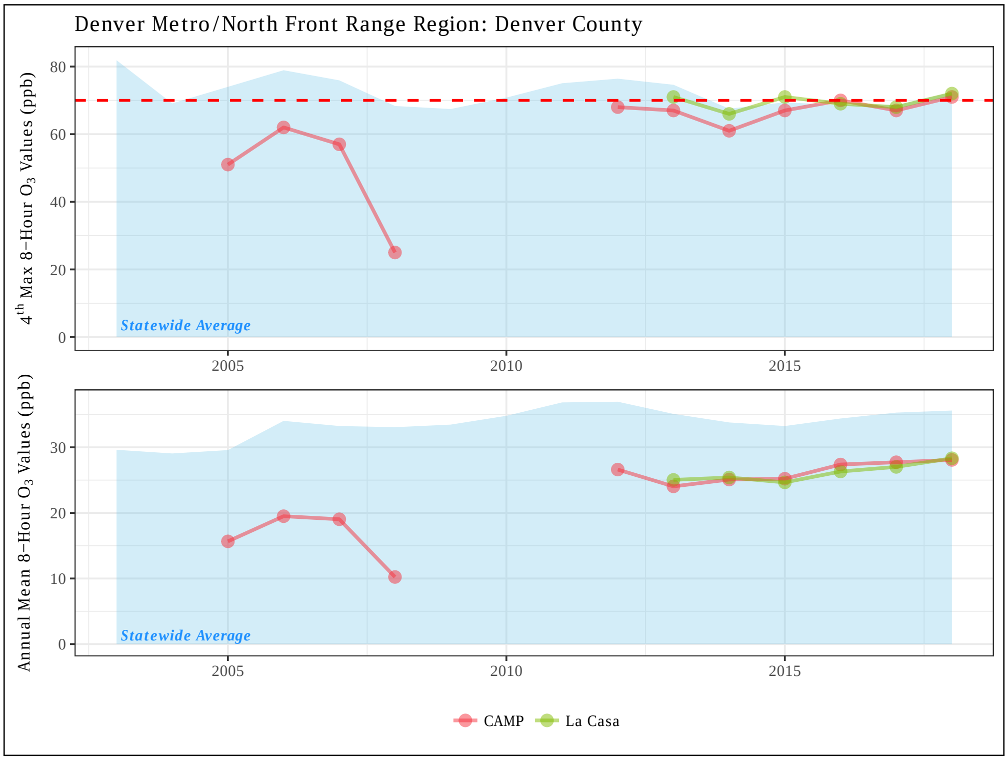

Figure 4.18: Fifteen-year trend in ozone eight-hour NAAQS values (top) and annual mean eight-hour concentrations (bottom) for monitoring sites in Denver County. The eight-hour NAAQS (70 ppb) is shown as a dashed red line.

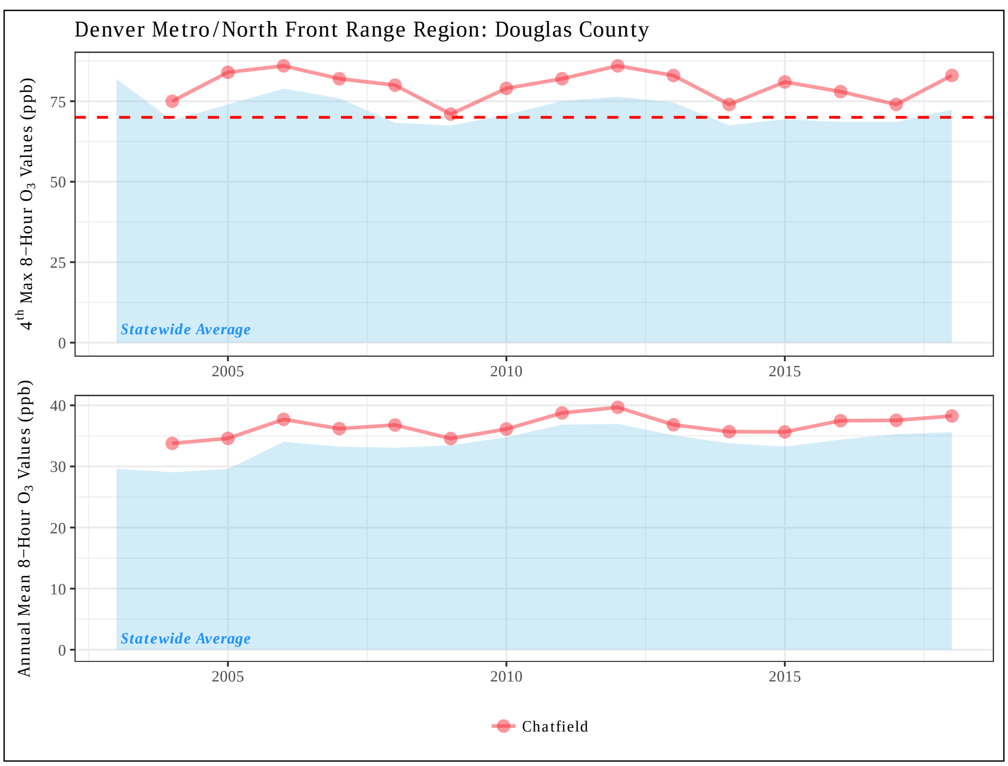

Figure 4.19: Fifteen-year trend in ozone eight-hour NAAQS values (top) and annual mean eight-hour concentrations (bottom) for monitoring sites in Douglas County. The eight-hour NAAQS (70 ppb) is shown as a dashed red line.

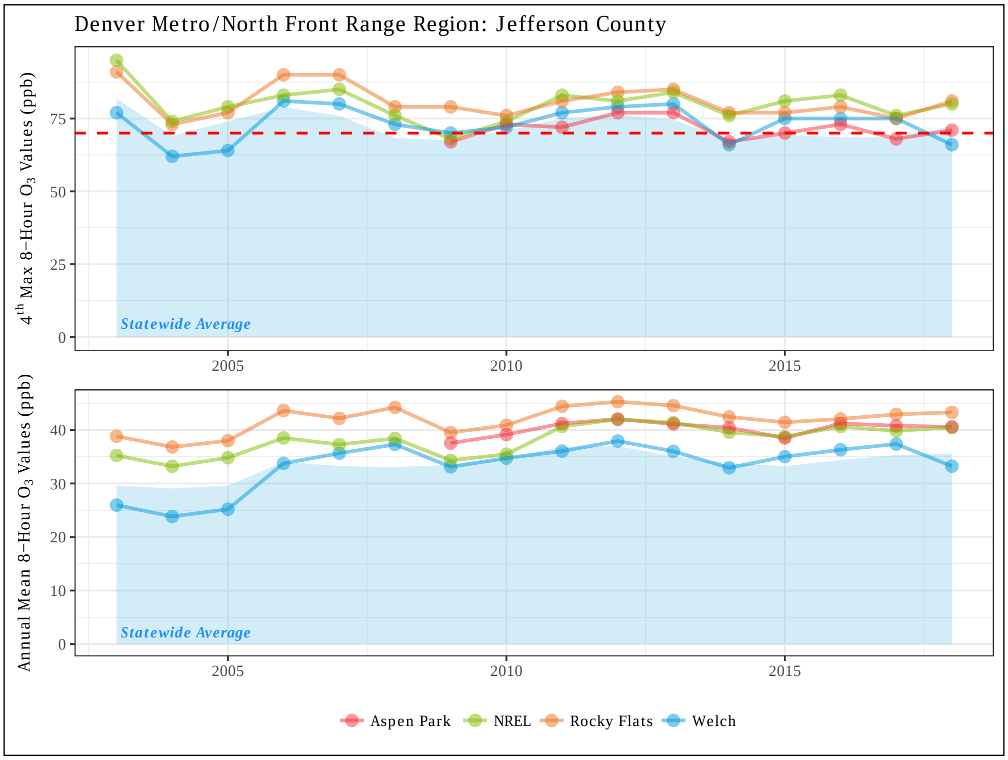

Figure 4.20: Fifteen-year trend in ozone eight-hour NAAQS values (top) and annual mean eight-hour concentrations (bottom) for monitoring sites in Jefferson County. The eight-hour NAAQS (70 ppb) is shown as a dashed red line.

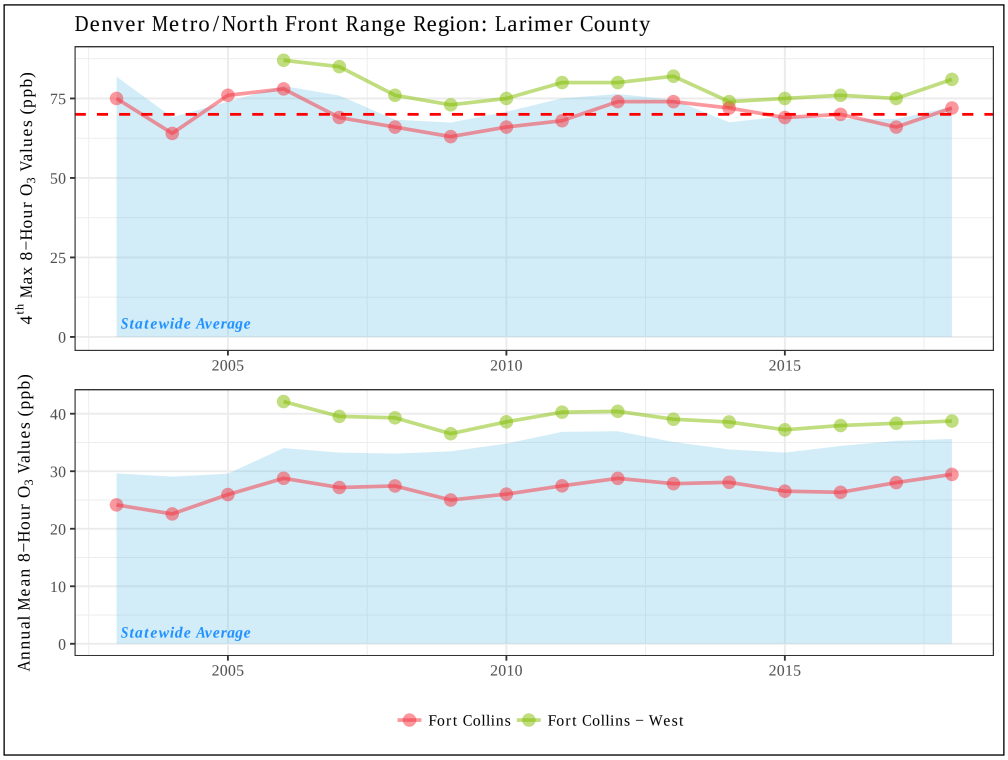

Figure 4.21: Fifteen-year trend in ozone eight-hour NAAQS values (top) and annual mean eight-hour concentrations (bottom) for monitoring sites in Larimer County. The eight-hour NAAQS (70 ppb) is shown as a dashed red line.

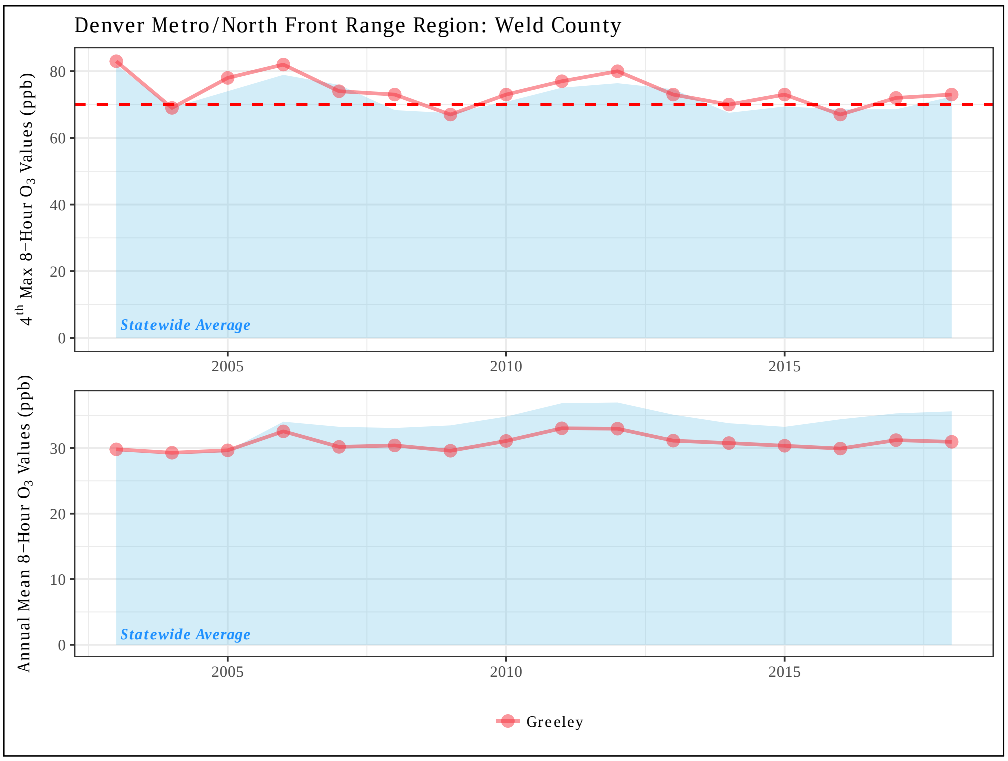

Figure 4.22: Fifteen-year trend in ozone eight-hour NAAQS values (top) and annual mean eight-hour concentrations (bottom) for monitoring sites in Weld County. The eight-hour NAAQS (70 ppb) is shown as a dashed red line.

4.2.4 Nitrogen Dioxide

Table 4.6: Summary of NO_2 values recorded at monitoring stations in the Denver Metro / Northern Front Range region during 2018.

Site Name	County	NO_2 (ppb)		
		Annual Mean	98^{th} Percentile	3-Year Ave. of 98^{th} Percentile
Welby	Adams	15.6	60.3	60
CAMP	Denver	18.5	66.2	69
La Casa	Denver	18.7	57.4	61
I-25 Denver	Denver	23.9	62.2	63
I-25 Globeville	Denver	27.0	69.6	70

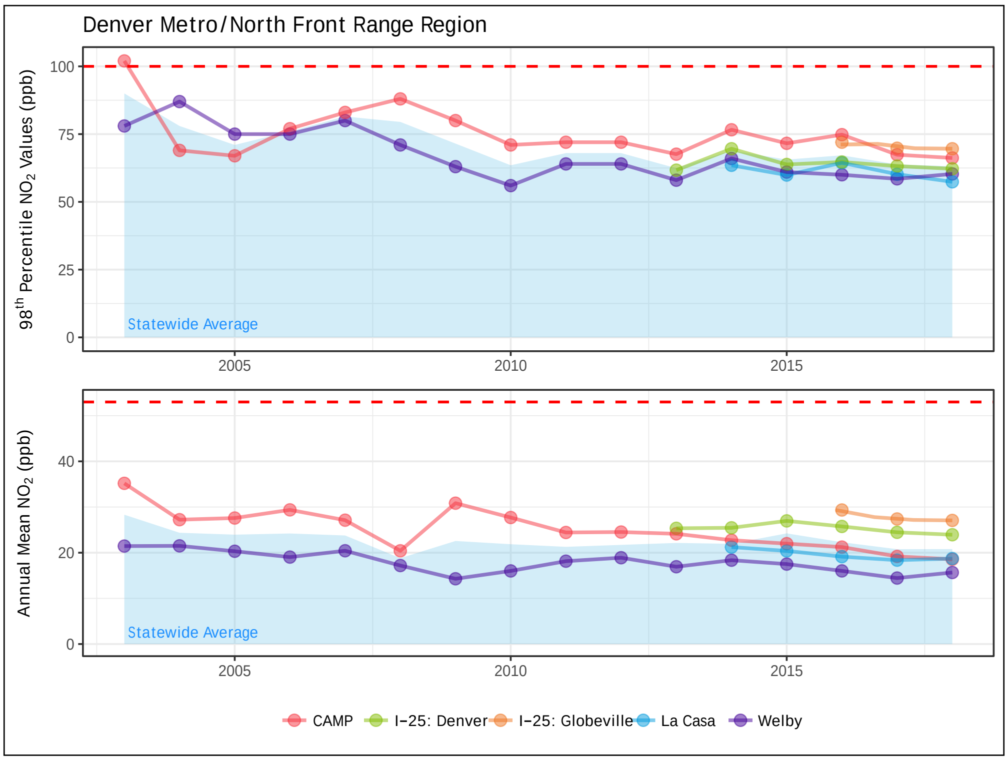

Figure 4.23: Fifteen-year trend in one-hour (top) and annual mean (bottom) nitrogen dioxide NAAQS values for monitoring sites in the Denver Metro/Northern Front Range region. The one-hour and annual mean standards (100 ppb and 53 ppb, respectively) are shown as dashed red lines.

4.2.5 Sulfur Dioxide

Table 4.7: Summary of SO_2 values recorded at monitoring stations in the Denver Metro/Northern Front Range region during 2018.

Site Name	County	SO_2 (ppb)		
		Annual Mean	99^{th} Percentile	3-Year Ave. of 99^{th} Percentile
Welby	Adams	0.89	6.2	14
CAMP	Denver	0.69	7.9	9
La Casa	Denver	0.59	6.8	12

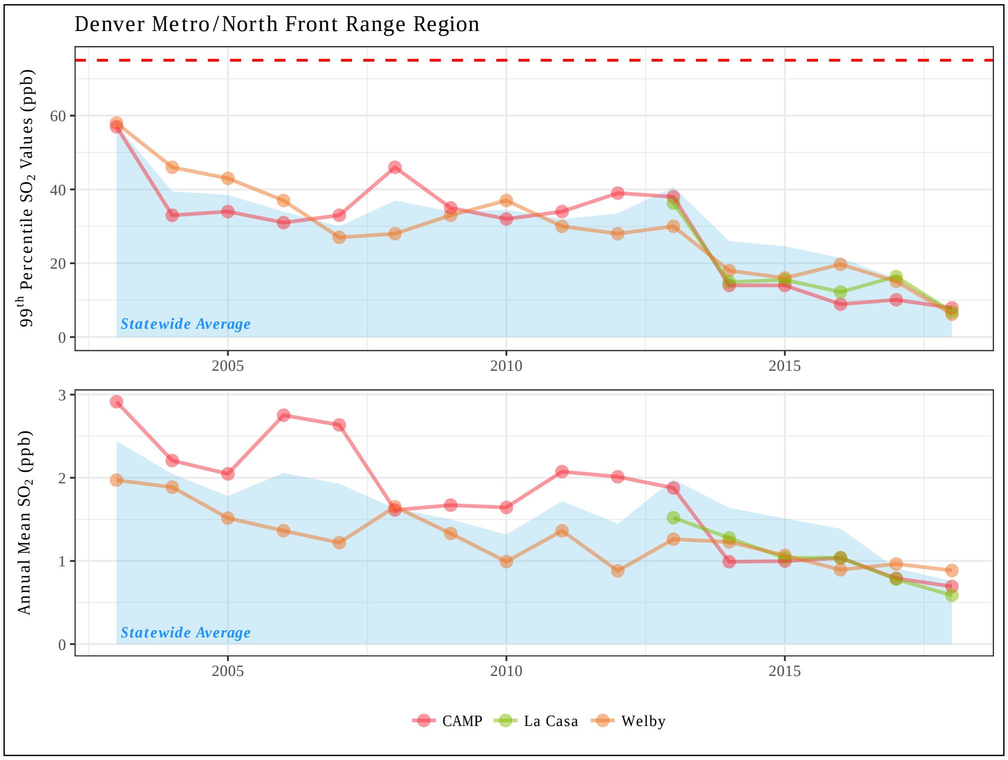

Figure 4.24: Fifteen-year trend in sulfur dioxide one-hour NAAQS values (top) and annual mean one-hour concentrations (bottom) for monitoring sites in the Denver Metro/Northern Front Range region. The one-hour NAAQS (75 ppb) is shown as a dashed red line.

4.2.6 Visibility

Visibility data for Denver is 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 for 25% of the year in Denver.

Table 4.8: 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	2	5	8	14	0	2
February	3	4	6	9	0	6
March	0	2	5	24	0	0
April	1	7	5	13	1	3
May	0	2	10	13	0	6
June	0	7	12	11	0	0
July	1	11	16	2	0	1
August	5	16	4	5	0	1
September	0	7	8	13	2	0
October	2	7	7	10	0	5
November	0	8	5	14	0	3
December	1	10	15	4	0	1
Sum	15	86	101	132	3	28

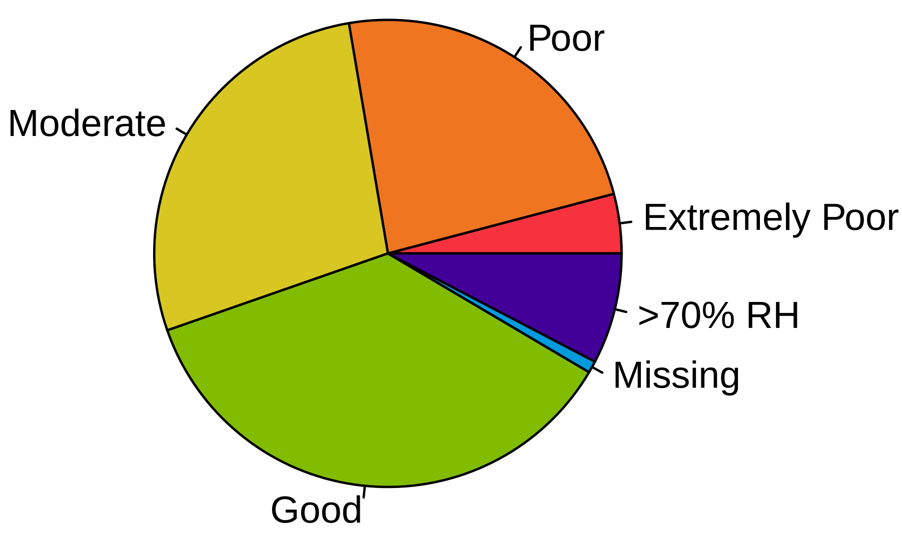

Figure 4.25: Denver visibility data.

4.2.7 Meteorology

See section 3.4 for more details on the wind rose plots below.

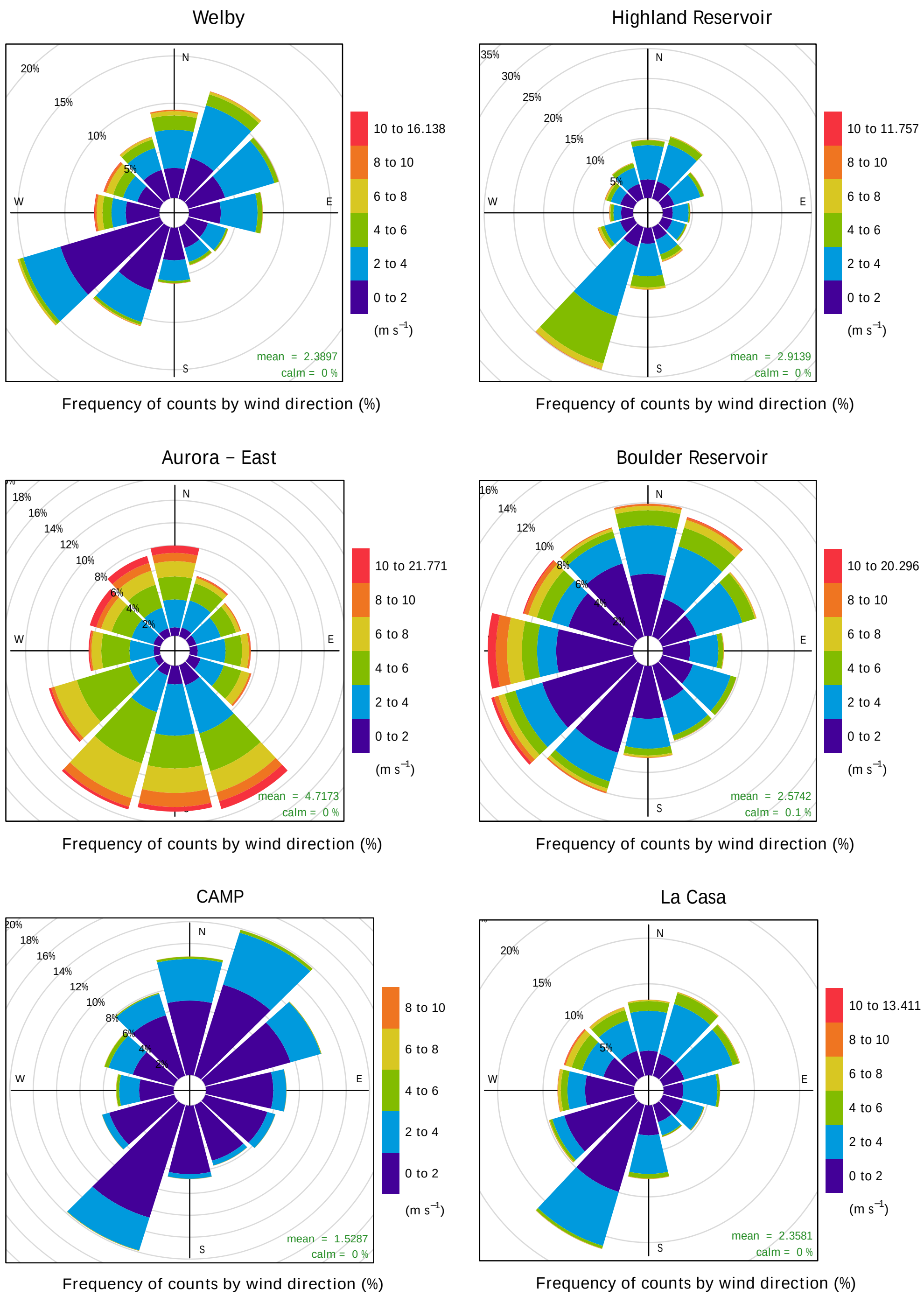

Figure 4.26: Wind roses for sites in the Denver Metro/North Front Range Region during 2018.

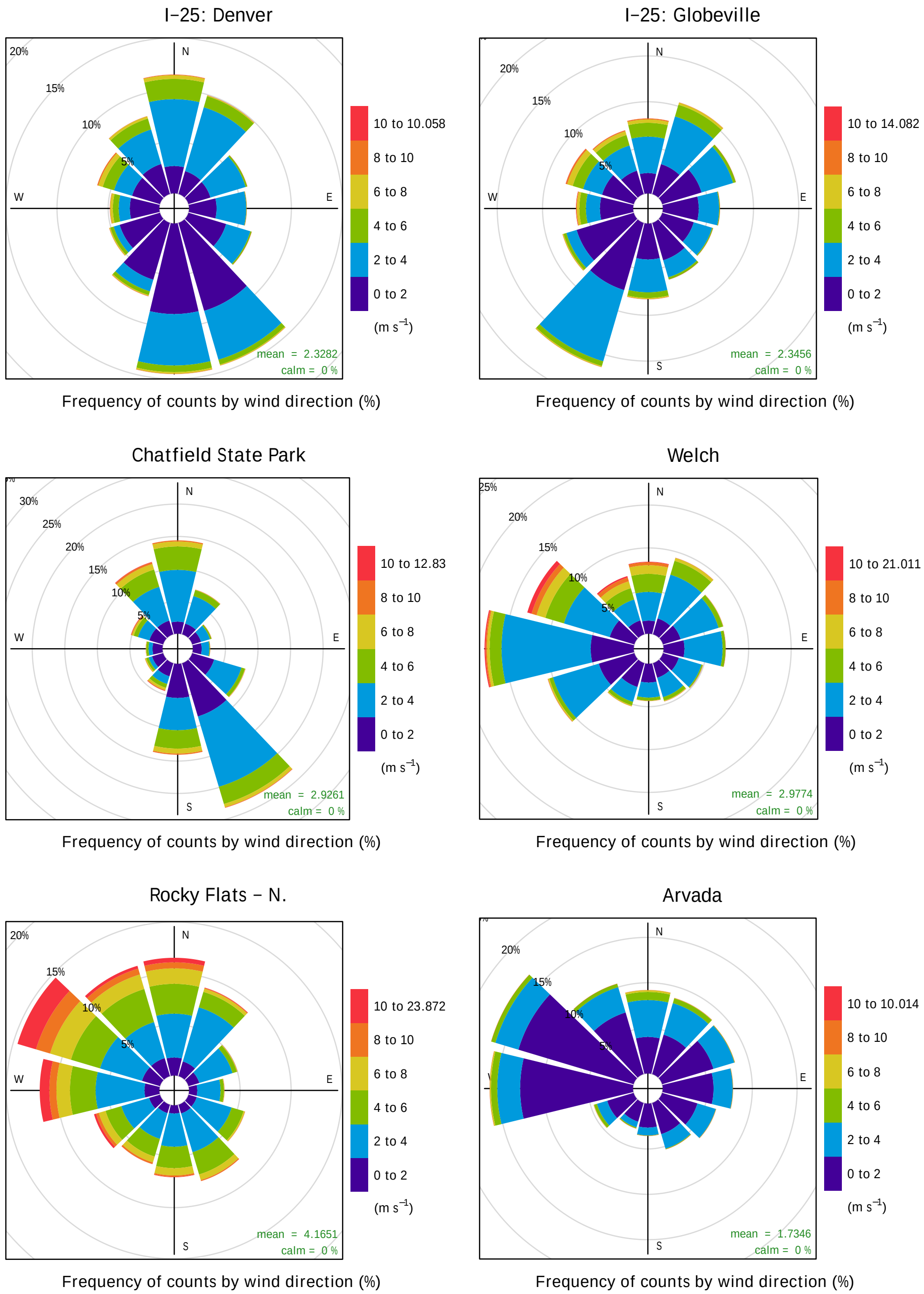

Figure 4.27: Wind roses for sites in the Denver Metro/North Front Range Region during 2018 (continued).

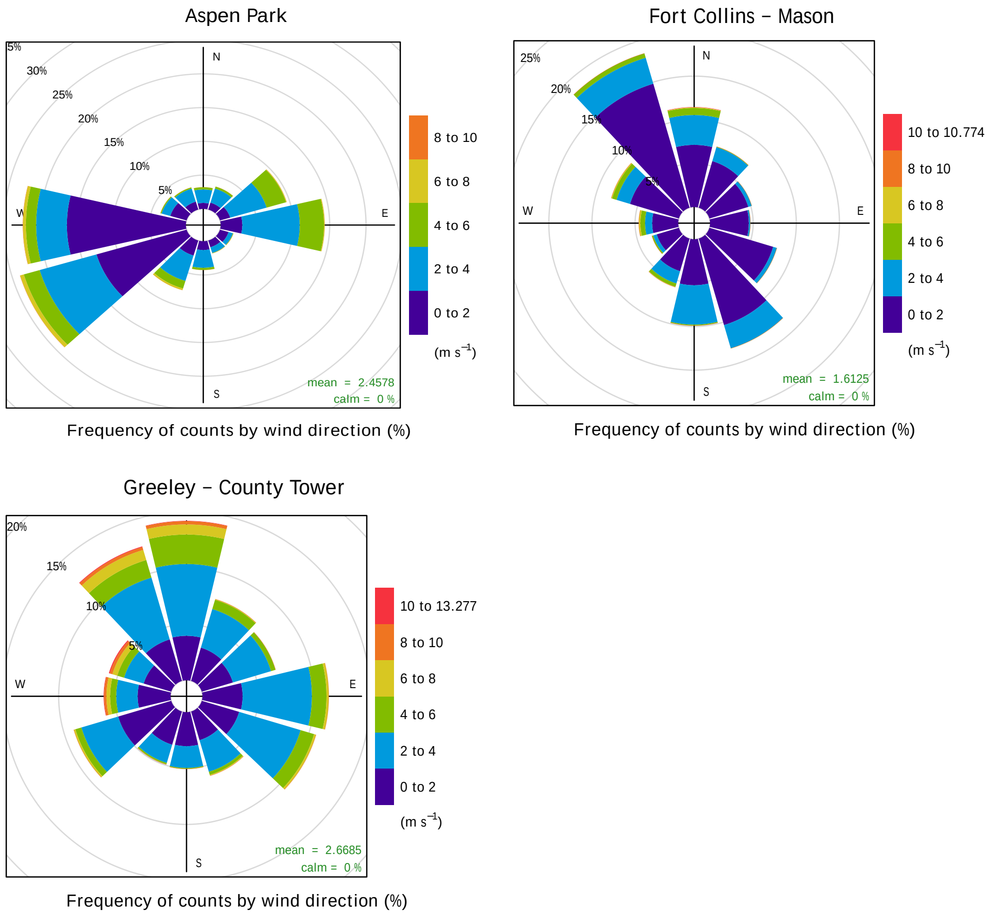

Figure 4.28: Wind roses for sites in the Denver Metro/North Front Range Region during 2018 (continued).

4.3 Eastern High Plains Region

4.3.1 Particulate Matter

Table 4.9: Summary of PM_{10} values recorded at monitoring stations in the Eastern High Plains region during 2018, with proposed exceptional events included.

Site Name	County	PM_{10} (µg m^{-3})		
		Annual Average	24-Hr Max	3-Year Exceedances
Lamar - Mun. Bldg.	Prowers	20.7	159	0.7

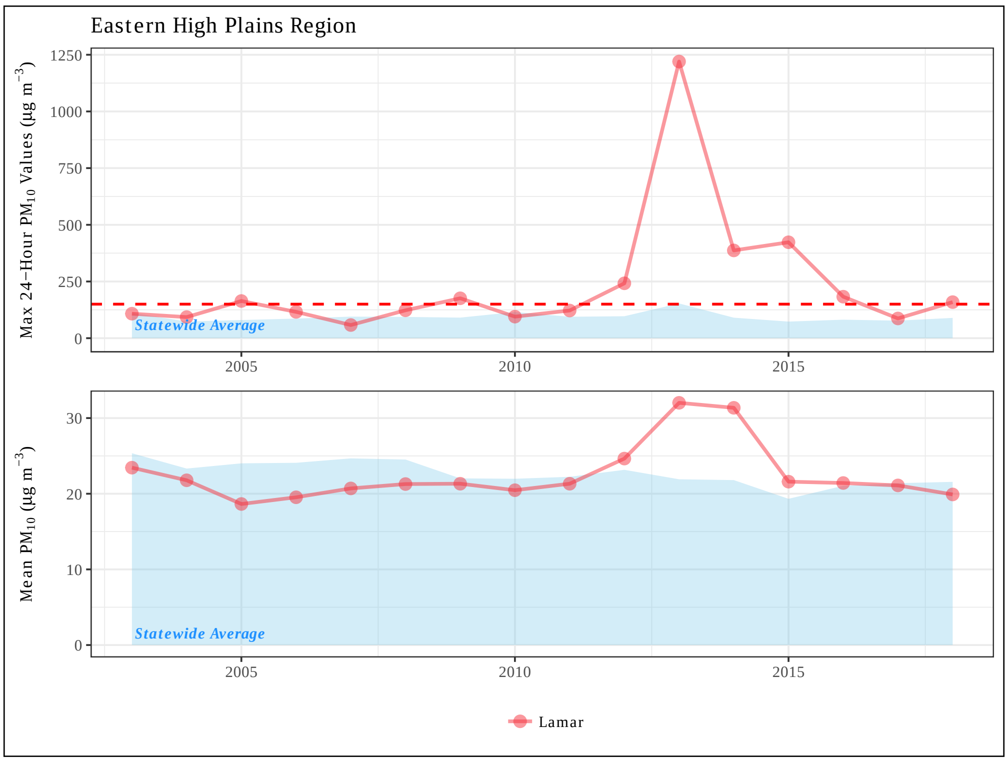

Figure 4.29: Fifteen-year trend in maximum 24-hour PM_{10} values (top) and annual mean concentrations (bottom) for monitoring sites in the Eastern High Plains region. The 24-hour NAAQS (150 µg m^{-3}) is shown as a dashed red line.

4.3.2 Meteorology

See section 3.4 for more details on the wind rose plot below.

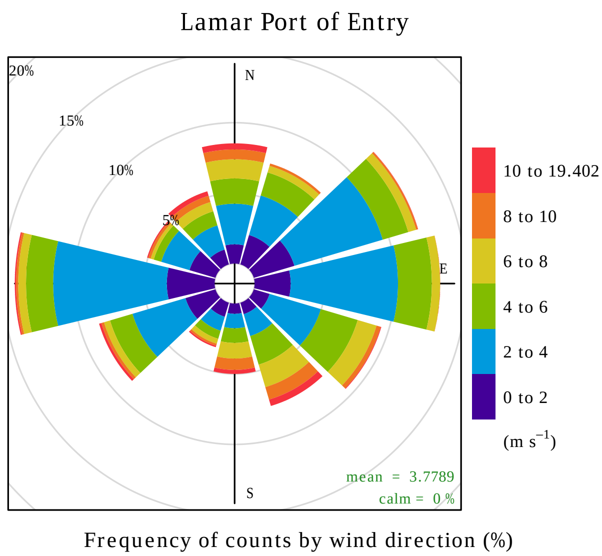

Figure 4.30: Wind rose from the Lamar - Port of Entry meteorological station.

4.4 Pikes Peak Region

4.4.1 Particulate Matter

Table 4.10: Summary of PM_{10} values recorded at the Colorado College station during 2018.

Site Name	County	PM_{10} (µg m^{-3})		
		Annual Average	24-Hr Max	3-Year Exceedances
Colorado College	El Paso	19.1	40	0

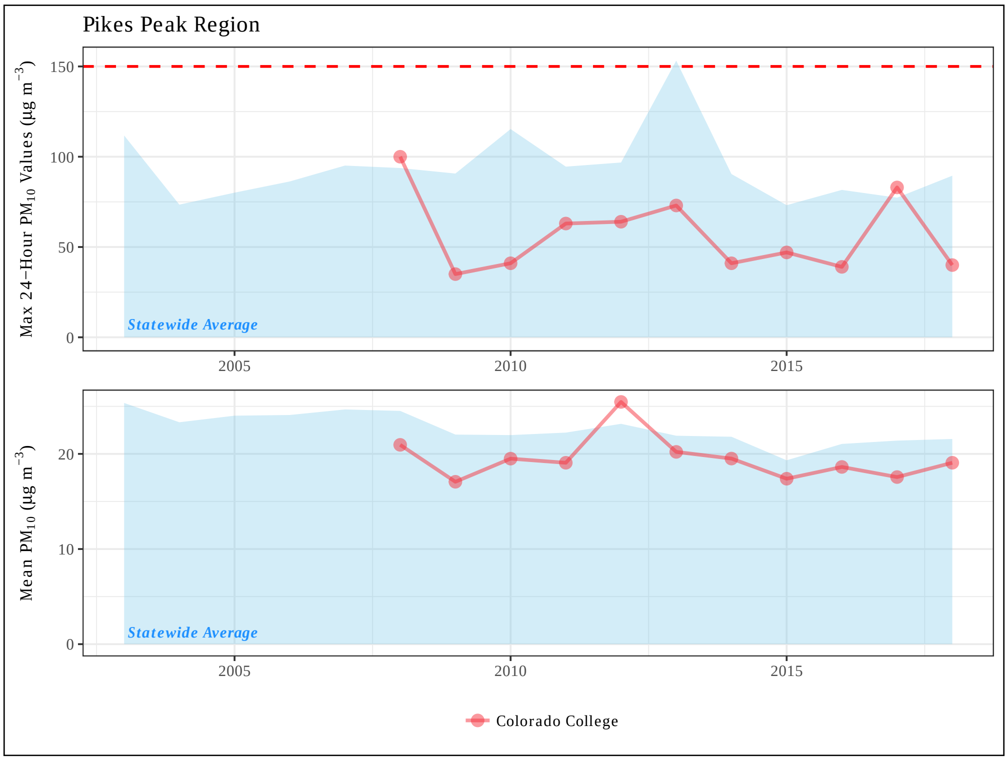

Figure 4.31: Fifteen-year trend in maximum 24-hour PM_{10} values (top) and annual mean concentrations (bottom) for monitoring sites in the Pikes Peak region. The 24-hour NAAQS (150 µg m^{-3}) is shown as a dashed red line.

Table 4.11: Summary of $PM_{2.5}$ values recorded at the Colorado College station during 2018.

Site Name	County	$PM_{2.5}$ (µg m^{-3})		
		Annual Average	Annual 98^{th} Percentile	3-Year Ave. of 98^{th} Percentile
Colorado College	El Paso	6.2	15.5	15

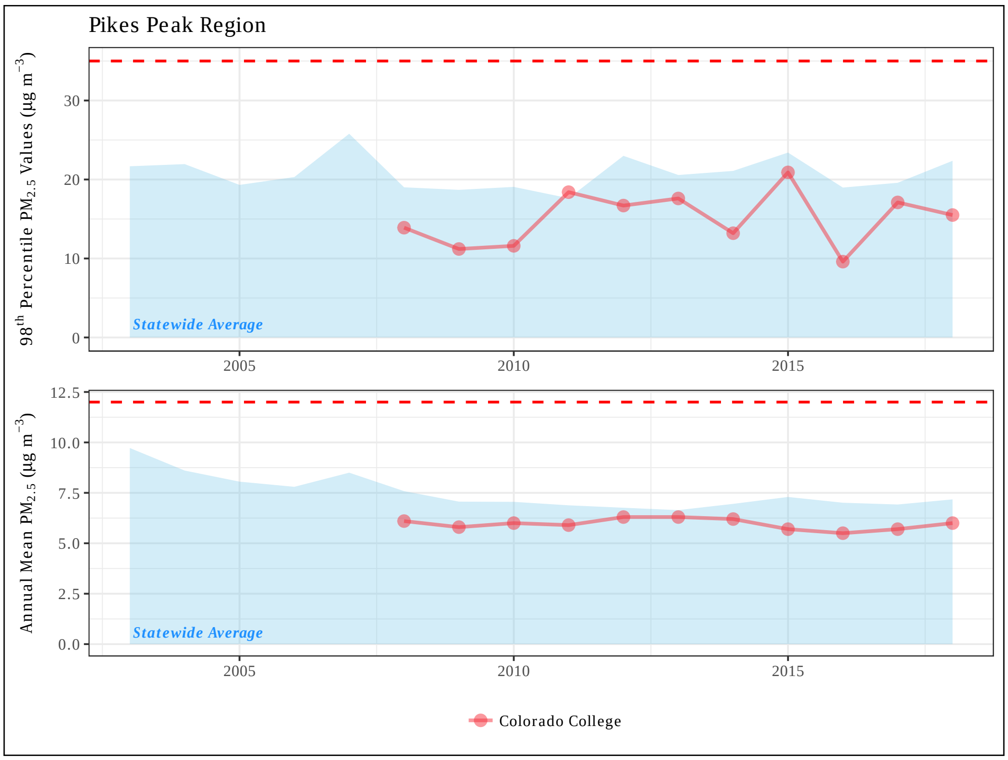

Figure 4.32: Fifteen-year trend in 24-hour $PM_{2.5}$ annual 98^{th} percentile values (top) and annual mean concentrations (bottom) for monitoring sites in the Pikes Peak region. The 24-hour and annual mean NAAQS (35 µg m^{-3} and 12 µg m^{-3}, respectively) are shown as dashed red lines.

4.4.2 Carbon Monoxide

Table 4.12: Summary of CO values recorded at the Highway 24 (Colorado Springs) station during 2018.

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	2.8	2.5	1.5	1.5

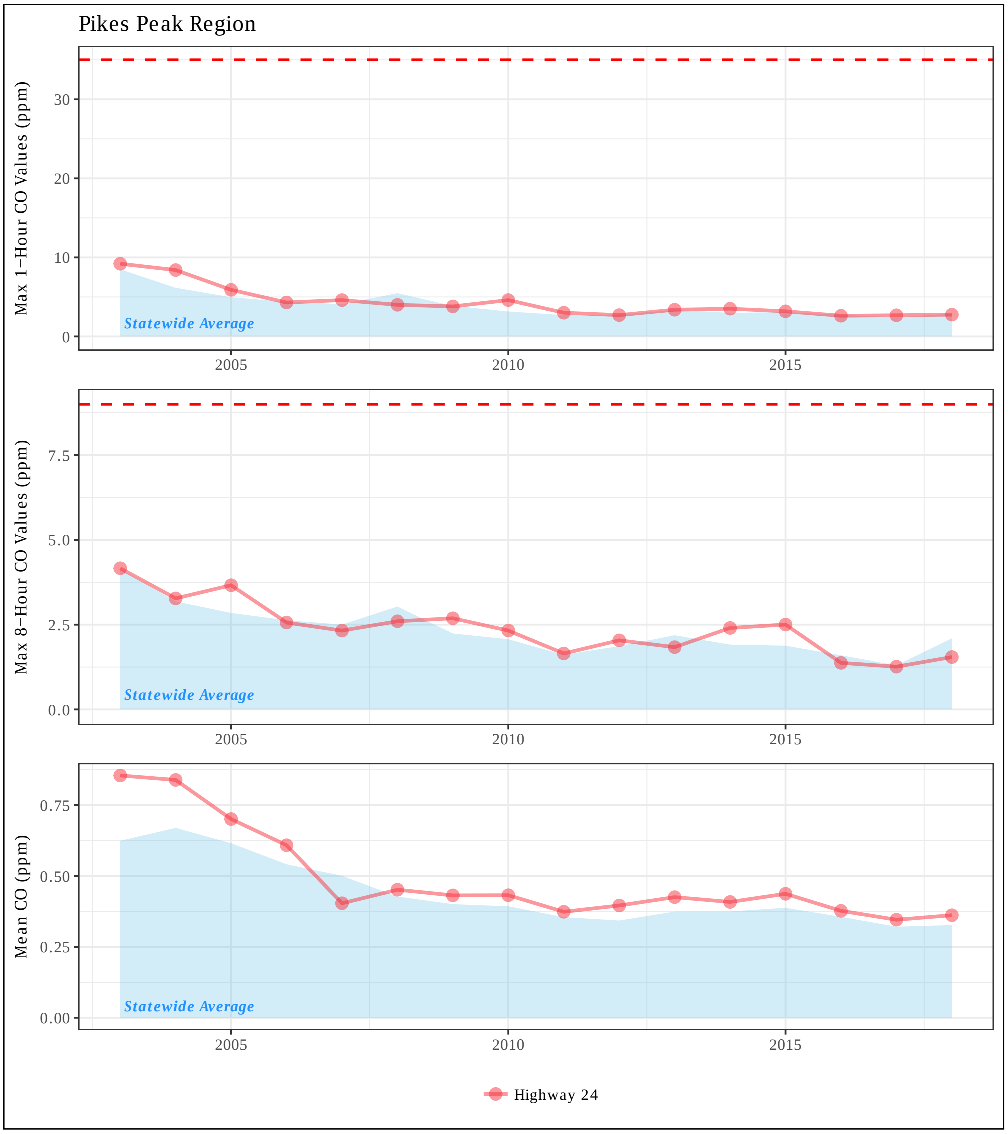

Figure 4.33: Fifteen-year trend in annual maximum one-hour (top) and eight-hour (center) CO values and annual mean eight-hour CO concentrations (bottom) for monitoring sites in the Pikes Peak region. The one-hour and eight-hour NAAQS (35 ppm and 9 ppm, respectively) are shown as dashed red lines.

4.4.3 Ozone

Table 4.13: Summary of O_3 values recorded at monitoring stations in the Pikes Peak region during 2018.

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	76	73	70
Manitou Springs	El Paso	76	72	69

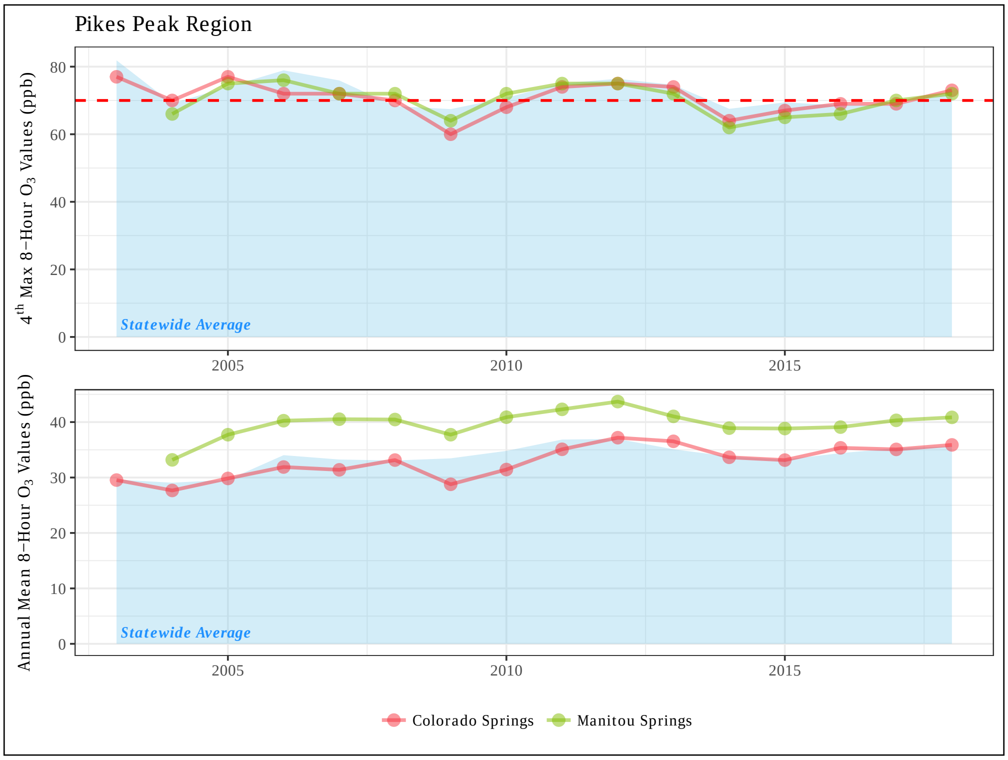

Figure 4.34: Fifteen-year trend in ozone eight-hour NAAQS values (top) and annual mean eight-hour concentrations (bottom) for monitoring sites in the Pikes Peak region. The eight-hour NAAQS (70 ppb) is shown as a dashed red line.

4.4.4 Sulfur Dioxide

Table 4.14: Summary of SO_2 values recorded at the Highway 24 monitoring site in Colorado Springs during 2018.

Site Name	County	SO_2 (ppb)		
		Annual Mean	99^{th} Percentile	3-Year Ave. of 99^{th} Percentile
Highway 24	El Paso	0.87	9.0	25

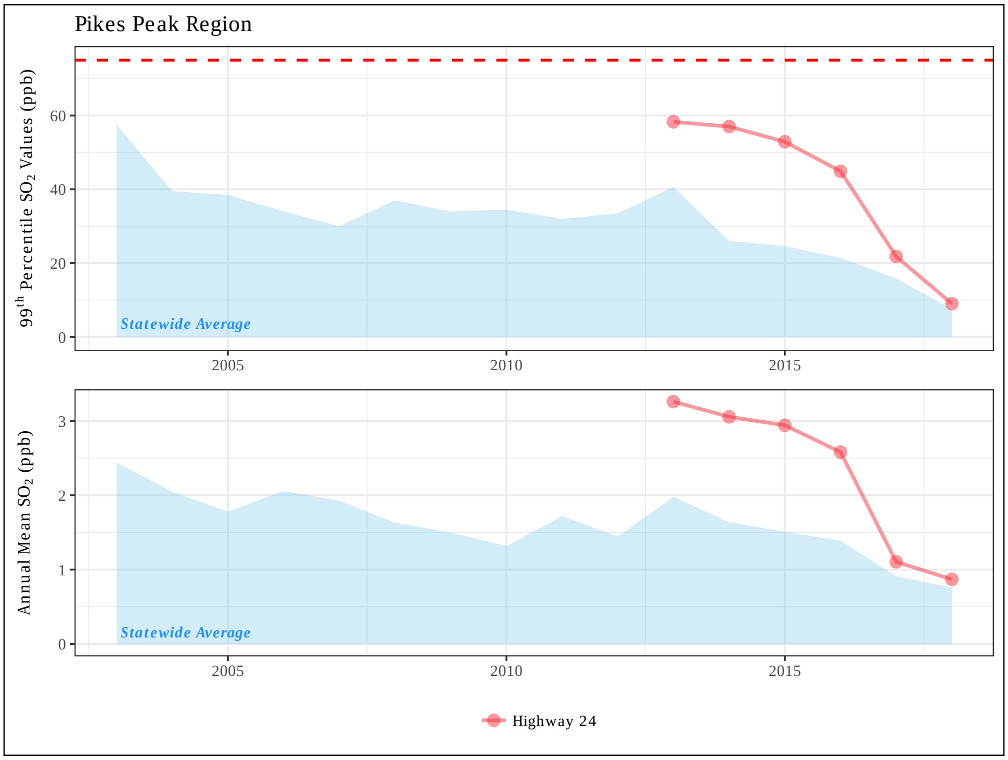

Figure 4.35: Fifteen-year trend in sulfur dioxide one-hour NAAQS values (top) and annual mean one-hour concentrations (bottom) for monitoring sites in the Pikes Peak region. The one-hour NAAQS (75 ppb) is shown as a dashed red line.

4.4.5 Meteorology

See section 3.4 for more details on the wind rose plot below.

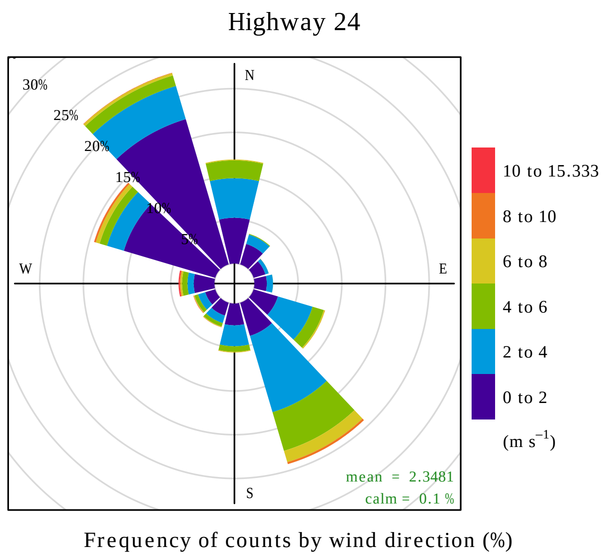

Figure 4.36: Wind rose from the Highway 24 meteorological station.

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 annual average of 1.0 exceedances over the last three years and is not in violation of the standard.

4.5.1 Particulate Matter

Table 4.15: Summary of PM_{10} values recorded at monitoring stations in the San Luis Valley region during 2018.

Site Name	County	PM_{10} (µg m^{-3})		
		Annual Average	24-Hr Max	3-Year Exceedances
Alamosa - Mun. Bldg.	Alamosa	22.9	379	1.0

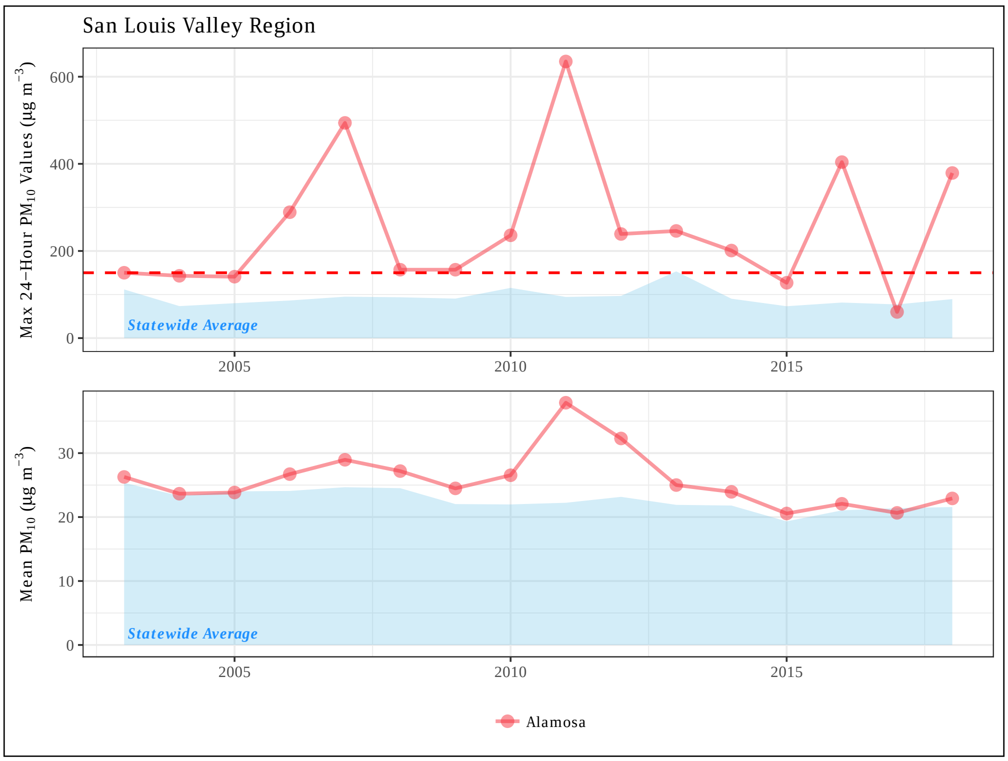

Figure 4.37: Fifteen-year trend in maximum 24-hour PM_{10} values (top) and annual mean concentrations (bottom) for monitoring sites in the San Luis Valley region. The 24-hour NAAQS (150 µg m^{-3}) is shown as a dashed red line.

4.6 South Central Region

4.6.1 Particulate Matter

Table 4.16: Summary of PM_{10} values recorded at the Pueblo monitoring station during 2018.

Site Name	County	PM_{10} (µg m^{-3})		
		Annual Average	24-Hr Max	3-Year Exceedances
Pueblo	Pueblo	20.7	155	2.2

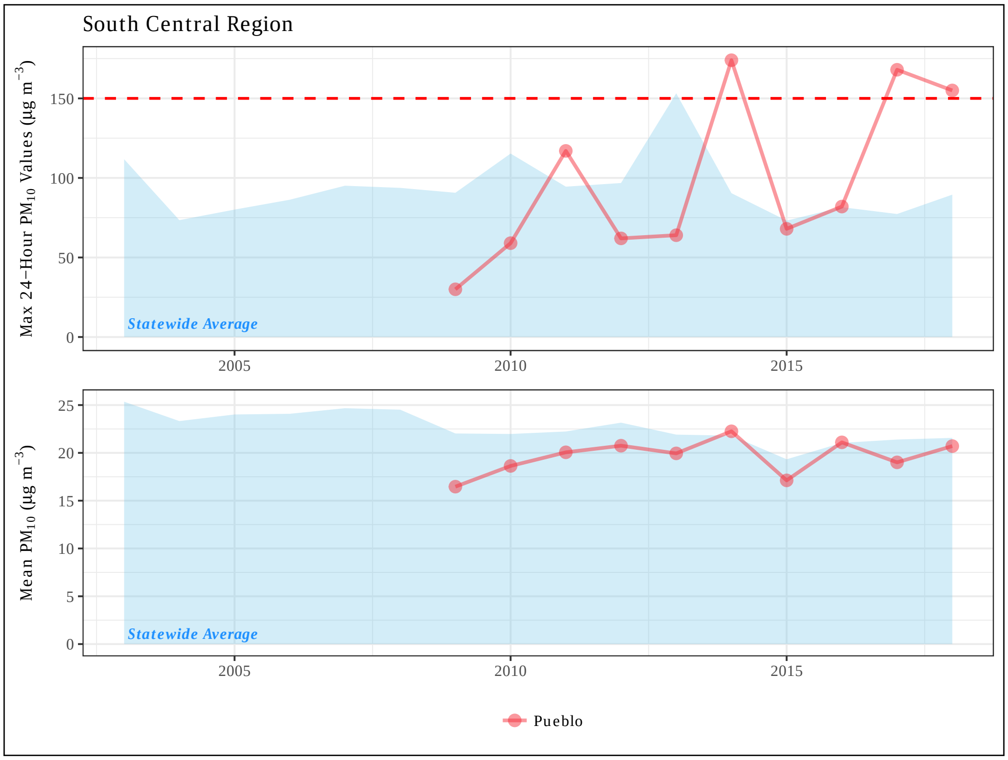

Figure 4.38: Fifteen-year trend in maximum 24-hour PM_{10} values (top) and annual mean concentrations (bottom) for monitoring sites in the South Central region. The 24-hour NAAQS (150 µg m^{-3}) is shown as a dashed red line.

Table 4.17: Summary of $PM_{2.5}$ values recorded at the Pueblo monitoring station during 2018.

Site Name	County	$PM_{2.5}$ (µg m^{-3})		
		Annual Average	Annual 98th Percentile	3-Year Ave. of 98th Percentile
Pueblo	Pueblo	6.2	15.8	14

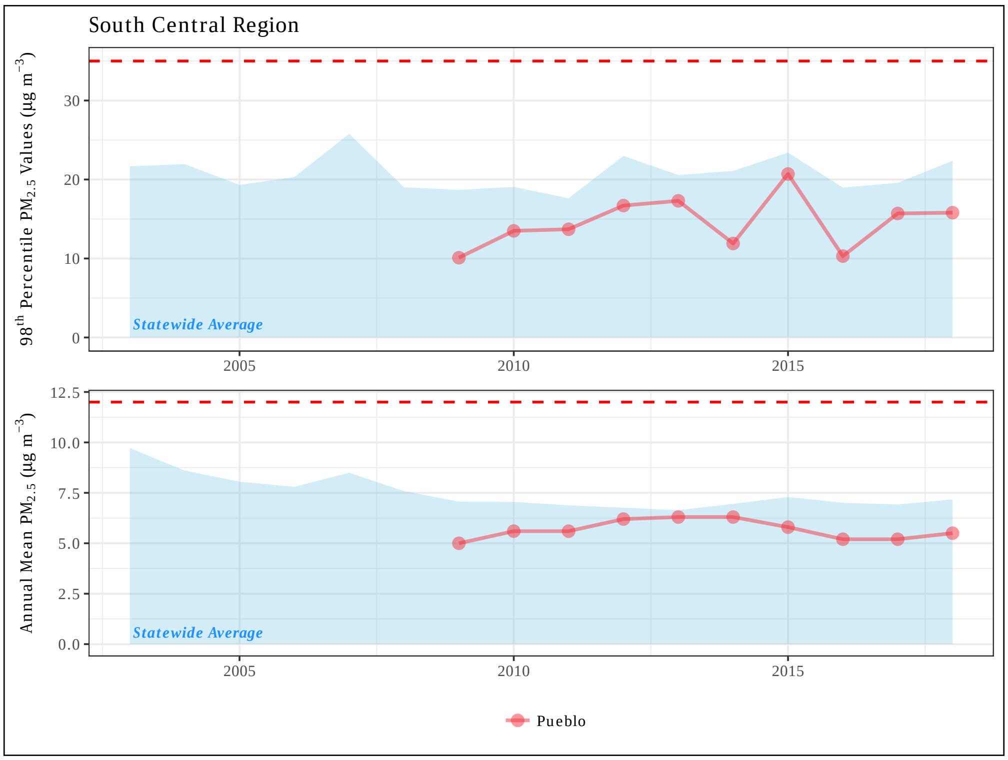

Figure 4.39: Fifteen-year trend in 24-hour $PM_{2.5}$ annual 98^{th} percentile values (top) and annual mean concentrations (bottom) for monitoring sites in the South Central region. The 24-hour and annual mean NAAQS (35 µg m^{-3} and 12 µg m^{-3}, respectively) are shown as dashed red lines.

4.7 Southwest Region

4.7.1 Particulate Matter

Table 4.18: Summary of PM_{10} values recorded at monitoring sites in the Southwest region during 2018.

Site Name	County	PM_{10} (µg m^{-3})		
		Annual Average	24-Hr Max	3-Year Exceedances
Pagosa Springs School	Archuleta	18.2	88	0
Durango	La Plata	20.3	147	0

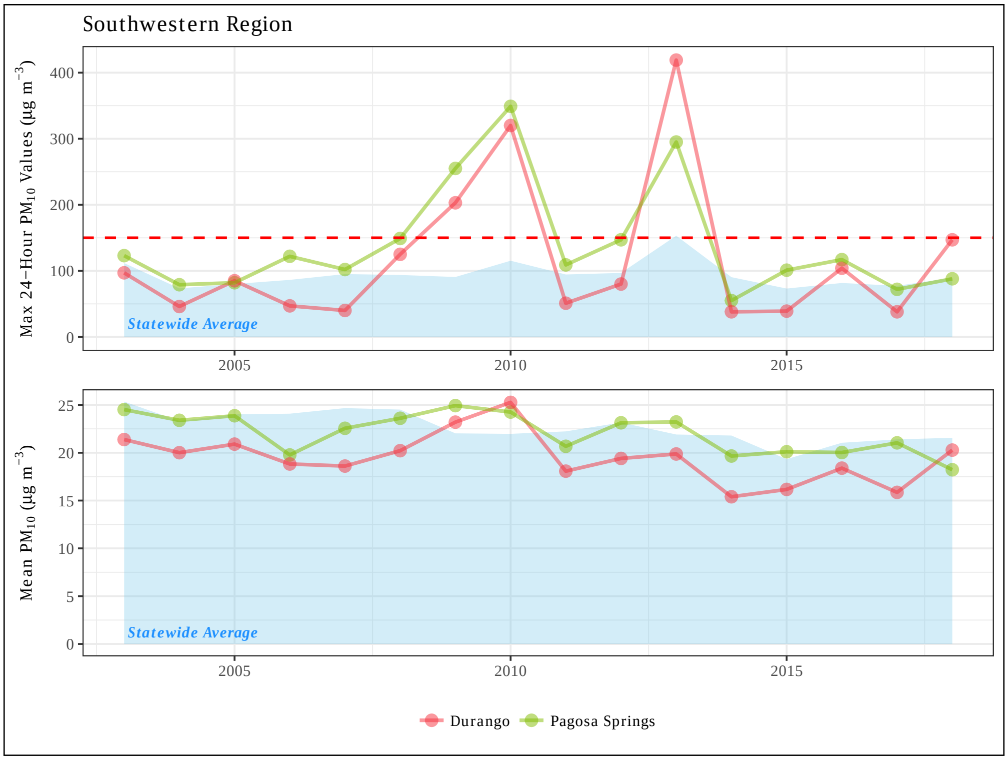

Figure 4.40: Fifteen-year trend in maximum 24-hour PM_{10} values (top) and annual mean concentrations (bottom) for monitoring sites in the Southwest region. The 24-hour NAAQS (150 µg m^{-3}) is shown as a dashed red line.

4.7.2 Ozone

Table 4.19: Summary of O_3 values recorded at monitoring stations in the Southwest region during 2018.

Site Name	County	Ozone 8-Hour Average (ppm)		
		1^{st} Max.	4^{th} Max.	3-Year Ave. of 4^{th} Max.
Cortez - Health Dept.	Montezuma	72	67	63

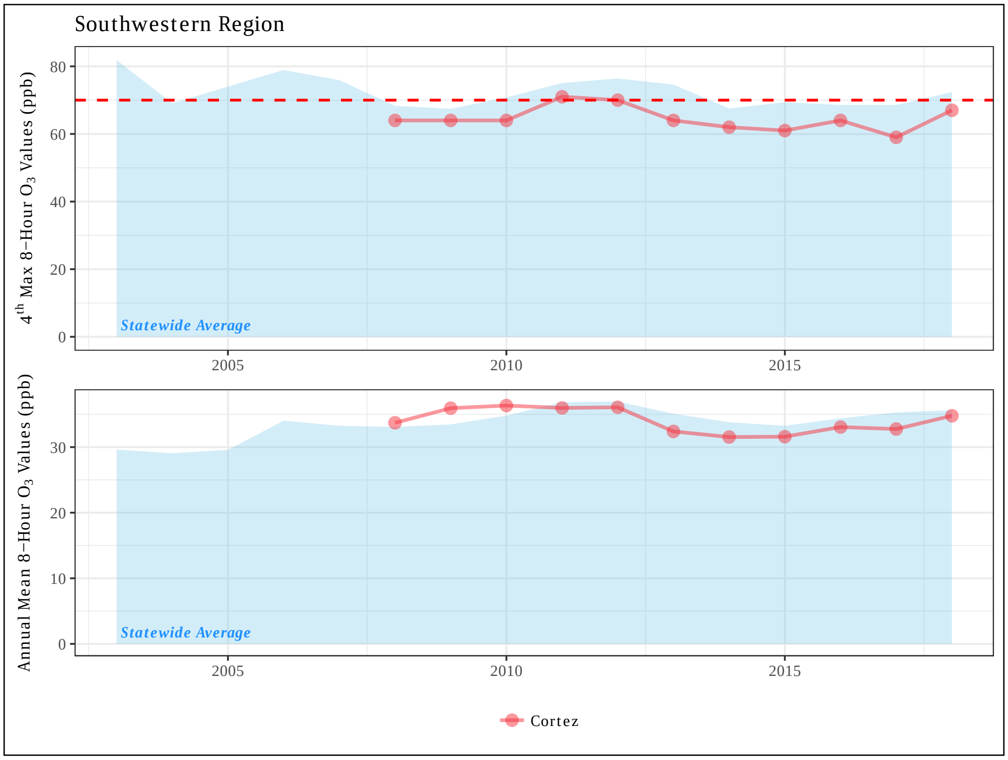

Figure 4.41: Fifteen-year trend in ozone eight-hour NAAQS values (top) and annual mean eight-hour concentrations (bottom) for monitoring sites in the Southwest region. The eight-hour NAAQS (70 ppb) is shown as a dashed red line.

4.8 Western Slope Region

4.8.1 Particulate Matter

Particulate monitoring at the Rifle Library site commenced in January 2017 and so the three-year average of annual exceedances cannot yet be calculated for this site.

Table 4.20: Summary of PM_{10} values recorded at monitoring sites in the Western Slope region during 2018.

Site Name	County	PM_{10} (µg m^{-3})		
		Annual Average	24-Hr Max	3-Year Exceedances
Delta - Health Dept.	Delta	21.8	51	0
Parachute	Garfield	14.7	35	0
Rifle - Library	Garfield	18.4	63	-
Grand Junction - Powell Bldg.	Mesa	17.0	45	0
Telluride	San Miguel	18.0	47	0

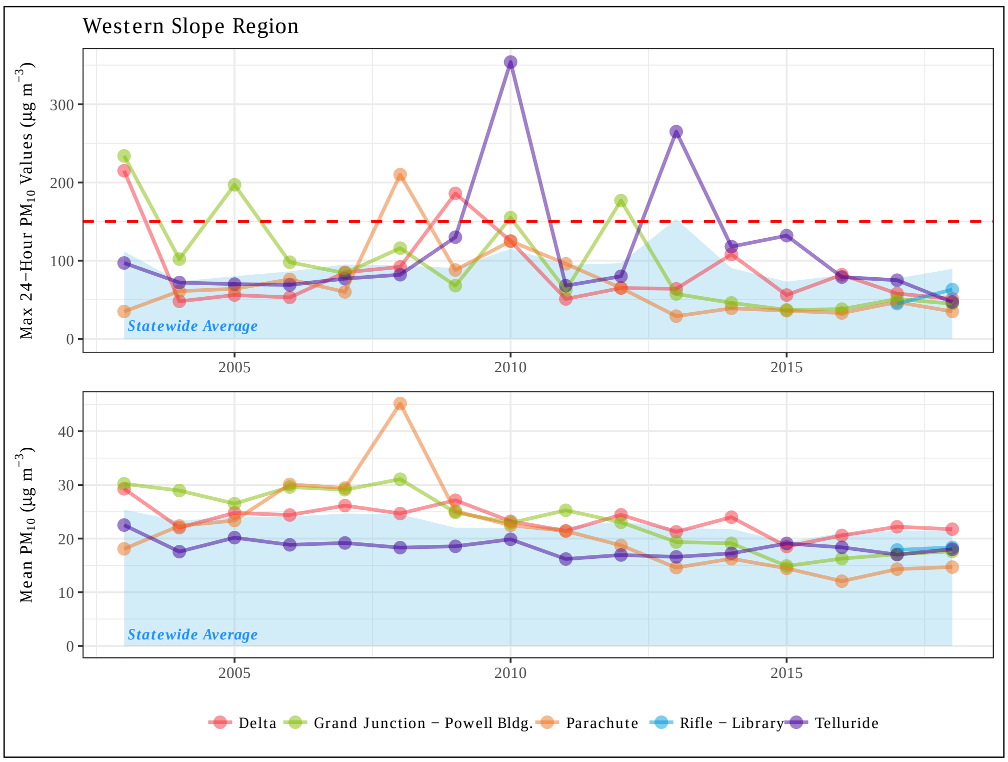

Figure 4.42: Fifteen-year trend in maximum 24-hour PM_{10} values (top) and annual mean concentrations (bottom) for monitoring sites in the South Central region. The 24-hour NAAQS (150 µg m^{-3}) is shown as a dashed red line.

Table 4.21: Summary of $PM_{2.5}$ values recorded at the Grand Junction - Powell Bldg. monitoring site during 2018.

Site Name	County	$PM_{2.5}$ ($\mu g\ m^{-3}$)		
		Annual Average	Annual 98^{th} Percentile	3-Year Ave. of 98^{th} Percentile
Grand Junction - Powell Bldg.	Mesa	5.9	16.4	17

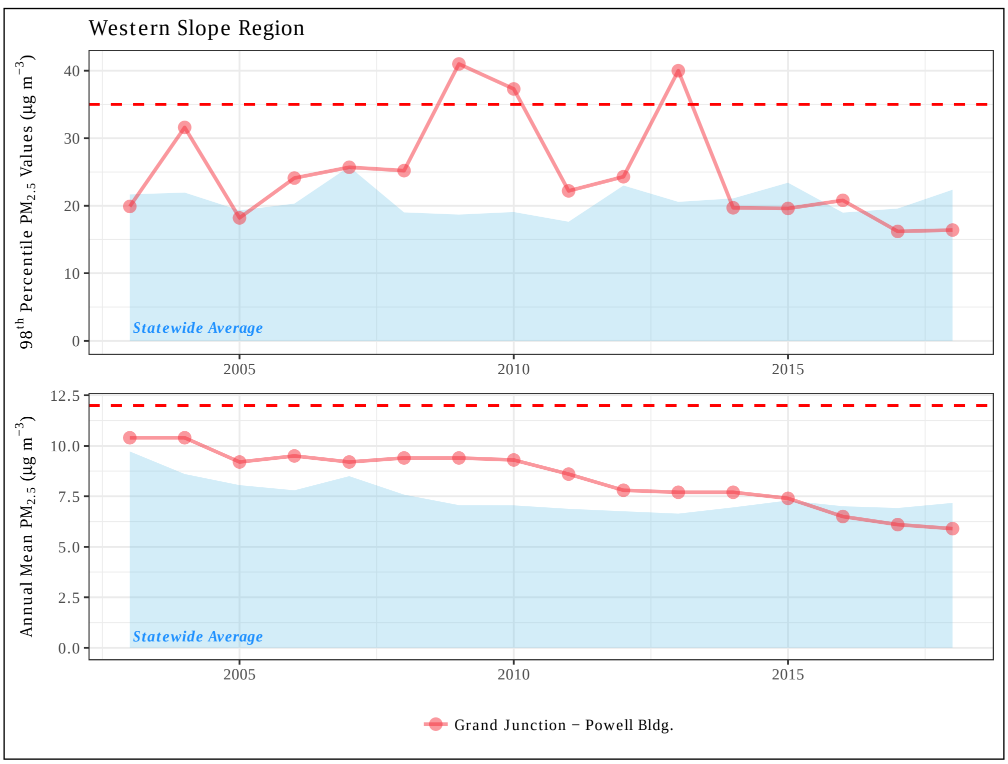

Figure 4.43: Fifteen-year trend in 24-hour $PM_{2.5}$ annual 98^{th} percentile values (top) and annual mean concentrations (bottom) for monitoring sites in the South Central region. The 24-hour and annual mean NAAQS (35 $\mu g\ m^{-3}$ and 12 $\mu g\ m^{-3}$, respectively) are shown as dashed red lines.

4.8.2 Carbon Monoxide

Table 4.22: Summary of CO values recorded at the Grand Junction - Pitkin station during 2018.

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	1.2	1.2	0.9	0.8

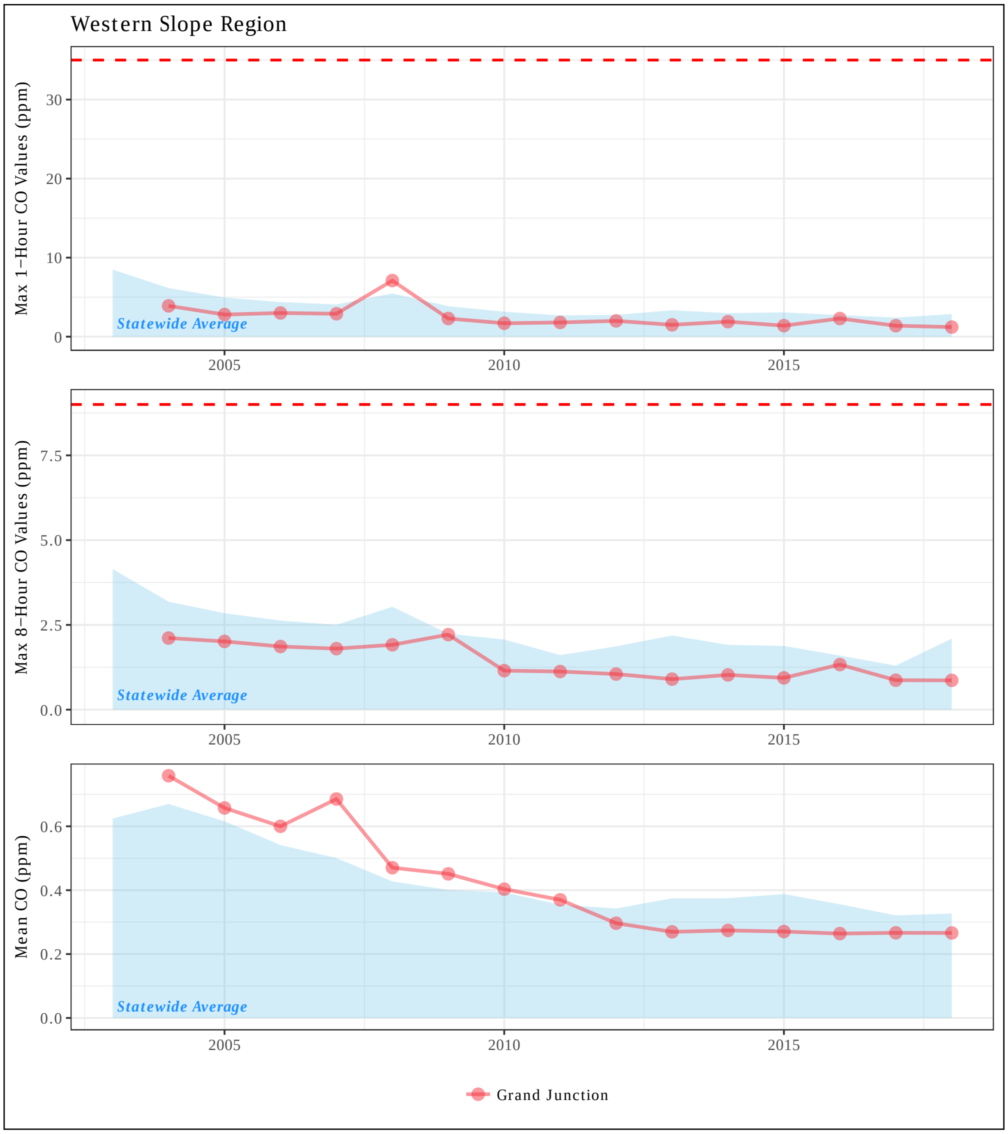

Figure 4.44: Fifteen-year trend in annual maximum one-hour (top) and eight-hour (center) CO values and annual mean eight-hour CO concentrations (bottom) for monitoring sites in the Western Slope region. The one-hour and eight-hour NAAQS (35 ppm and 9 ppm, respectively) are shown as dashed red lines.

4.8.3 Ozone

Ozone monitoring at Paradox commenced in March 2016; therefore, the three-year average value cannot be calculated for comparison to the NAAQS at this site.

Table 4.23: Summary of O_3 values recorded at monitoring stations in the Western Slope region during 2018.

Site Name	County	Ozone 8-Hour Average (ppm)		
		1st Max.	4th Max.	3-Year Ave. of 4th Max.
Rifle - Health Dept.	Garfield	86	65	61
Palisade	Mesa	78	69	65
Elk Springs	Moffat	73	64	62
Paradox	Montrose	77	65	-

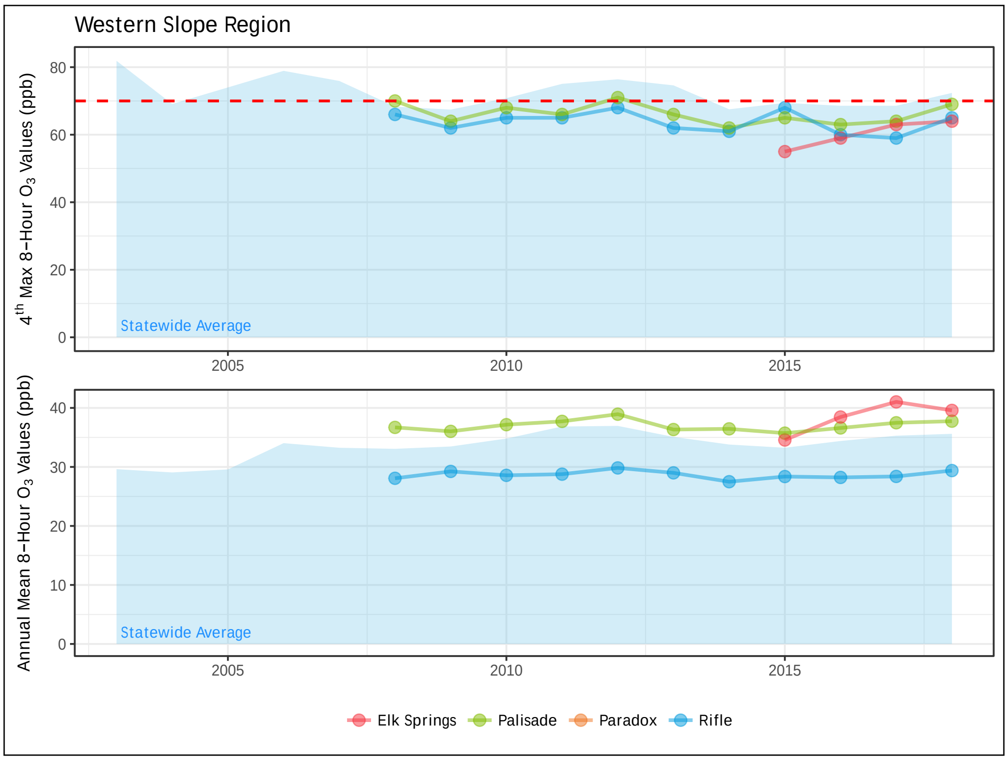

Figure 4.45: Fifteen-year trend in ozone eight-hour NAAQS values (top) and annual mean eight-hour concentrations (bottom) for monitoring sites in the Western Slope region. The eight-hour NAAQS (70 ppb) is shown as a dashed red line.

4.8.4 Meteorology

See section 3.4 for more details on the wind rose plots below.

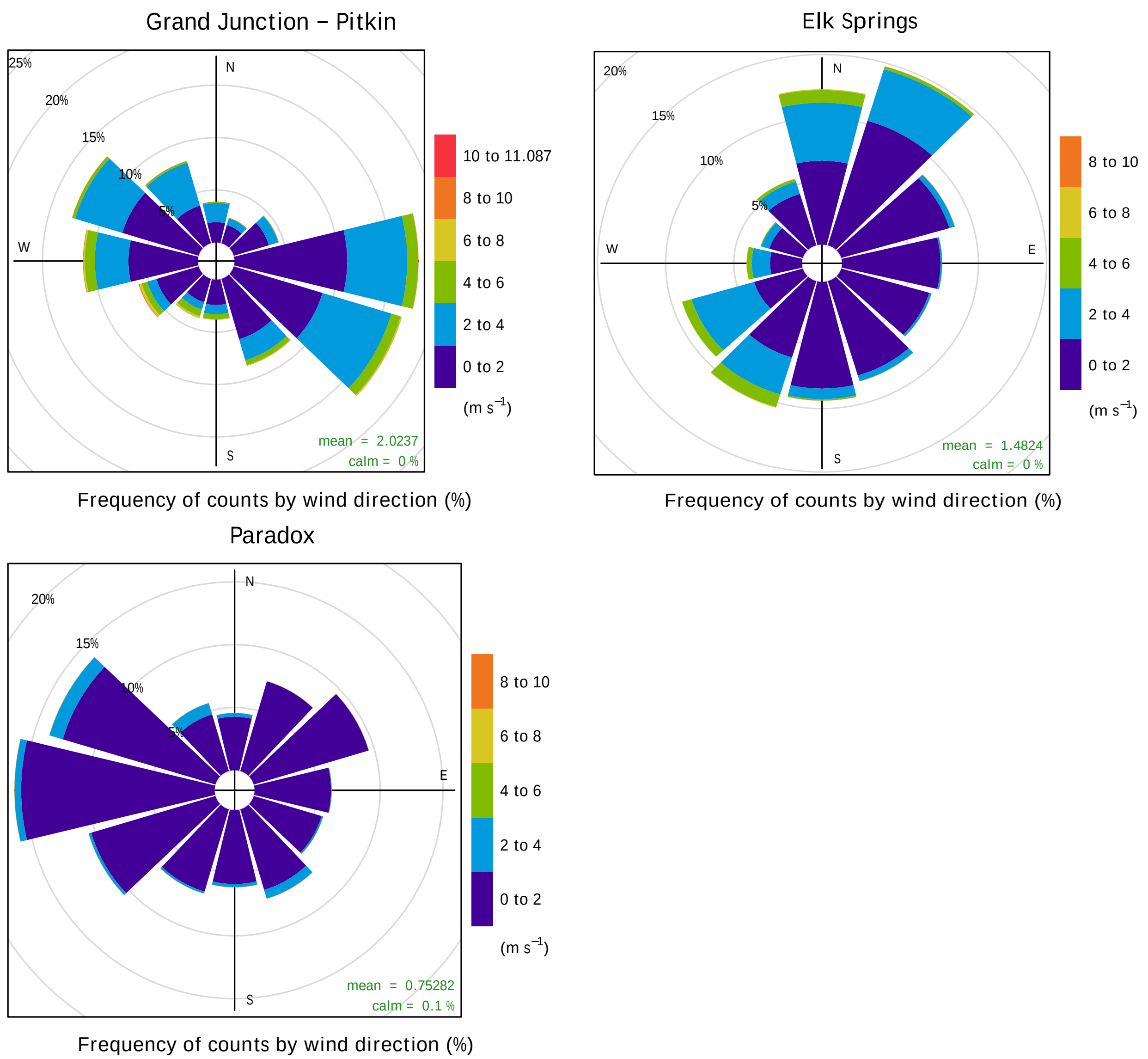

Figure 4.46: Wind roses for sites in the Western Slope Region during 2018.

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, 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.

In all of the graphs in this section, the range is illustrated as blue shading, where the lower and upper limits are defined as the minimum and maximum monthly averages, respectively. This is the range for the entire state. The sites are not grouped by monitoring region in this section, rather they are presented in order of their Air Quality Site ID, which is an EPA designated code derived from the state and county where the site is located, along with a unique site number. Each graph has been limited in the number of sites it presents for clarity sake, but for each pollutant set, the minimum and maximum state-wide range is the same. Data in the graphs below may include exceptional events (see subsubsection 2.2.5.4).

5.1 Carbon Monoxide

CO is normally higher in the winter months and lower in the summer, for reasons previously discussed (see subsection 2.2.1).

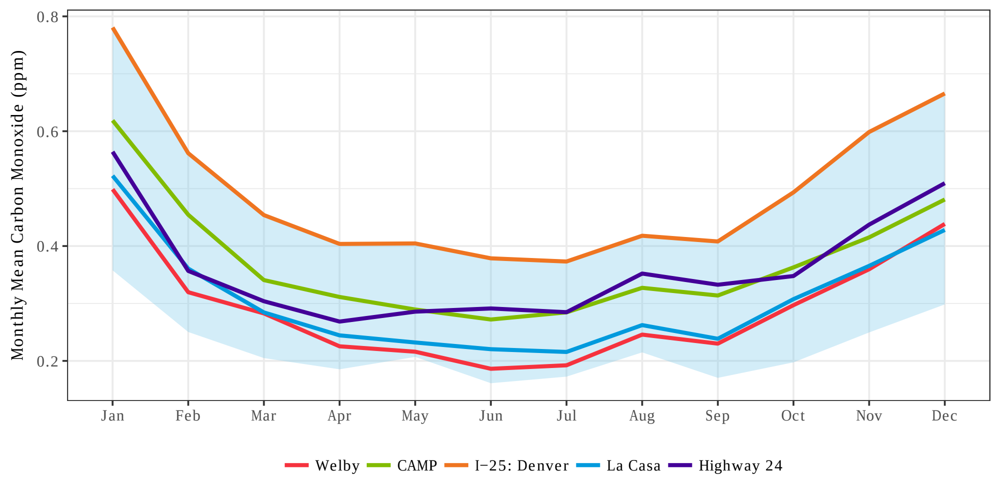

Figure 5.1: Monthly mean carbon monoxide concentrations. The blue shaded region shows the statewide range of monthly mean values.

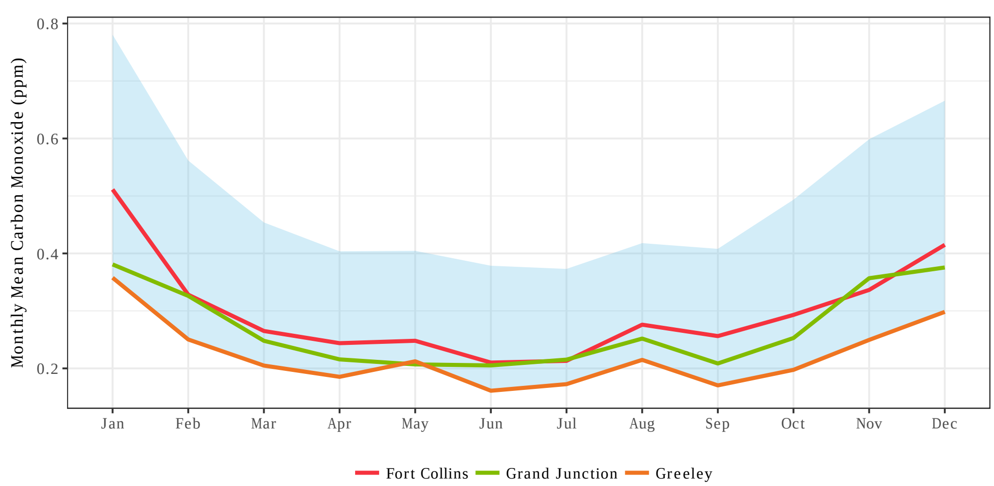

Figure 5.2: Monthly mean carbon monoxide concentrations. The blue shaded region shows the statewide range of monthly mean values.

5.2 Sulfur Dioxide

Sulfur dioxide was measured at four stations during 2018 by APCD in Colorado: Welby, La Casa, CAMP, and Highway 24 (Colorado Springs). Sulfur 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.

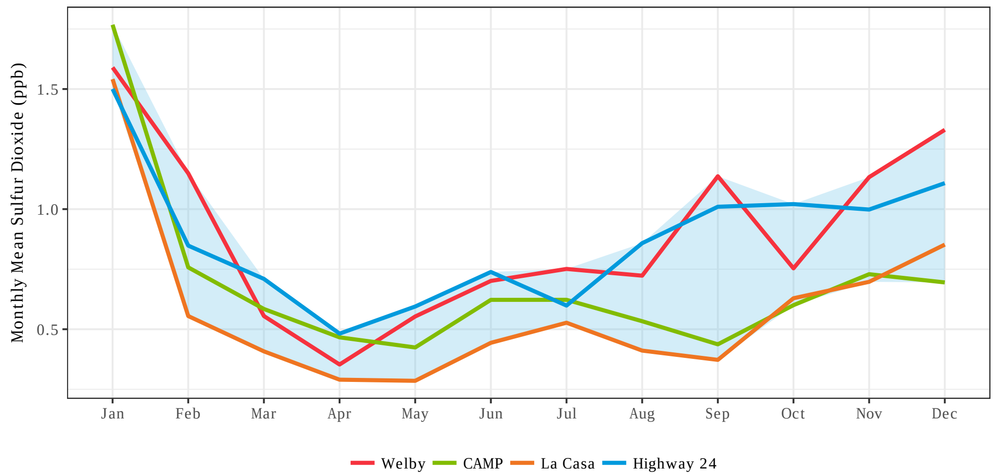

Figure 5.3: Monthly mean sulfur dioxide concentrations. The blue shaded region shows the statewide range of monthly mean values.

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.

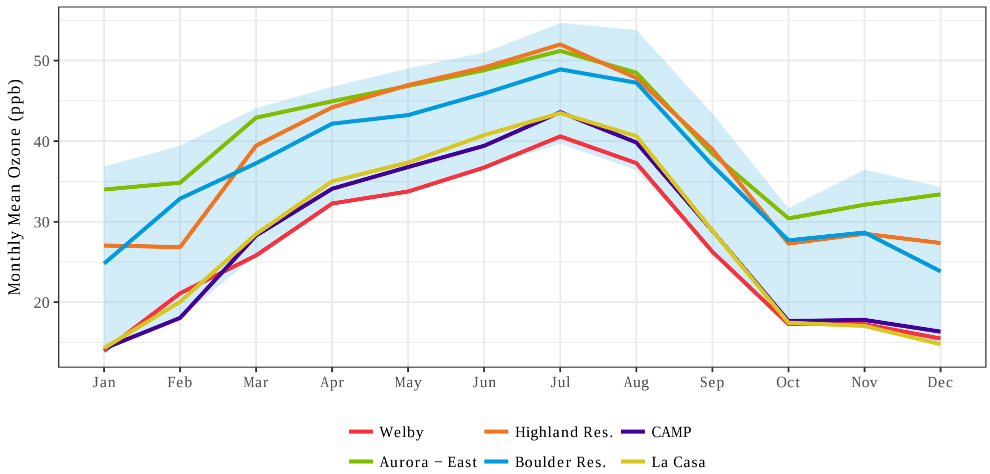

Figure 5.4: Monthly mean ozone concentrations. The blue shaded region shows the statewide range of monthly mean values.

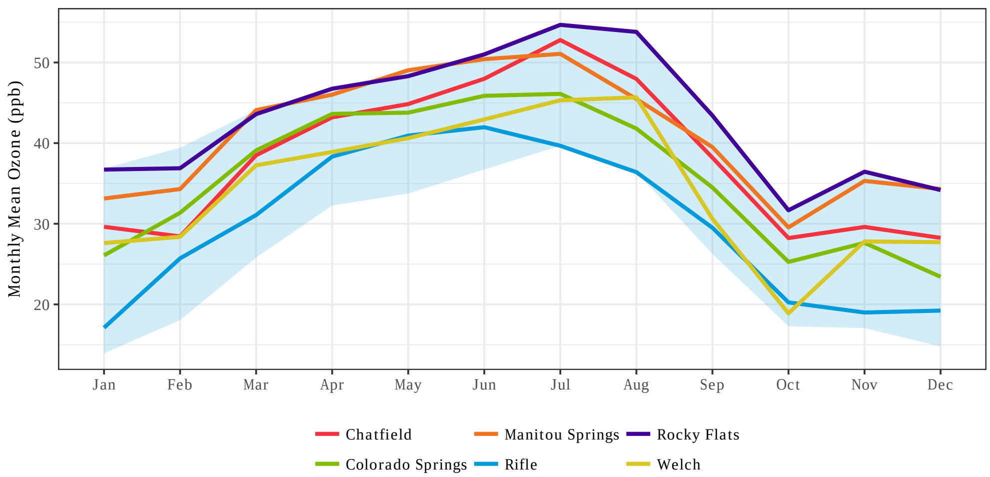

Figure 5.5: Monthly mean ozone concentrations. The blue shaded region shows the statewide range of monthly mean values.

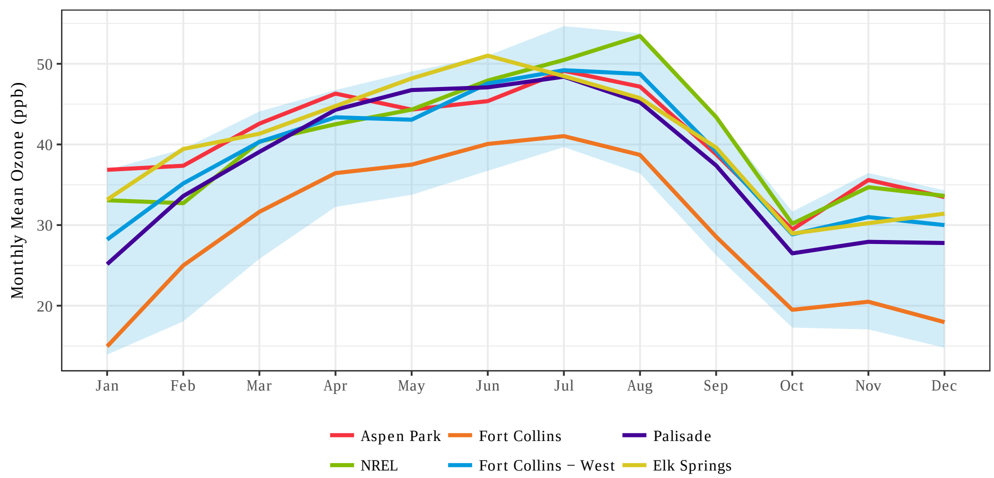

Figure 5.6: Monthly mean ozone concentrations. The blue shaded region shows the statewide range of monthly mean values.

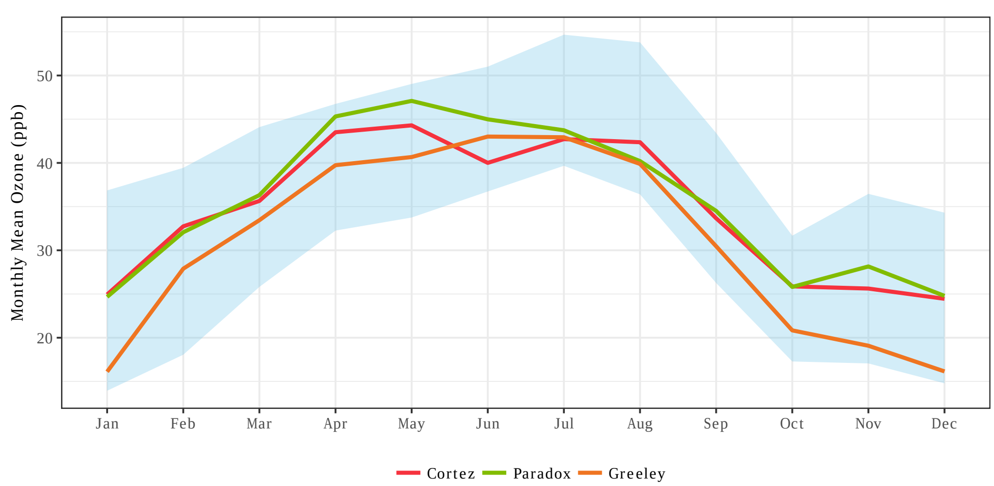

Figure 5.7: Monthly mean ozone concentrations. The blue shaded region shows the statewide range of monthly mean values.

5.4 Nitrogen Dioxide

Nitrogen dioxide was measured at five stations during 2018 by APCD in Colorado: Welby, Camp, La Casa, I-25 Globeville and I-25 Denver. 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.

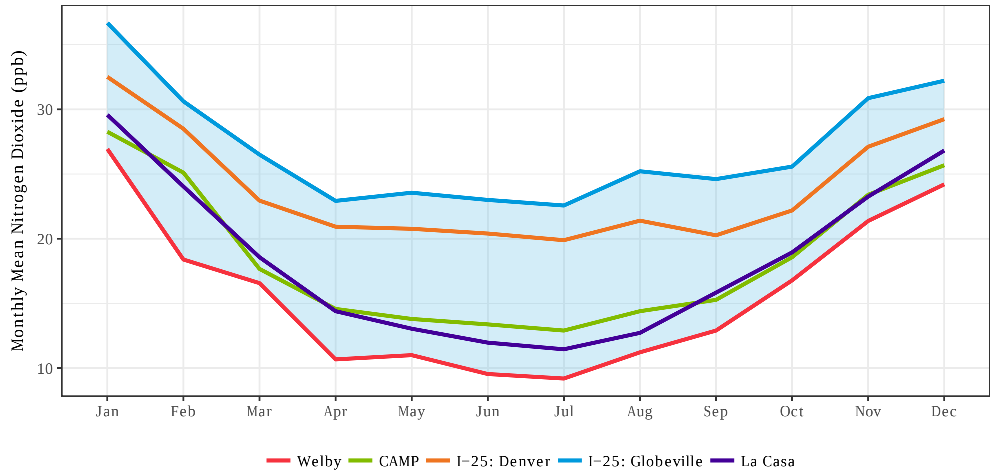

Figure 5.8: Monthly mean nitrogen dioxide concentrations. The blue shaded region shows the statewide range of monthly mean values.

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, typically associated with high winds and blowing dust. 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.

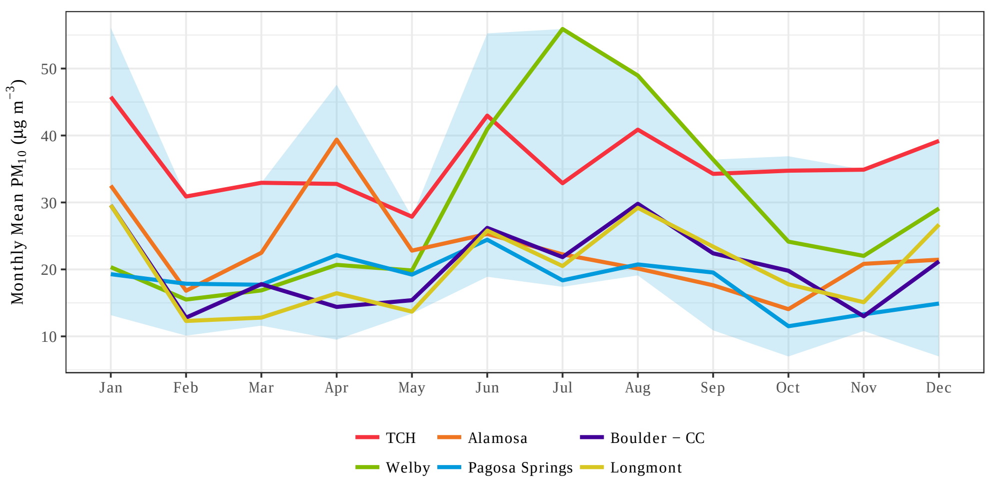

Figure 5.9: Monthly mean PM_{10} concentrations. The blue shaded region shows the statewide range of monthly mean values.

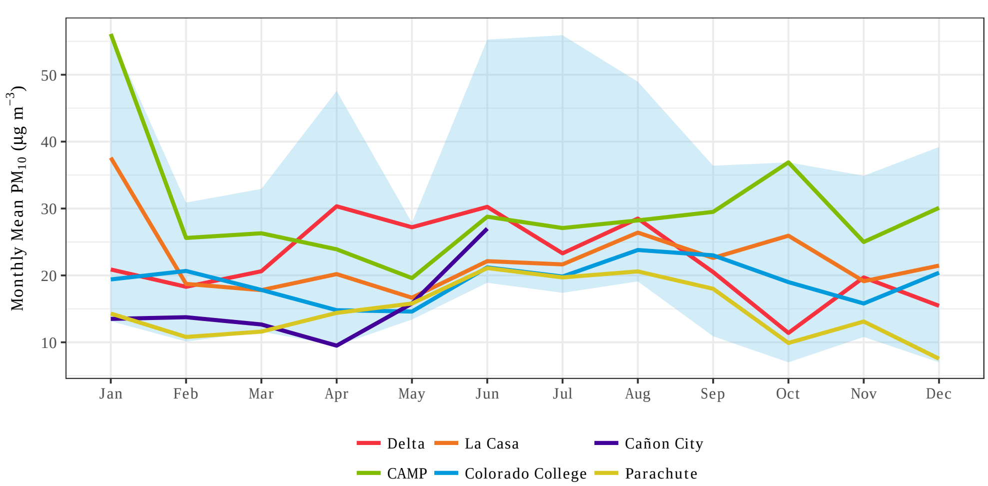

Figure 5.10: Monthly mean PM_{10} concentrations. The blue shaded region shows the statewide range of monthly mean values.

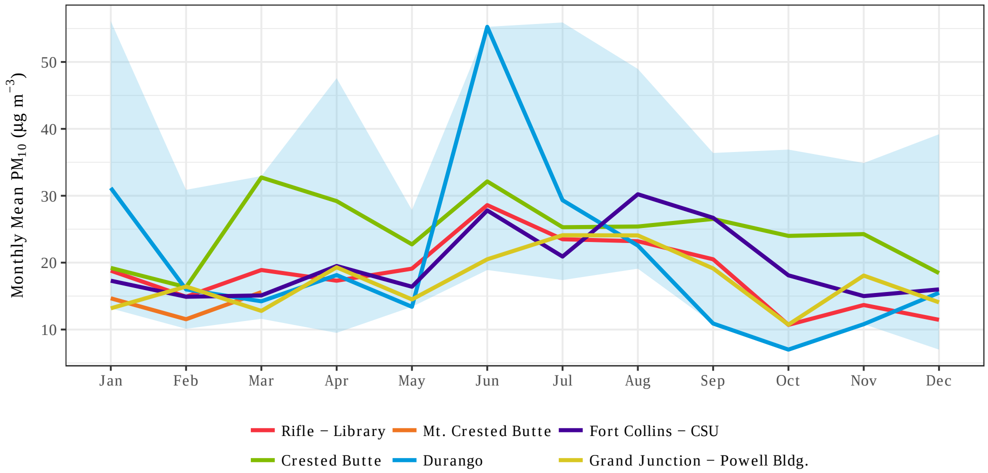

Figure 5.11: Monthly mean PM_{10} concentrations. The blue shaded region shows the statewide range of monthly mean values.

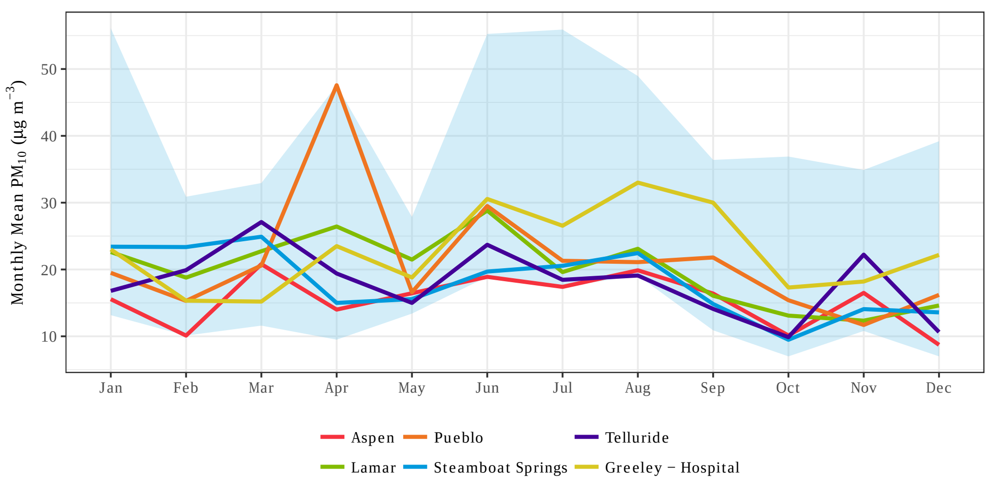

Figure 5.12: Monthly mean PM_{10} concentrations. The blue shaded region shows the statewide range of monthly mean values.

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. The graphs here may include exceptional event data.

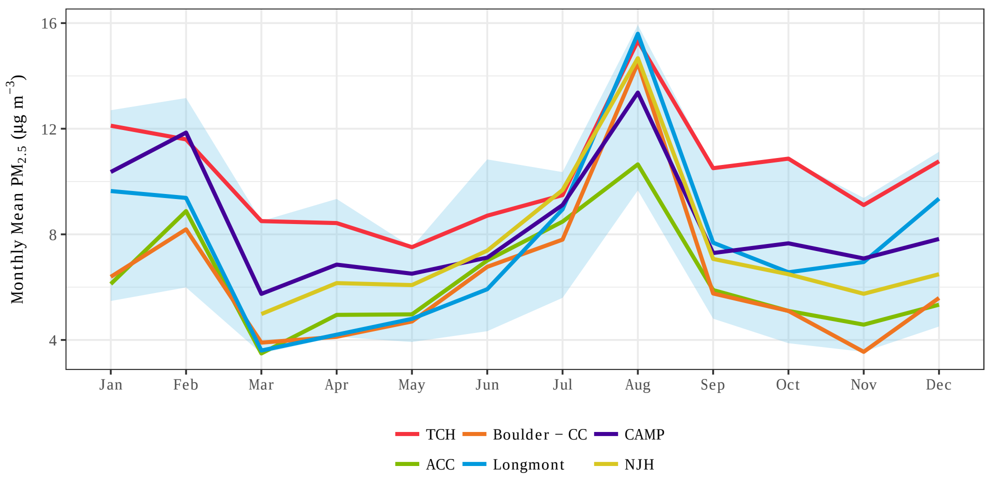

Figure 5.13: Monthly mean PM$_{2.5}$ concentrations. The blue shaded region shows the statewide range of monthly mean values.

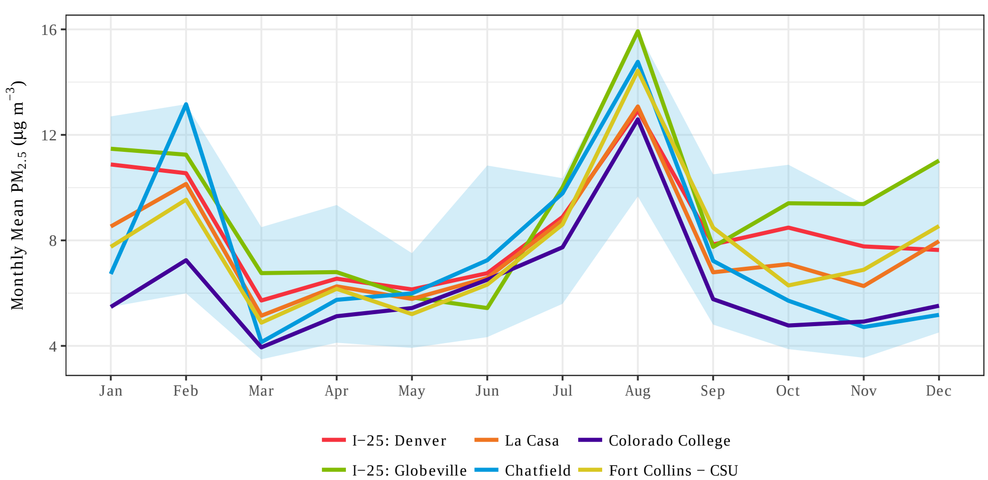

Figure 5.14: Monthly mean PM$_{2.5}$ concentrations. The blue shaded region shows the statewide range of monthly mean values.

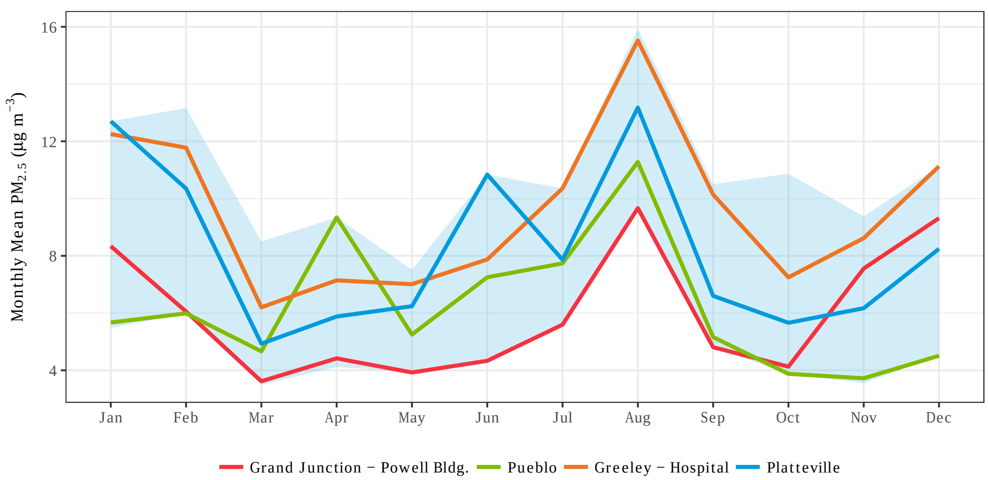

Figure 5.15: Monthly mean $PM_{2.5}$ concentrations. The blue shaded region shows the statewide range of monthly mean values.

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. 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 Quality Control

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.

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.

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

Site	Parameter	Precision Count	Precision Complete (%)	CV (%)	Bias (%)	Prob. Limits Lower	Prob. Limits Upper	Data Complete (%)
Welby	CO	22	85	2.25	+2.13	-2.5	4.7	98
CAMP	CO	23	88	3.77	+3.7	-4.14	7.9	97
La Casa	CO	21	81	2.48	+2.97	-1.81	6.12	98
I-25: Denver	CO	22	85	2.89	+/-2.43	-3.74	5.48	96
Highway 24	CO	20	77	1.82	+1.76	-1.94	3.89	99
Fort Collins - Mason	CO	21	81	2.18	+2.84	-1.33	5.65	98
Grand Junction - Pitkin	CO	19	73	2.19	+2.03	-2.5	4.48	96
Greeley - County Tower	CO	21	81	0.92	+2.89	1.18	4.12	99
Welby	SO_2	23	88	4.06	+/-3.34	-7.28	5.7	95
CAMP	SO_2	22	85	3.09	+/-2.87	-3.71	6.16	93
La Casa	SO_2	21	81	1.92	-3.29	-5.85	0.3	94
Highway 24	SO_2	20	77	2.78	+/-2.24	-4.15	4.73	94
Welby	NO_2	23	88	3.17	+/-4.06	-8.11	2.03	93
CAMP	NO_2	21	81	2.06	+3.48	-0.43	6.17	94
La Casa	NO_2	18	69	1.83	+/-1.45	-2.97	2.82	81
I-25: Denver	NO_2	23	88	2.53	+2.09	-3.0	5.08	89
I-25: Globeville	NO_2	22	85	3.91	+/-3.46	-4.93	7.56	88
Welby	O_3	22	85	2.5	+/-2.44	-5.35	2.64	95
Highland Reservoir	O_3	22	85	2.31	+/-1.87	-3.45	3.92	96
Aurora - East	O_3	21	81	2.72	+/-2.22	-4.36	4.32	97
Boulder Reservoir	O_3	20	77	2.48	+/-2.24	-3.02	4.92	93
CAMP	O_3	22	85	2.62	+/-2.27	-3.38	4.98	99
La Casa	O_3	21	81	3.56	+/-2.85	-5.92	5.45	95
Chatfield State Park	O_3	19	73	2.73	+/-2.36	-5.07	3.67	96
U.S. Air Force Academy (USAFA)	O_3	19	73	2.43	+/-2.15	-4.84	2.9	98
Manitou Springs	O_3	19	73	2.37	+3.22	-1.23	6.32	97
Welch	O_3	18	69	4.76	+/-3.91	-6.89	8.02	71
Rocky Flats - N.	O_3	20	77	2.08	+/-1.73	-3.42	3.22	96
NREL	O_3	21	81	2.71	+/-2.5	-3.33	5.35	98
Aspen Park	O_3	19	73	3.21	+/-2.68	-5.97	4.3	97
Fort Collins - West	O_3	20	77	2.19	+/-2.37	-4.99	2.03	99
Fort Collins - Mason	O_3	22	85	1.74	+/-1.38	-2.87	2.69	99
Elk Springs	O_3	17	65	1.42	+/-1.16	-2.47	2.05	91
Paradox	O_3	23	88	1.25	+1.71	-0.65	3.35	90
Greeley - County Tower	O_3	21	81	3.23	+/-2.61	-5.63	4.68	96

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 table below summarizes 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. 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. 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 25^{th} and 75^{th} 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 positive bias of 2.32% in 2018. SO_2 showed a non-signed bias of 2.68%. O_3 showed a non-signed bias of 1.98% for 2018. There was no sign associated with the calculated bias (2.67%) for the NO_2 precision checks for the organization as a whole in 2018.

6.3.2.4 Performance Evaluation (Accuracy Audits)

Audits were performed at least twice on every gaseous analyzer within the APCD network during the 2018 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 2018 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 2018 for CO were compared to the probability intervals. Out of the 65 audit concentration points taken for CO in 2018, 55% fell between the probability intervals for the organization. There were 164 audit concentration points taken during 2018 for APCD's O_3 network. Of those 164 ozone audit points, 18 fell outside the probability intervals. This means that 89% of the audit points for O_3 fell between the probability intervals in 2018. Out of the 105 audit points taken in 2018 for NO_2, 66% fell between the probability limits. Out of the 32 audit points taken for SO_2 in 2018, 84% fell between the probability intervals. Therefore, all four gaseous criteria pollutants do not meet the requirement that specifies that 95% 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 2018 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 pushing 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.

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 2018 met or exceeded APCD DQO goals for every gaseous analyzer, with a minimum of two audits performed on every analyzer.

Table 6.2 summarizes the statistical evaluations for all gaseous precision, accuracy, bias, and completeness data. 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 6.3 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 6.3 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 6.3 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 6.3 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 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 2018 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 6.3. 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 Results

Table 6.3 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.

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

Site	Parameter	Verification Count	Verification Complete (%)	Bias (%)	Mean % Difference	Std. Dev. % Difference
Tri County Health (TCH)	PM_{10}	16	100	-1.09	-0.7	0.73
Welby	PM_{10}	20	100	+/-1.82	0.15	1.81
Alamosa - Municipal Bldg.	PM_{10}	4	100	+/-3.76	-0.84	2.41
Pagosa Springs School	PM_{10}	4	100	+/-3.16	-0.21	2.57
Longmont - Municipal Bldg.	PM_{10}	1	25	-0.52	-0.52	-
Longmont - Municipal Bldg.	PM_{10}	1	25	+1.04	1.04	-
Boulder Chamber of Commerce (CC)	PM_{10}	2	50	+/-2.32	0.12	2.25
Delta Health Dept.	PM_{10}	4	100	+/-3.78	0.27	2.87
CAMP	PM_{10}	1	25	+0.1	0.1	-
CAMP	PM_{10}	1	25	+1.27	1.27	-
La Casa	PM_{10}	8	67	+/-0.73	0.13	0.62
La Casa	PM_{10}	9	75	+/-0.46	-0.22	0.33
Colorado College	PM_{10}	19	100	+0.93	0.61	0.69
Cañon City - City Hall	PM_{10}	1	25	-4.49	-4.49	-
Rifle - Garfield County Library	PM_{10}	4	100	+/-2.26	-0.62	1.37
Crested Butte	PM_{10}	2	50	+/-4.0	0.5	1.18
Crested Butte	PM_{10}	1	25	+5.23	5.23	-
Fort Collins - CSU	PM_{10}	2	50	+/-7.66	0.68	4.78
Grand Junction - Powell Bldg.	PM_{10}	11	92	+/-1.5	0.71	1.16
Grand Junction - Powell Bldg.	PM_{10}	12	100	+/-1.33	0.59	1.07
Aspen	PM_{10}	4	100	+/-5.13	1.41	3.37
Lamar - Municipal Bldg.	PM_{10}	7	100	+/-1.32	0.24	1.1
Pueblo - Fountain School	PM_{10}	3	75	+/-4.9	-1.06	2.41
Steamboat Springs	PM_{10}	8	100	+/-2.83	0.46	2.41
Tri County Health (TCH)	$PM_{2.5}$	12	100	+/-1.17	0.09	1.1
Tri County Health (TCH)	$PM_{2.5}$	23	100	+/-3.23	-0.55	3.21
Arapaho Community College (ACC)	$PM_{2.5}$	13	100	+1.48	1.1	0.76
Longmont - Municipal Bldg.	$PM_{2.5}$	15	100	+/-1.98	0.22	1.9
Longmont - Municipal Bldg.	$PM_{2.5}$	12	100	+/-1.26	0.06	1.15
Boulder Chamber of Commerce (CC)	$PM_{2.5}$	18	100	-1.8	-1.1	1.31
CAMP	$PM_{2.5}$	23	100	-1.49	-0.9	1.31
CAMP	$PM_{2.5}$	22	100	+/-0.5	0.03	0.49
CAMP	$PM_{2.5}$	28	100	+/-3.28	-0.19	3.32
National Jewish Health (NJH)	$PM_{2.5}$	17	100	+/-0.93	0.09	0.88
La Casa	$PM_{2.5}$	8	67	+/-1.1	-0.05	0.96
La Casa	$PM_{2.5}$	25	100	+3.81	2.86	2.27
I-25: Denver	$PM_{2.5}$	20	100	+1.3	1.13	0.44
I-25: Denver	$PM_{2.5}$	25	100	+/-2.83	-0.05	2.85
I-25: Globeville	$PM_{2.5}$	24	100	+4.51	2.61	3.43
Chatfield State Park	$PM_{2.5}$	12	100	+/-0.69	0.02	0.66
Chatfield State Park	$PM_{2.5}$	21	100	+/-1.49	0.25	1.48
Colorado College	$PM_{2.5}$	34	100	+/-2.99	1.39	2.78
Fort Collins - CSU	$PM_{2.5}$	34	100	+/-3.28	0.95	3.4
Grand Junction - Powell Bldg.	$PM_{2.5}$	14	100	+/-3.98	0.31	3.72
Pueblo - Fountain School	$PM_{2.5}$	26	100	+/-0.68	0.11	0.75
Greeley - Hospital	$PM_{2.5}$	36	100	+/-3.51	-2.16	2.89
Platteville - Middle School	$PM_{2.5}$	12	100	+/-0.86	0.42	0.71

Table 6.4: Collocated QC check statistics for filter-based particulate monitoring data.

Site	Parameter	Total Valid Pairs	CV
Longmont	PM_{10}	38	7.05
CAMP	PM_{10}	53	4.78
La Casa	PM_{10}	57	8.71
Crested Butte	PM_{10}	41	7.06
GJ - Powell Bldg.	PM_{10}	47	6.06
Tri County Health	$PM_{2.5}$	55	22.10
CAMP	$PM_{2.5}$	55	8.27
I-25: Denver	$PM_{2.5}$	52	16.25
Chatfield State Park	$PM_{2.5}$	85	17.00

6.5 EPA Data Quality Assessment

6.5.1 PEP / NPAP Audits

The performance audits conducted during 2018 are summarized in Table 6.5 and Table 6.6.

Table 6.5: $PM_{2.5}$ PEP results.

Audit Date	Site	PEP Result ($\mu g\ m^{-3}$)	Site Result ($\mu g\ m^{-3}$)	Percent Difference
2018/04/25	NJH	3.6	6.5	80.6%
2018/04/25	Ft. Collins - CSU	4.0	6.7	67.5%
2018/06/19	Longmont	5.0	4.3	14.0%
2018/06/19	Boulder	4.7	3.8	19.2%
2018/10/13	NJH	6.1	7.4	21.3%
2018/10/13	Ft. Collins - CSU	5.2	6.8	30.8%
2018/12/04	Longmont	8.6	8.1	5.8%
2018/12/04	Boulder	2.9	2.2	24.1%

Table 6.6: NPAP results for gaseous audits.

Audit Date	Site	Parameter	NPAP Results				Station Results				Percent Differences			
			L2	L3	L4	L5	L2	L3	L4	L5	L2	L3	L4	L5
2018/05/29	Boulder	O_3 (ppm)	0.015	0.014	0.035	0.033	0.049	0.047	0.076	0.074	-10.6%	-6.9%	-4.9%	-2.6%
2018/05/29	Aspen Park	O_3 (ppm)	0.016	0.015	0.029	0.027	0.059	0.056	0.078	0.074	-8.5%	-5.3%	-4.8%	-5.6%
2018/05/30	Greeley	CO (ppm)	0.196	0.172			2.104	2.100	3.483	3.500	-12.4%		-0.2%	0.5%
2018/05/30	Greeley	O_3 (ppm)	0.018	0.016	0.035	0.033	0.065	0.064	0.082	0.081	-9.7%	-4.8%	-1.7%	-1.1%
2018/09/11	CAMP	O_3 (ppm)	0.017	0.016			0.049	0.047	0.076	0.075	-9.4%		-3.1%	-1.3%
2018/09/12	Welby	SO_2 (ppm)	0.003	0.004			0.018	0.018	0.047	0.047	16.1%		3.4%	1.9%
2018/09/12	Welby	O_3 (ppm)	0.017	0.014	0.035	0.032	0.063	0.059	0.081	0.078	-17.4%	-8.5%	-5.6%	-3.9%

APPENDIX A: MONITORING SITE DESCRIPTIONS

This appendix provides detailed information for all monitoring sites considered in this Data Report. 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.

The following abbreviations are used in Table A-1 below, with orientation (Orient) referring to the monitoring objective and scale referring to the size of the area that concentrations from the monitor represent.

Orientation
P.O. - Population oriented
Back - Background orientation
SPM - Special Purpose Monitor
H.C. - Highest Concentration
POC - Parameter Occurrence Code
SLAMS - State or Local Air Monitoring Stations

Scale (Area Represented)[1]
Micro - Micro-scale (several m – 100 m)
Middle - Middle Scale (100 – 500 m)
Neigh - Neighborhood Scale (0.5 – 4 km)
Urban - Urban Scale (4 – 50 km)
Region - Regional Scale (50 – hundreds of km)

Table A-1. Monitoring Locations and Parameters Monitored

AQS #	***Site Name***	***Address***		***Site Start***	***Elevation (m)***	***Latitude***	***Longitude***
	Parameter	POC	Start	Orient/Scale	Monitor	Type	Sample
Adams							
08 001 0008	*Tri County Health*	*4201 E 72nd Ave.*		*Jul-16*	*1,574*	*39.82835*	*-104.93836*
	PM_{10}	1	Jul-16	P.O. Neigh	R&P PARTISOL 2025	SLAMS	1 in 1
	$PM_{2.5}$	2	Jul-16	P.O. Neigh	R&P PARTISOL 2025	SLAMS	1 in 6
	$PM_{2.5}$	3	Jul-16	P.O. Neigh	GRIMM EDM 180	SPM	Continuous
	$PM_{2.5}$ Speciation	5	Jul-16	P.O. Neigh	SASS	Trends Spec.	1 in 6
	$PM_{2.5}$ Carbon	5	Jul-16	P.O. Neigh	URG 3000N	Trends Spec.	1 in 6

[1] "Appendix D to Part 58 – Network Design Criteria for Ambient Air Quality Monitoring," 40 Federal Register 58 (15 January 2015).

AQS #	Site Name	Address		Site Start	Elevation (m)	Latitude	Longitude
	Parameter	POC	Start	Orient/Scale	Monitor	Type	Sample
08 001 3001	*Welby*	*3174 E. 78th Ave.*		*Jul-73*	*1,554*	*39.838119*	*-104.94984*
	CO (Trace)	1	Jul-73	P.O. Neigh	THERMO 48i-TLE	SLAMS	Continuous
	SO_2	2	Jul-73	P.O. Neigh	TAPI 100E	SLAMS	Continuous
	NO/NO_x	2	Jan-76	P.O. Urban	TAPI 200UP	SPM	Continuous
	NO_2	1	Jan-76	P.O. Urban	TAPI 200EU	SLAMS	Continuous
	O_3	2	Jul-73	P.O. Neigh	TAPI 400E	SLAMS	Continuous
	WS/WD/Temp	1	Jan-75	P.O. Neigh	MET-ONE	SPM	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
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	P.O. Neigh	MET-ONE	SPM	Continuous
08 005 0005	*Arapahoe Community College (ACC)*	*6190 S. Santa Fe Dr.*		*Dec-98*	*1,636*	*39.604399*	*-105.019526*
	$PM_{2.5}$	1	Mar-99	P.O. Neigh	R&P PARTISOL 2025	SLAMS	1 in 3
08 005 0006	*Aurora - East*	*36001 E. Quincy Ave.*		*Apr-11*	*1,552*	*39.63854*	*-104.56913*
	O_3	1	Apr-09	P.O. Region	TAPI 400E	SLAMS	Continuous
	WS/WD/Temp	1	Jun-09	P.O. Neigh	MET-ONE	SPM	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

AQS #	Site Name	Address		Site Start	Elevation (m)	Latitude	Longitude
	Parameter	POC	Start	Orient/Scale	Monitor	Type	Sample
Boulder							
08 013 0003	*Longmont - Municipal Bldg.*	*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_{10} Collocated	2	Sep-14	P.O. Micro	SA/GMW 1200	SLAMS	1 in 6
	$PM_{2.5}$	1	Jan-99	P.O. Neigh	R&P PARTISOL 2025	SLAMS	1 in 3
	$PM_{2.5}$	3	Nov-05	P.O. Neigh	TEOM 1400AB	SPM	Continuous
08 013 0012	*Boulder Chamber of Commerce*	*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	R&P PARTISOL 2025	SLAMS	1 in 3
08 013 0014	*Boulder Reservoir*	*5565 N. 51st*		*Sep-16*	*1,586*	*40.070016*	*-105.220238*
	O_3	1	Sep-16	H.C. Urban	TAPI 400E	SLAMS	Continuous
	WS/WD/Temp/RH	1	Sep-16	H.C. Urban	RM YOUNG	SPM	Continuous
08 013 1001	*Boulder - CU Athens*	*2102 Athens St.*		*Dec-80*	*1,622*	*40.012969*	*-105.264212*
	$PM_{2.5}$	3	Feb-04	P.O. Neigh	TEOM FDMS	SPM	Continuous

AQS #	Site Name	Address		Site Start	Elevation (m)	Latitude	Longitude
	Parameter	POC	Start	Orient/Scale	Monitor	Type	Sample
Denver							
08 031 0002	*CAMP*	*2105 Broadway*		*Jan-65*	*1,593*	*39.751184*	*-104.987625*
	CO (Trace)	2	Jan-71	P.O. Micro	THERMO 48i-TLE	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/NO_x	1	Jan-73	Other	TAPI 200EU	Other	Continuous
	NO_2	1	Jan-73	P.O. Neigh	TAPI 200EU	SLAMS	Continuous
	WS/WD/Temp	1	Jan-65	P.O. Neigh	MET-ONE	SPM	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	Apr-13	P.O. Micro	GRIMM EDM 180	SLAMS	Continuous
	$PM_{2.5}$	1	Jan-99	P.O. Micro	R&P PARTISOL 2025	SLAMS	1 in 1
	$PM_{2.5}$ Collocated	2	Sep-01	P.O. Micro	R&P PARTISOL 2025	SLAMS	1 in 6
	$PM_{2.5}$	3	Apr-13	P.O. Micro	GRIMM EDM 180	SPM	Continuous
08 031 0013	*National Jewish Health*	*14th Ave. & Albion St.*		*Jan-83*	*1,620*	*39.738578*	*-104.939925*
	$PM_{2.5}$	3	Oct-03	P.O. Neigh	TAPI T640	SPM	Continuous
	PM_{10}	3	Mar-18	P.O. Neigh	TAPI T640	SPM	Continuous
08 031 0016	*DESCI*	*1901 E. 13th Ave.*		*Dec-90*	*1,623*	*39.7357*	*-104.9582*
	Transmissometer	1	Dec-89	Other	OPTEC LPV-3	SPM	Continuous
	Nephelometer	1	Dec-00	Other	OPTEC NGN-2	SPM	Continuous
	Relative Humidity	1	Dec-89	Other	RM YOUNG	SPM	Continuous

AQS #	Site Name	Address		Site Start	Elevation (m)	Latitude	Longitude
	Parameter	POC	Start	Orient/Scale	Monitor	Type	Sample
08 031 0026	*La Casa*	*4587 Navajo St.*		*Oct-13*	*1,594*	*39.779429*	*-105.005174*
	CO (Trace)	1	Oct-12	P.O. Neigh	THERMO 48i-TLE	NCore	Continuous
	SO_2 (Trace)	1	Oct-12	P.O. Neigh	TAPI 100EU	NCore	Continuous
	NO_Y	1	Oct-12	P.O. Neigh	TAPI 200EU	NCore	Continuous
	CAPS NO_2	1	Jul-14	P.O. Neigh	TAPI 500U	NCore	Continuous
	O_3	1	Oct-12	Neigh/Urban	TAPI 400E	NCore	Continuous
	WS/WD/Temp	1	Oct-12	P.O. Neigh	MET-ONE	NCore	Continuous
	Relative Humidity	1	Oct-12	P.O. Neigh	MET-ONE	NCore	Continuous
	Total Solar Radiation	1	Apr-18	P.O. Neigh	KIPP & ZONEN	NCore	Continuous
	Temp (Lower)	2	Oct-12	P.O. Neigh	MET-ONE	NCore	Continuous
	PM_{10}	1	Oct-12	P.O. Neigh	R&P PARTISOL 2025	SLAMS	1 in 3
	PM_{10} Collocated	2	Oct-12	P.O. Neigh	R&P PARTISOL 2025	SLAMS	1 in 6
	PM_{10}	3	Feb-14	P.O. Neigh	GRIMM EDM 180	SLAMS	Continuous
	$PM_{2.5}$	1	Oct-12	P.O. Neigh	R&P PARTISOL 2025	NCore	1 in 3
	$PM_{2.5}$	3	Feb-14	P.O. Neigh	GRIMM EDM 180	SLAMS	Continuous
	$PM_{2.5}$ Speciation	5	Oct-12	P.O. Neigh	SASS	Supplem. Speciation	1 in 3
	$PM_{2.5}$ Carbon	5	Oct-12	P.O. Neigh	URG 3000N	Supplem. Speciation	1 in 3

AQS #	Site Name	Address		Site Start	Elevation (m)	Latitude	Longitude
	Parameter	POC	Start	Orient/Scale	Monitor	Type	Sample
08 031 0027	*I-25: Denver*	*971 W. Yuma Street*		*Jun-13*	*1,586*	*39.732146*	*-105.015317*
	CO (Trace)	1	Jun-13	Near Road	THERMO 48i-TLE	SLAMS	Continuous
	NO_2	1	Jun-13	Near Road	TAPI 200E	SLAMS	Continuous
	NO/NO_x	1	Jun-13	Near Road	TAPI 200E	SPM	Continuous
	WS/WD/Temp	1	Jun-13	Near Road	MET-ONE	SPM	Continuous
	PM_{10}	3	Dec-13	Near Road	GRIMM EDM 180	SLAMS	Continuous
	$PM_{2.5}$	1	Jan-14	Near Road	R&P PARTISOL 2025	SLAMS	1 in 6
	$PM_{2.5}$	3	Dec-13	Near Road	GRIMM EDM 180	SLAMS	Continuous
	$PM_{2.5}$ Carbon	5	Oct-13	Near Road	API 633	SPM	Continuous
08 031 0028	*I-25: Globeville*	*4905 Acoma Street*		*10/1/2015*	*1,587*	*39.785823*	*-104.988857*
	NO_2	1	10/1/2015	Near Road	TAPI 200E	SLAMS	Continuous
	NO/NO_x	1	10/1/2015	Near Road	TAPI 200E	SPM	Continuous
	WS/WD/Temp/RH	1	10/1/2015	Near Road	RM YOUNG	SPM	Continuous
	PM_{10}	3	10/1/2015	Near Road	GRIMM EDM 180	SLAMS	Continuous
	$PM_{2.5}$	3	10/1/2015	Near Road	GRIMM EDM 180	SLAMS	Continuous
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	P.O. Neigh	MET-ONE	SPM	Continuous
	$PM_{2.5}$	1	Jul-05	P.O. Neigh	R&P PARTISOL 2025	SPM	1 in 3
	$PM_{2.5}$	3	May-04	P.O. Neigh	TAPI T640	SPM	Continuous
	PM_{10}	3	Jun-17	P.O. Neigh	TAPI T640	SPM	Continuous

AQS #	Site Name	Address		Site Start	Elevation (m)	Latitude	Longitude
	Parameter	POC	Start	Orient/Scale	Monitor	Type	Sample
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	H.C. Urban	TAPI 400E	SLAMS	Continuous
08 041 0015	*Highway 24*	*690 W. Hwy. 24*		*Nov-98*	*1,824*	*39.830895*	*-104.839243*
	CO (Trace)	1	Nov-98	P.O. Micro	THERMO 48i-TLE	SLAMS	Continuous
	SO_2	1	Jan-13	P.O. Micro	TAPI 100EU	SLAMS	Continuous
	WS/WD/Temp	1	Aug-14	P.O. Micro	RM YOUNG	SPM	Continuous
	Relative Humidity	1	Aug-14	P.O. Micro	RM YOUNG	SPM	Continuous
08 041 0016	*Manitou Springs*	*101 Banks Pl.*		*Apr-04*	*1,955*	*38.853097*	*-104.901289*
	O_3	1	Apr-04	H.C. 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	R&P PARTISOL 2025	SLAMS	1 in 6
	PM_{10}	3	Jun-16	P.O. Neigh	GRIMM EDM 180	SLAMS	Continuous
	$PM_{2.5}$	3	Dec-07	P.O. Neigh	GRIMM EDM 180	SLAMS	Continuous
Fremont							
08 043 0003	*Cañon City - City Hall*	*128 Main St.*		*Oct-04*	*1,626*	*38.43829*	*-105.24504*
	PM_{10}	1	Oct-04	P.O. Neigh	SA/GMW 1200	SLAMS	1 in 6
Garfield							
08 045 0012	*Rifle - Health Dept.*	*195 W. 14th Ave.*		*Jun-08*	*1,629*	*39.54182*	*-107.784125*
	O_3	1	Jun-08	P.O. Neigh	TAPI 400E	SLAMS	Continuous
Jefferson							
08 059 0002	*Arvada*	*9101 W. 57th Ave.*		*Jan-73*	*1,640*	*39.800333*	*-105.099973*
	WS/WD/Temp	1	Jan-75	P.O. Neigh	MET-ONE	SPM	Continuous

AQS #	Site Name	Address		Site Start	Elevation (m)	Latitude	Longitude
	Parameter	POC	Start	Orient/Scale	Monitor	Type	Sample
08 059 0005	*Welch*	*12400 W. Hwy. 285*		*Aug-91*	*1,742*	*39.638781*	*-105.13948*
	O_3	1	Aug-91	P.O. Urban	TAPI 400E	SLAMS	Continuous
	WS/WD/Temp	1	Nov-91	P.O. Neigh	MET-ONE	SPM	Continuous
08 059 0006	*Rocky Flats - N.*	*16600 W. Hwy. 128*		*Jun-92*	*1,802*	*39.912799*	*-105.188587*
	NO_Y	1	Oct-12	P.O. Neigh	TAPI 200EU	PAMS	Continuous
	CAPS NO_2	1	Jul-14	P.O. Neigh	TAPI 500U	PAMS	Continuous
	O_3	1	Sep-92	H.C. Urban	TAPI 400E	PAMS	Continuous
	WS/WD/Temp	1	Sep-92	P.O. Neigh	MET-ONE	PAMS	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	P.O. Neigh	MET-ONE	SPM	Continuous
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-15	P.O. Neigh	GRIMM EDM 180	SPM	Continuous
	$PM_{2.5}$	3	Jun-15	P.O. Neigh	GRIMM EDM 180	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*	*40.57747*	*-105.07892*
	CO (Trace)	1	Dec-80	P.O. Neigh	THERMO 48i-TLE	SLAMS	Continuous
	O_3	1	Dec-80	P.O. Neigh	TAPI 400E	SLAMS	Continuous
	WS/WD/Temp	1	Jan-81	P.O. Neigh	MET-ONE	SPM	Continuous

AQS #	Site Name	Address		Site Start	Elevation (m)	Latitude	Longitude
	Parameter	POC	Start	Orient/Scale	Monitor	Type	Sample
Mesa							
08 077 0017	*Grand Junction - Powell Bldg.*	*650 South Ave.*		*Feb-02*	*1,398*	*39.063798*	*-108.561173*
	PM_{10} & NATTS Metals	3	Jan-05	P.O. Neigh	R&P PARTISOL 2025	SLAMS	1 in 3
	PM_{10} Collocated & NATTS	4	Mar-05	P.O. Neigh	R&P PARTISOL 2025	SLAMS	1 in 6
	PM_{10}	3	Jan-14	P.O. Neigh	GRIMM EDM 180	SPM	Continuous
	$PM_{2.5}$	3	Jan-14	P.O. Neigh	GRIMM EDM 180	SPM	Continuous
08 077 0018	*Grand Junction - Pitkin*	*645 1/4 Pitkin Ave.*		*Jan-04*	*1,398*	*39.064289*	*-108.56155*
	WS/WD/Temp	1	Jan-04	P.O. Neigh	MET-ONE	SPM	Continuous
	Relative Humidity	1	Jan-04	P.O. Neigh	RM YOUNG	SPM	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	P.O. Neigh	RM YOUNG	SPM	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
Montrose							
Pitkin							
08 097 0006	*Aspen*	*215 N. Garmisch St.*		*Jan-15*	*2,408*	*39.192958*	*-106.823257*
	PM_{10}	1	Feb-15	P.O. Neigh	SA/GMW 1200	SLAMS	1 in 3
Prowers							
08 099 0002	*Lamar - Municipal Bldg.*	*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

AQS #	Site Name	Address		Site Start	Elevation (m)	Latitude	Longitude
	Parameter	POC	Start	Orient/Scale	Monitor	Type	Sample
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	R&P 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*	*-104.70693*
	PM_{10}	2	Mar-87	P.O. Neigh	SA/GMW 1200	SLAMS	1 in 3
	$PM_{2.5}$	3	Feb-99	P.O. Neigh	GRIMM EDM 180	SPM	Continuous
08 123 0008	*Platteville - Middle School*	*1004 Main St.*		*Dec-98*	*1,469*	*40.209387*	*-104.82405*
	$PM_{2.5}$	1	Aug-99	P.O. Region	R&P 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*	*-104.73744*
	O_3	1	Jun-02	H.C. Neigh	TAPI 400E	SLAMS	Continuous
	WS/WD/Temp	1	Feb-12	P.O. Neigh	MET-ONE	SPM	Continuous
	CO (Trace)	1	Apr-16	P.O. Neigh	THERMO 48i-TLE	SLAMS	Continuous

Tri County Health Dept. - Commerce City, 4201 E. 72nd Ave. (08 001 0008):

Tri County Health Dept. - Commerce City site is 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 three schools in the immediate vicinity, an elementary school to the south, 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.

This is a replacement site for the Alsup Elementary school (08-001-0006) site which was dismantled due to a roofing project on the building.

PM_{10} and $PM_{2.5}$ monitoring began in August of 2016. There is a collocated $PM_{2.5}$ FRM along with a continuous $PM_{2.5}$ GRIMM EDM dust monitor, a filter based low volume PM_{10} monitor, a trends speciation monitor, and a $PM_{2.5}$ carbon monitor all in operation.

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

Located 8 miles 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. The monitoring shows that high CO levels 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 in the SLAMS network, and is population oriented for a neighborhood scale.

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 hit 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 due to growth in trees that are not allowed to be removed.

The Welby SO_2 monitor began operation in July of 1973.

PM_{10} monitoring began at Welby in June and July of 1990 with a high volume PM_{10} monitor and a PM_{10} continuous TEOM monitor. Meteorological monitoring began in January of 1975.

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 concentrations 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 Highlands monitoring site had to be shut down from approximately Oct. of 2013 to Sept. of 2015 due to major construction activities on the property. The site is currently back up and monitoring for ozone and meteorological parameters.

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 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 360^0 exposure. Based on the topography and meteorology of the area ACC is in an area where $PM_{2.5}$ emissions may collect. 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 on a 1 in 3 day sample 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 aid in the determination of the eastern most extent of the high urban O_3 concentrations. 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 purpose 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 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 surrounds 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 for this area predominantly blow from the north, 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 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 30 miles north of Denver along the St. Vrain Creek and is about six miles east of the foothills. Longmont is partly a bedroom community for the Denver-Boulder area. The elevation is 4978 feet. The Front Range peaks rise to an elevation of 14,000 feet just to the west of Longmont. In general, the area experiences low relative humidity, light precipitation and abundant sunshine.

The station began operations in 1985 with the installation of PM_{10} followed by $PM_{2.5}$ monitors 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 estimate for the controlling street easily falls 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 on a 1 in 6 day sample schedule. In September of 2014 APCD installed a collocated sampler at the site to meet EPA PM_{10} high volume collocation requirements.

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 7,000 feet east of the base of the Front Range foothills and about 50 feet 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, while the $PM_{2.5}$ monitoring did not begin until January of 1999.

The predominant wind direction at the APCD'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 on a 1 in 6 day sample schedule.

Boulder Reservoir, 5545 Reservoir Road (08 013 0014):

The city of Boulder is located about 30 miles to the northwest of Denver. The Boulder Reservoir is a 700 acre multi-use recreation and water storage facility owned and managed by the city of Boulder. It is operated as a water supply by the Northern Colorado Water Conservancy District. The Reservoir is located about 5.5 miles to the North East of the city of Boulder. This site is a replacement site for the South Boulder Creek site which was shut down January 1st, 2016 due to large trees that had grown over the years that could not be removed, making the site no longer meet siting criteria.

The Boulder Reservoir is a highest concentration oriented urban scale SLAMS monitor. The site monitors for ozone and meteorological parameters and has been sampling since September of 2016.

Boulder – CU - Athens, 2102 Athens Street (08 013 1001):

The Boulder - CU site is located at the edge of a low usage parking lot to the immediate north of the site and south of the University of Colorado football practice fields. This location provides a good neighborhood representation for particulates. The site houses a continuous TEOM particulate monitor inside the shelter. The site began operation in November 2004. A dome is erected each fall over the practice field and remains inflated until early spring when it is removed for the summer months.

CAMP, 2105 Broadway (08 031 0002):

The City and County of Denver is located approximately 30 miles east of the foothills of the Rocky Mountains. Denver sits in a basin, and the terrain of the city is characterized as 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. The CO monitor was updated to a Thermo 48iTLE trace level monitor in April 2017 to better characterize lower level concentrations seen in recent years.

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 monitored through January 2008. 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 sequential filter based FRM monitor. A continuous TEOM FEM $PM_{2.5}$ monitor was installed in February of 2001 and an FDMS was installed on the instrument November 1, 2003. In April 2013, the TEOM/FDMS was replaced with a GRIMM EDM 180 continuous monitor, which concurrently measures both PM_{10} and $PM_{2.5}$.

Meteorological monitoring began at this site in January of 1965.

National Jewish Health, 14th Avenue & Albion Street (08 031 0013):

This site is located three miles east of the Denver CBD, close to a very busy intersection (Colorado Boulevard and Colfax Avenue). The current site began operations in 1982. 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. Data from this continuous TEOM particulate 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.

DESCI:

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. Renovations at the Federal Building forced the transmissometer to temporarily move to 1255 19th Street in 2010, and quality control measurements showed no meaningful difference between old and new locations. 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 station also monitors relative humidity in order to resolve low visibility because of fog or rain.

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 the La Casa site in northwest Denver and includes a trace gas/precursor-level CO analyzer, and a NOy analyzer, in addition to the trace level SO_2, O_3, meteorology, and particulate monitors are located here. La Casa has been 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 NOy 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 low volume PM_{10} samplers, and a Lo-Vol $PM_{2.5}$ on the shelter roof. The Lo-vol PM_{10} concentrations are very useful as they are used in conjunction 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 filter-based monitor, a continuous TEOM/FDMS FEM instrument, a supplemental $PM_{2.5}$ speciation monitor, and a carbon speciation monitor. In early 2015, the TEOM/FDMS was replaced with a GRIMM EDM 180 continuous monitor, which concurrently measures both PM_{10} and $PM_{2.5}$.

PM_{10}/lead monitoring began in January 2013. Lead monitoring at La Casa was discontinued December 31st, 2015 due to extremely low concentrations measured at the site. EPA has removed the lead monitoring requirement from all NCore sites due to the low concentrations measured throughout the country. Ambient lead concentrations will still be measured at the $PM_{2.5}$ speciation and IMPROVE sites throughout the state, as well as on the PM_{10} sampler at Grand Junction Powell (08 077 0017) as part of the National Air Toxics Trends Stations project.

I-25 Denver, 913 Yuma Street (08 031 0027):

The I-25 Denver site is an EPA-required near roadway NO_2 monitoring site. It was established in June 2013. It is measuring $NO/NO_2/NO_x$ by chemiluminescence. Trace level CO, Teledyne API Model 633 Black Carbon Aethalometer, $PM_{2.5}$ with a filter based sequential FRM on a 1 and 6 day schedule, continuous PM_{10} & $PM_{2.5}$ (with a GRIMM EDM 180), and meteorological parameters are also measured here.

I-25 Globeville, 4905 Acoma Street (08 031 0028):

The I-25 Globeville site is a second EPA-required near roadway NO_2 monitoring site. It was established Oct. 1st, 2015. It is measuring $NO/NO_2/NO_x$ by chemiluminescence. The site is also equipped with sensors to measure meteorological parameters and continuous PM_{10} and $PM_{2.5}$ with a GRIMM EDM 180 instrument.

Chatfield State Park, 11500 N. Roxborough Park Road (08 035 0004):

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 FRM sequential filter based monitor in 2005. Meteorological monitoring began in April of 2004.

Colorado Springs, USAFA Road 640 (08 041 0013):

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 9 miles north of the CBD. This location is near the south entrance of the Air Force Academy but away from any roads. This is a population oriented urban scale SLAMS monitor.

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

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 0.8 miles 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 Highway 24 to meet monitoring criteria for an increased population found during the 2010 census. To supplement SO_2 monitoring at the site, APCD added an RM Young meteorological tower in August of 2014, which also includes an RH sensor.

Manitou Springs, 101 Banks Place (08 041 0016):

The Manitou Springs ozone site is located 4 miles west of Colorado Springs. It was established because of concern that the high concentration urban O_3 area was traveling farther up the Fountain Creek drainage and the current monitoring network was not adequate. 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 APCD 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 an 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. In the summer of 2016 the filter based $PM_{2.5}$ FRM instrument was removed and the GRIMM EDM 180 was designated as the primary sampler used to compare to the $PM_{2.5}$ NAAQS. Currently there is also a low volume filter-based PM_{10} sampler operated on a 1 in 6 day schedule at the site.

The nearest representative meteorological site is located at the Highway 24 monitoring site. 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 on the SLAMS network (PM_{10} and $PM_{2.5}$).

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

Cañon City is located 39 miles 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 top of the City Hall building 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 sample schedule.

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

The Rifle Health site is located at the Garfield County Health Department building. The site is approximately 1 kilometer 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 site with a neighborhood scale.

Arvada, 9101 57th Avenue (08 059 0002):

The city of Arvada is located 15 miles west-northwest of the Denver central business district (CBD). The Arvada site began operation before 1973. It is located to the northwest of the Denver CBD near the western end of the diurnal midday wind flow of the high concentration urban O_3 area. As a result, when conditions are proper for daylong O_3 production, this site has received some of the highest levels in the city. In the early and mid-1990s, these wind patterns caused Arvada to have the most exceedances in the metro area. In the 5-Year Network Assessment Plan the Arvada site was deemed to be redundant. The last valid O_3 sample was taken 12/31/2011, and the instrument was removed shortly after that. Meteorological monitoring began in 1975 and continues today.

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

The APCD 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 North, 16600 W. Highway 128 (08 059 0006):

The Rocky Flats - N site is located north-northeast of the former plant on the south side of Colorado Highway 128, approximately 1¼ miles to the west of Indiana Street. The site began operation in June of 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 – N 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 during the study, 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. It frequently exceeds the current standard.

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 8,100 feet. Because the site is nearly 3,000 feet 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.

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. In the summer of 2016 APCD removed the filter based FRM $PM_{2.5}$ sampler and designated the GRIMM EDM 180 continuous particulate monitor as the primary method for $PM_{2.5}$ NAAQS comparisons. Currently there are filter based high volume PM_{10} neighborhood scale SLAMS monitors on a 1 in 3 day schedule and a continuous GRIMM EDM 180 that measures PM_{10} and $PM_{2.5}$ operated at the site.

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

The Fort Collins-West ozone 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.

Fort Collins- Mason, 708 S. Mason Street (08 069 1004):

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. In May of 2016 the CO monitor was upgraded to a Thermo 48i-TLE trace level instrument. The current level of monitoring is in part a function of the resulting CO State Maintenance Plan (SMP) for the area. It is a population oriented neighborhood scale SLAMS monitor.

O_3 monitoring began in 1980, and continues today.

Meteorological monitoring began at the site January 1st, 1981. 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.

Grand Junction - Powell, 650 South Avenue (08 077 0017):

Grand Junction is the largest city on the western slope. It is located in the broad valley of the Colorado River. The monitors are on county owned buildings in the south side of the city. This 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 half a mile north of the river and about a quarter mile east of the railroad yard. In the summer of 2016 the primary filter based FRM was removed and the GRIMM EDM 180 continuous particulate monitor was designated as the primary to compare to the $PM_{2.5}$ NAAQS. Currently the GRIMM monitors for continuous $PM_{2.5}$ and PM_{10} and there are also two low volume filter based collocated PM_{10} monitors operated at the site on a 1 in 3 day and 1 in 6 day sample schedule.

Grand Junction - Pitkin, 645¼ Pitkin Avenue (08 077 0018):

Meteorological monitors were installed in 2004, and include wind speed, wind direction, and temperature sensors. The meteorological tower was outfitted January 5th, 2015 with RM Young meteorological sensors, including a RH sensor. This site is also part of the National Air Toxics Trends Station Network. This network is a national EPA project to assess levels of urban air toxics around the country. EPA requires that the site include a carbon monoxide monitor, as an indication of automobile traffic in the area.

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. Ozone and meteorological 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.

The O_3 monitor 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. Ozone monitoring commenced in May 2008 and the first $PM_{2.5}$ filter was sampled June 20th, 2008. $PM_{2.5}$ monitoring was discontinued at the site in July of 2015 due to the site completing sampling requirements and the site returning low $PM_{2.5}$ concentrations. This site is an urban scale SLAMS monitor.

Aspen Yellow Brick School, 215 North Garmisch (08 097 0008):

Aspen is at the upper end of a steep mountain valley. Aspen does not have an interstate highway 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 41 miles to the northeast. There is currently a high volume filter based PM_{10} monitor and a continuous PM_{10}/$PM_{2.5}$ GRIMM EDM 180 monitor operated at this site.

The population oriented neighborhood scale SLAMS high volume PM_{10} monitor is operating on a 1 in 3 sample 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 standard of 150 $\mu g/m^3$, and both sites regularly record values above 100$\mu g/m^3$ as a 24-hour average. The Power Station site in Lamar has been shut down, because it did not meet siting criteria. The Lamar Municipal Building location houses population oriented neighborhood scale SLAMS high-volume PM_{10} monitors on a daily sample 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 4,474 feet to 4,814 feet (1,364 to 1,467 m). The Rocky Mountain Front Range is about 25 miles (40 km) west and the sight of 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 experiences average wind speed ranges from 7 miles per hour in the fall and early winter to 11 miles 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 found 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 site monitors for PM_{10} with high volume filter based sampling. This is a population oriented neighborhood scale SLAMS monitor on a daily sample 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, which is only about ½ mile 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 in this latitude are 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 sample schedule.

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

The Greeley PM_{10} and $PM_{2.5}$ monitors are on the roof of a hospital office building at 1516 Hospital Road. In the summer of 2016 the filter Based FRM was removed from the site and the GRIMM EDM 180 continuous particulate monitor was designated as the primary monitor for NAAQS comparisons. The site currently has Hi Volume filter based PM_{10} monitors on a 1 in 3 day sample schedule and a continuous GRIMM instrument that measures $PM_{2.5}$ and $PM_{10.}$ This is a population-oriented neighborhood scale SLAMS site. 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 estimate for the most controlling street easily falls into the neighborhood scale in accordance with federal guidelines found in 40 CFR, Part 58.

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 11 miles 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 five miles east of I-25, at an elevation of 4,825 feet. The area is characterized by relatively flat terrain and is located about one mile east of the South Platte. The National Oceanic and Atmospheric Administration 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 and is currently still monitoring.

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 $PM_{2.5}$ filter based FRM SLAMS monitor is operating on a 1 in 3 day sample 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 sample schedule.

<u>Greeley, Weld County Tower, 3101 35th Avenue (08 123 0009):</u>

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. The Greeley West Annex carbon monoxide monitoring site was dismantled in June of 2015 and moved to the Weld County Tower site. Carbon Monoxide monitoring began at the Weld County Tower site in April of 2015 with a Thermo 48C monitor. The CO monitor at Weld County Tower was upgraded from a Thermo 48C to a Thermo 48iTLE trace level analyzer on April 28th, 2016.

Meteorological monitoring began in February of 2012.