DALLAS-FORT WORTH AREA EXCEPTIONAL EVENT DEMONSTRATION FOR OZONE ON AUGUST 16, 17, AND 21, 2020

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APRIL 14, 2021 PUBLIC COMMENT DOCUMENT

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EXECUTIVE SUMMARY

On August 16, 17, and 21, 2020, the Grapevine Fairway monitoring site measured maximum daily eight-hour averages of 77, 88, and 77 parts per billion (ppb) respectively. These maximum daily averages cause the Dallas-Fort Worth (DFW) area to violate the 2008 eight-hour ozone National Ambient Air Quality Standard (NAAQS). This demonstration provides support for the influence of emissions from exceptional or natural events (wildfires) in Colorado and California that adversely influenced ozone measurements at the site.

Based on an initial analysis, the Texas Commission on Environmental Quality (TCEQ) entered a preliminary flag and notified the United States Environmental Protection Agency (EPA) of its intent to submit an exceptional event demonstration for the dates above as required by the Exceptional Events Rule (EER). The TCEQ submits this Exceptional Event Demonstration in support of the determination that the DFW area was influenced by exceptional events on August 16, 17, and 21, 2020. These events caused exceedances of the 2008 eight-hour ozone NAAQS. The TCEQ requests that the EPA concur with this technical demonstration and enter an exceptional event flag for the appropriate Air Quality System data records for the Grapevine Fairway, Continuous Air Monitoring Site (CAMS) 70, ozone measurements on August 16, 17, and 21, 2020.

The TCEQ's determination is substantiated through the accumulated weight of evidence documented in this package. Specifically, this demonstration shows:

- trajectory analysis and satellite imagery evidence of emissions transport from wildfires in Colorado (for exceedances on August 16 and 17, 2020) and California (for the exceedance on August 21, 2020) to the Grapevine Fairway monitor;
- analyses of historical ozone measurements showing that wildfire emissions affected ozone concentrations over a large portion of the DFW area on August 16 through 17, 2020 and August 21, 2020;
- analyses of satellite imagery detailing elevated Atmospheric Optical Depth measurements on August 16 through 17, 2020 and August 21, 2020;
- analyses of speciated fine particulate matter ($PM_{2.5}$) data showing a strong correspondence between organic carbon measurements and maximum daily eight-hour ozone averages at the Grapevine Fairway monitoring site between August 10, 2020 and August 25, 2020;
- analysis of carbon monoxide (CO) and $PM_{2.5}$ ratios at the Dallas Hinton monitoring site that were inconsistent with an urban or mobile source signature, suggesting impact from other sources, such as wildfires;
- matching day analyses showing that when controlled for the presence of smoke, meteorologically similar days would not have experienced ozone exceedances on August 16, 17, and 21, 2020; and
- statistical regression model analysis that shows a 16 ppb wildfire contribution to ozone at the Grapevine Fairway monitoring site on August 17, 2020.

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LIST OF ACRONYMS

AOD	Aerosol Optical Depth
AQI	Air Quality Index
AQS	Air Quality System
ARL	Air Resource Laboratory
CAMS	Continuous Air Monitoring Site
CFR	Code of Federal Regulations
CO	Carbon Monoxide
CDT	Central Daylight Time
CST	Central Standard Time
DFW	Dallas-Fort Worth
EER	Exceptional Events Rule
EPA	Environment Protection Agency
GAM	Generalized Additive Models
GLM	Generalized Linear Models
HMS	Hazard Mapping System
hPa	Hectopascals
km	Kilometers
LEADS	Leading Environmental Analysis and Display System
mb	Millibar
MODIS	Moderate Resolution Imaging Spectroradiometer
mph	Miles Per Hour
NAAQS	National Ambient Air Quality Standards
NAM	North American Mesoscale Forecast System
NASA	National Aeronautics and Space Administration
NER	Normalized Enhancement Ratio
NO_2	Nitrogen Dioxide
NOAA	National Oceanic and Atmospheric Administration
NO_X	Nitrogen Oxides
NO_Y	Reactive Oxides of Nitrogen
PAMS	Photochemical Assessment Monitoring Station
PM_{10}	Particulate Matter less than or equal to 10 microns in diameter
$PM_{2.5}$	Fine Particulate Matter less than or equal to 2.5 microns in diameter
ppb	Parts Per Billion
SIP	State Implementation Plan
Suomi-NPP	Suomi National Polar-orbiting Partnership
TCEQ	Texas Commission on Environmental Quality
UTC	Universal Coordinated Time
VIIRS	Visible Infrared Imaging Radiometer Suite
VOC	Volatile Organic Compound

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CHAPTER 1: INTRODUCTION

On August 16, 17, and 21, 2020, the Grapevine Fairway monitor measured maximum daily eight-hour ozone averages that were influenced by emissions from wildfires burning in California and Colorado in July and August 2020. Smoke from these fires coalesced into a plume, ozone and particulates formed in this wildfire plume and covered much of the central United States, ultimately influencing the air quality in the Dallas-Fort Worth (DFW) area. The measured maximum daily eight-hour ozone average on August 16, 17, and 21 was 77, 88, and 77 parts per billion (ppb) respectively.

The United States Environmental Protection Agency (EPA), per Federal Clean Air Act, §319, allows the exclusion of monitoring data influenced by exceptional events such as wildfires when making certain regulatory determinations relating to the National Ambient Air Quality Standards (NAAQS). The Texas Commission on Environmental Quality (TCEQ) has determined that the ozone concentrations exceeding the NAAQS on August 16, 17, and 21, 2020 qualify as an exceptional event under 40 Code of Federal Regulations (CFR) §50.14, the revised Exceptional Events Rule (EER). This document provides technical support to demonstrate that the wildfires in California and Colorado caused the measured exceedances at the Grapevine Fairway monitor on August 16, 17, and 21, 2020. The TCEQ requests that the EPA concur with this finding and exclude the maximum daily eight-hour ozone averages taken at the Grapevine Fairway monitor on these days from design value calculations. Without any exclusions, Grapevine Fairway's 2020 fourth highest maximum daily eight-hour ozone average is 77 ppb and the monitor's 2018 through 2020 ozone design value is 76 ppb. The EPA's concurrence that any one of these days was influenced by exceptional events would lower Grapevine Fairway's fourth highest daily maximum daily eight-hour ozone average to 73 ppb and its 2018 through 2020 ozone design value to 75 ppb. A 2018 through 2020 ozone design value of 75 ppb brings Grapevine Fairway and the entire DFW nonattainment area into attainment of the 2008 eight-hour ozone NAAQS.

The EPA has adopted a weight-of-evidence approach to evaluating exceptional event demonstrations (U.S. EPA, 2016a, p. 3). The TCEQ prepared analyses documenting the causal relationship between wildfire emissions and the measured high level of ozone at the Grapevine Fairway monitor.

This exceptional event demonstration is being published for public comment. Comments may be submitted until 5 PM Central Daylight Time (CDT) on May 14, 2021.

1.1 THE GRAPEVINE FAIRWAY MONITOR

The Grapevine Fairway monitor (Continuous Air Monitoring Site (CAMS) 70) is located several miles north of the DFW International Airport near Grapevine Lake (See Figure 1-1: *Location of Grapevine Fairway Monitor*). It has been active since August 4, 2000. Siting and instrumentation information for the Grapevine Fairway monitor is shown in Table 1-1: *Background Information for the Grapevine Fairway Monitor*. The Grapevine Fairway monitor is the design value setting monitor for the DFW area after the 2020 ozone season.

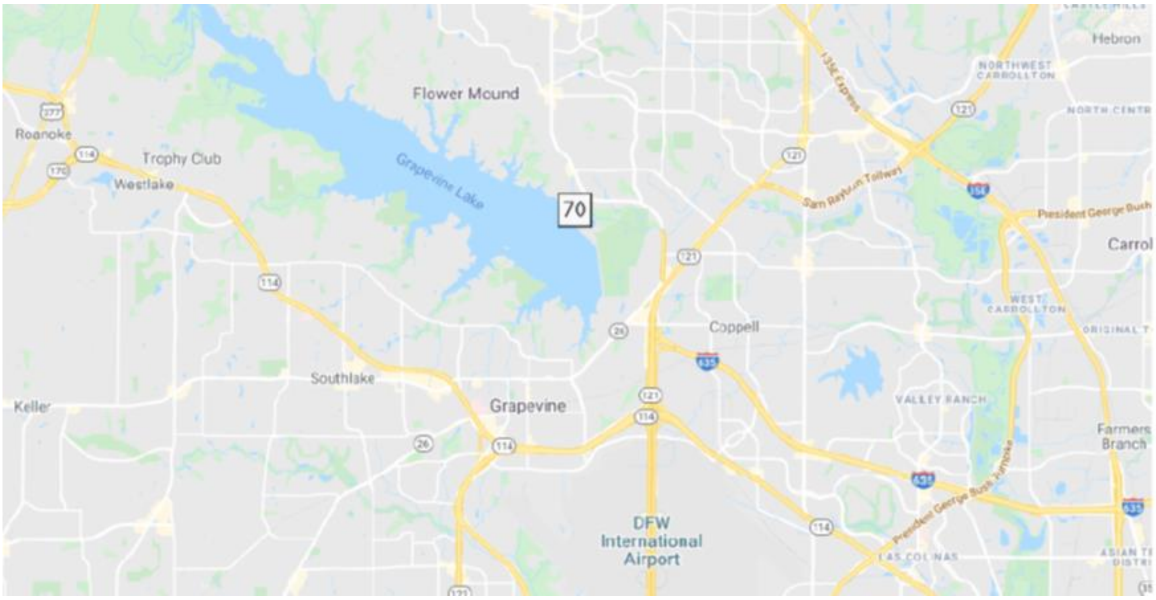

Figure 1-1: Location of Grapevine Fairway Monitor

Table 1-1: Background Information for the Grapevine Fairway Monitor

Monitor Detail	Value
Air Quality System (AQS) Number	484393009
Activation Date	August 4, 2000
Address	4100 Fairway Dr., Grapevine, TX 76051
Latitude/Longitude	N 32.984260º / W 97.063721º
Elevation	165.0 Meters
Pollutant Instrumentation	Ozone, Nitrogen Oxides (NO_X), and Volatile Organic Compound (VOC) Canister
Meteorological Instrumentation	Winds, Barometric Pressure, Dew Point Temperature, Relative Humidity, Solar Radiation, and Outdoor Temperature

1.2 HISTORICAL COMPARISON OF OZONE DATA

As required by the EER, the TCEQ compared maximum daily eight-hour ozone averages of the influenced days to all daily maximum daily eight-hour ozone averages from January 1, 2016 through December 31, 2020. Daily maximum daily eight-hour averages were estimated in accordance with EPA procedures for determining ozone design values.

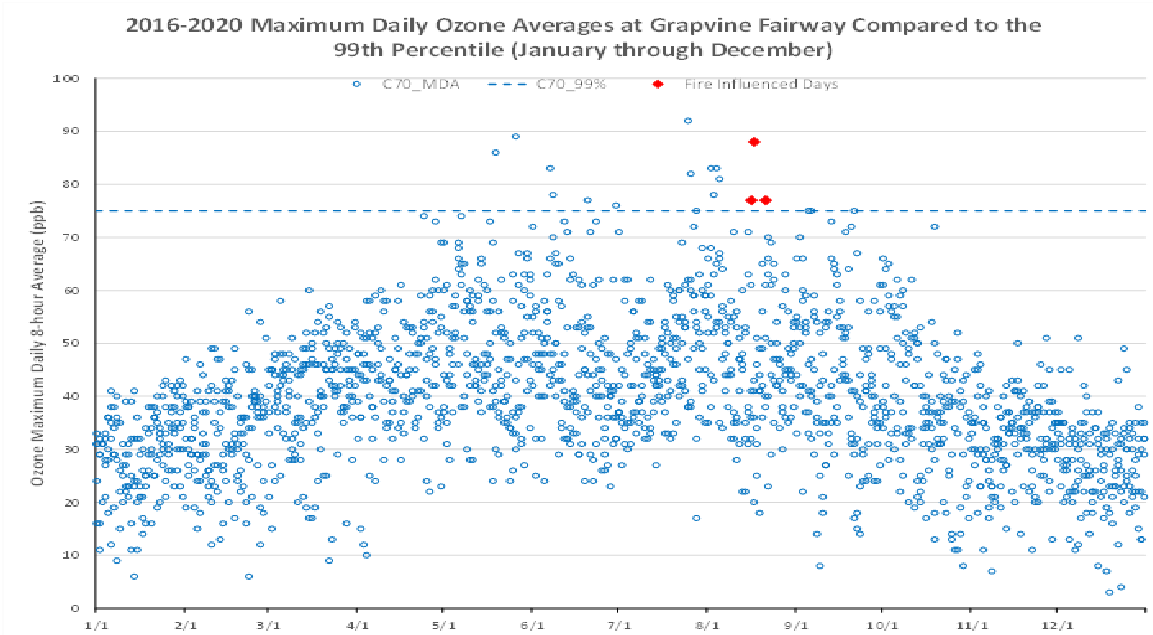

Figure 1-2: Historical Comparison of Maximum Daily Averages at Grapevine Fairway

Based on data for calendar years 2016-2020, the 99th percentile of maximum daily eight-hour ozone averages was determined to be 75 ppb. Figure 1-2: *Historical Comparison of Maximum Daily Averages at Grapevine Fairway* shows that all three influenced days lie above the 99th percentile line.

1.3 NARATIVE CONCEPTUAL MODEL

The DFW metropolitan area in Texas covers almost 9,300 square miles and is home to over 8 million residents according to the United States Census Bureau (2020). Despite its large size, the area has steadily improved its ozone air quality. Figure 1-3: *DFW and Grapevine Fairway Ozone Trends 2000 - 2020* shows that DFW's ozone design value has dropped from 102 ppb in 2000 to a preliminary 76 ppb in 2020. This represents a 25% decrease over that time frame.

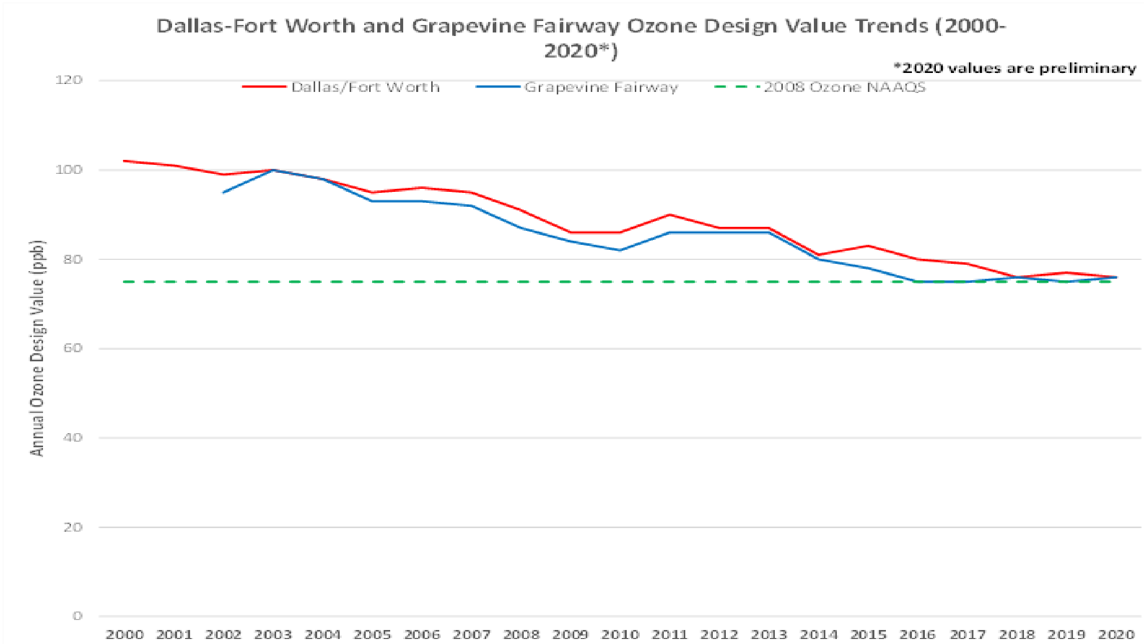

Figure 1-3: DFW and Grapevine Fairway Ozone Trends 2000 - 2020

1.3.1 Characteristics of a Typical High Ozone Event

Ozone in the DFW area typically forms due to a confluence of factors. These include ozone precursor emission sources and specific meteorological conditions. Meteorological processes strongly influence ozone formation through the transportation, dilution, or accumulation of emissions in the area. Meteorological conditions conducive to ozone formation include low wind speeds, temperature above 80 degrees Fahrenheit, and abundant sunshine, which allow emissions to accumulate and react extensively to form ozone. These conditions are generally associated with high-pressure systems. On high ozone days, ozone typically first forms in the center or southern portion of the DFW area and then is transported by slow southeasterly winds toward the north and northwest. High pressure systems associated with high ozone are most common in the late spring and late summer periods. Cold fronts can increase background ozone and precursor concentrations by transporting air masses from the north, which often have higher background levels of ozone. High-pressure systems which usually follow cold front passages then create ozone conducive conditions which use those higher background levels to form additional ozone.

High ozone is not likely when there are low pressure systems over the area. Cloudy weather and precipitation associated with these systems inhibit the formation of ozone. High ozone is also not likely when there are strong pressure gradients over the area which are associated with higher winds. This allows for dispersion of ozone and ozone precursors.

1.3.2 Characteristics of the Mid-August 2020 High Ozone Event

Synoptic scale upper-level ridging prevailed over the southwestern United States in the middle of August 2020. This resulted in extremely warm and dry conditions in the southwestern United States and California (see Figure 1-4: *Drought Conditions for the*

Western United States on August 18, 2020 and Figure 1-5: *Statewide Average Temperature Rankings for August 2020*). August 2020 had the highest average temperatures for these states. These conditions, combined with moderate to extreme drought, provided conditions conducive to wildfire development. As this system strengthened, clockwise circulation around the high-pressure system enhanced mid-level transport of air from California and Colorado to the DFW area. The location and strength of the Four Corners high pressure system as it intensifies and then slowly drifts westward is shown in the following figures:

- Figure 1-6: *NOAA 500 mb Height and Wind Analysis at 6:00 PM CST August 12, 2020*;
- Figure 1-7: *NOAA 500 mb Height and Wind Analysis at 6:00 PM CST August 13, 2020*;
- Figure 1-8: *NOAA 500 mb Height and Wind Analysis at 6:00 PM CST August 14, 2020;*
- Figure 1-9: *NOAA 500 mb Height and Wind Analysis at 6:00 PM CST August 15, 2020*;
- Figure 1-10: *NOAA 500 mb Height and Wind Analysis at 6:00 PM CST August 16, 2020*;
- Figure 1-11: *NOAA 500 mb Height and Wind Analysis at 6:00 PM CST August 17, 2020*;
- Figure 1-12: *NOAA 500 mb Height and Wind Analysis at 6:00 PM CST August 18, 2020*;
- Figure 1-13: *NOAA 500 mb Height and Wind Analysis at 6:00 PM CST August 19, 2020*;
- Figure 1-14: *NOAA 500 mb Height and Wind Analysis at 6:00 PM CST August 20, 2020*;
- Figure 1-15: *NOAA 500 mb Height and Wind Analysis at 6:00 PM CST August 21, 2020*; and
- Figure 1-16: *NOAA 500 mb Height and Wind Analysis at 6:00 PM CST August 22, 2020*.

On August 16, 2020, visible smoke that lofted from the Cameron Peak and Williams Fork fires in Colorado can be seen drifting over Kansas, Oklahoma, and the Texas panhandle into the DFW area by the Moderate Resolution Imaging Spectroradiometer (MODIS) Terra satellite (see Figure 1-17: *MODIS Terra True Color Satellite Image on August 16, 2020*). This is consistent with the flow seen in the 500 mb weather charts. Figure 1-18: *MODIS Terra True Color Satellite Image on August 17, 2020* shows that smoke is visible over Texas and New Mexico along with clouds associated with thunderstorms that occurred along the surface level stationary front over the DFW area on the evening of August 16, 2020. Figure 1-19: *MODIS Terra True Color Satellite Image on August 21, 2020* shows smoke over the DFW area on August 21, 2020.

Figure 1-20: *NOAA Surface Analysis at 6:00 PM CST August 16, 2020* shows evidence of a stationary front. Strong downdrafts, due to evaporation of rain falling through a very warm airmass, caused downward mixing of wildfire emissions towards the surface. Prior to the evening thunderstorms on the 16th, wind speeds were very light and variable over the area with no strong prevailing weather system. Downdrafts associated with the evening thunderstorms resulted in a peak wind gust at the Grapevine Fairway monitor of 47 miles per hour (mph). The downdrafts demonstrate that air from aloft was mixing to ground level. On the 17th, surface winds were light and from variable directions as the weak stationary front remained over the DFW area (see *Figure 1-21: NOAA Surface Analysis at 6:00 PM CST August 17, 2020*). The front moved out of the DFW area, allowing any accumulated pollutants to disperse, on August 18, 2020.

On the 19th and 20th, mid-level wind flow over the DFW area intensified as the area was between the strong high pressure ridging over the southwestern United States and a deep trough over the eastern United States. This allowed for smoke to again move into the area on August 21, 2020. Winds at the surface on the 18th and 19th were generally light out of the north but shifted to a more easterly wind on the 20th. Winds at the surface over the three days were generally light.

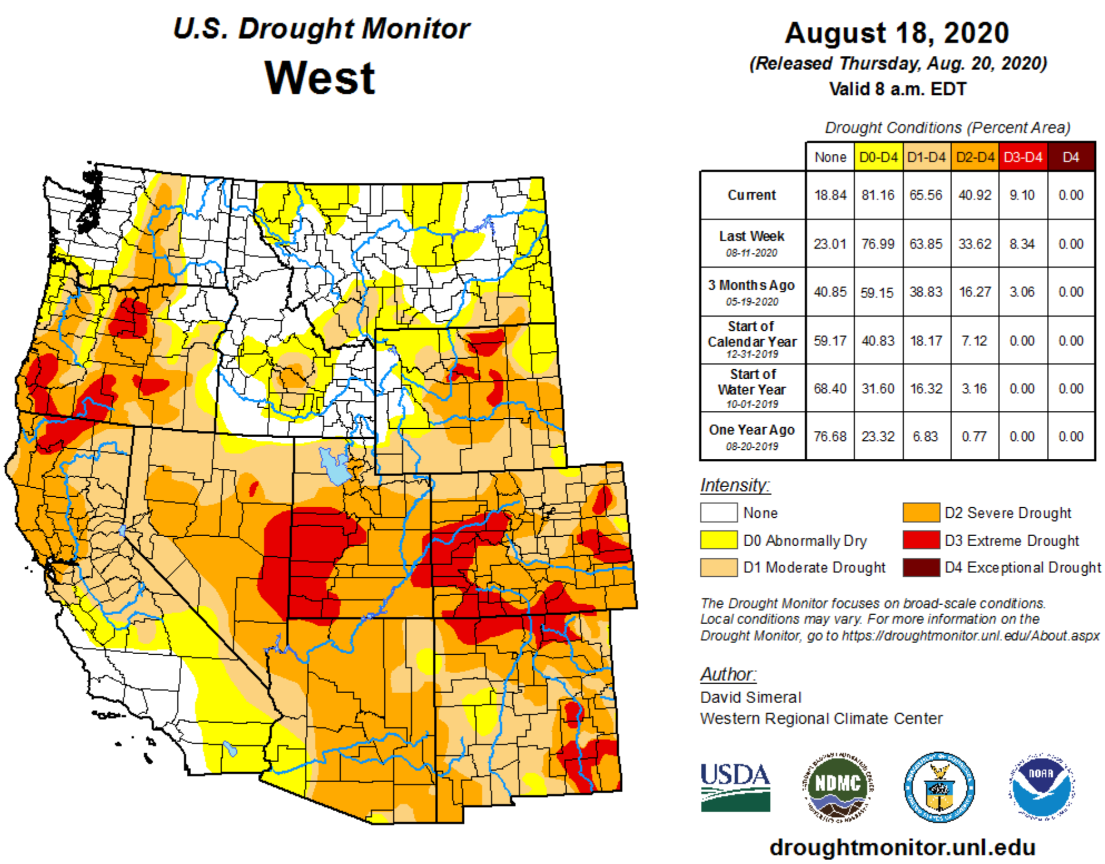

Figure 1-4: Drought Conditions for the Western United States on August 18, 2020

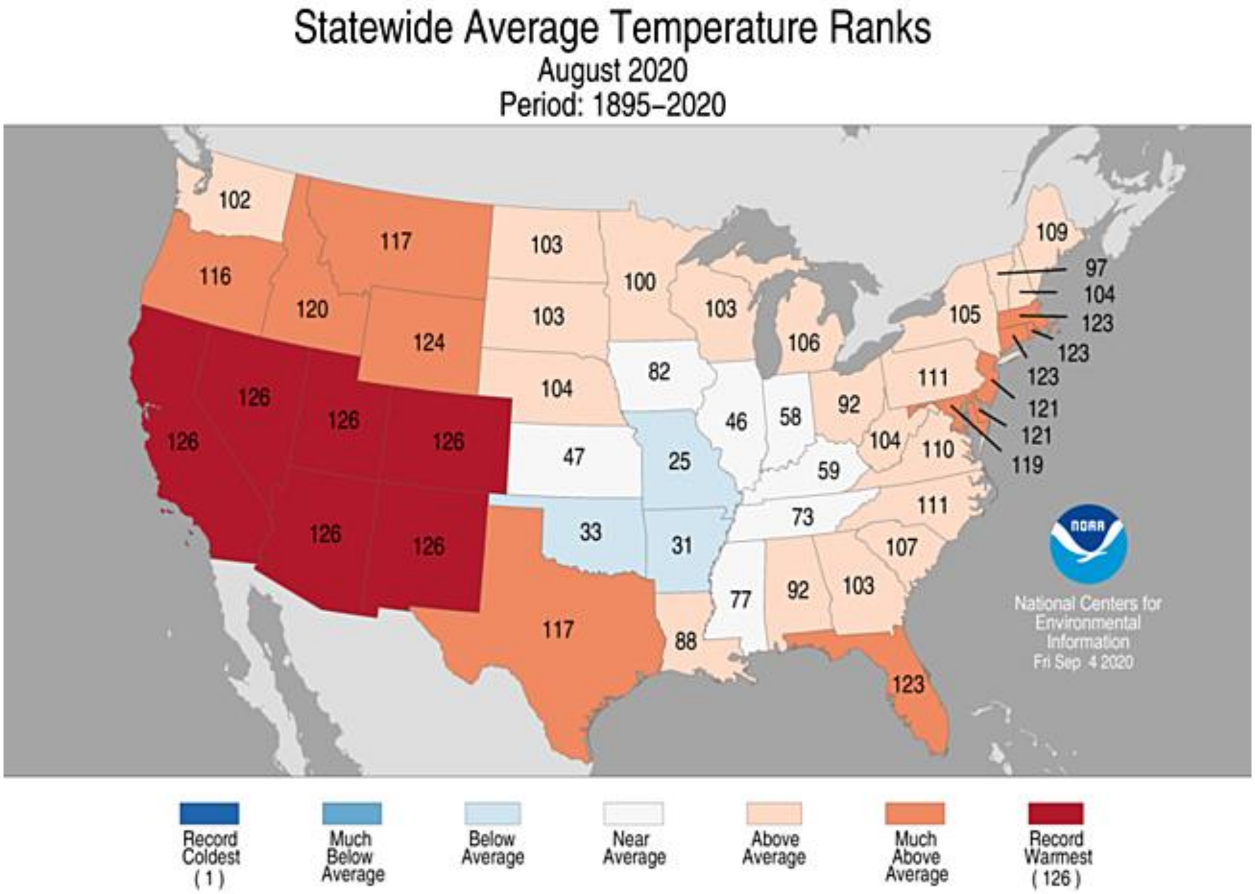

Figure 1-5: Statewide Average Temperature Rankings for August 2020

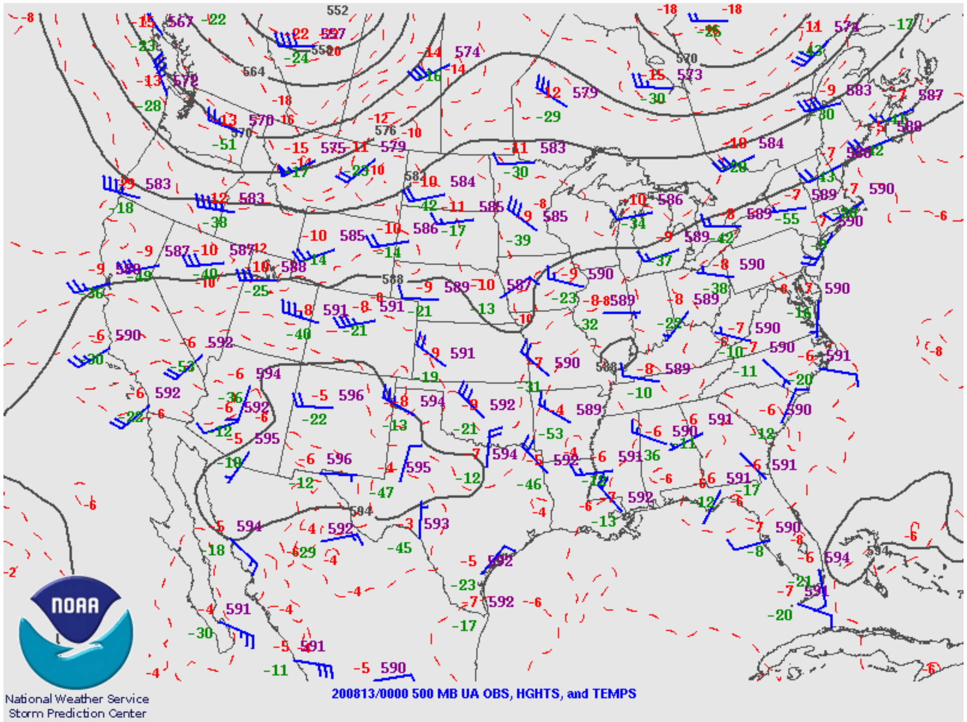

Figure 1-6: NOAA 500 mb Height and Wind Analysis at 6:00 PM CST August 12, 2020

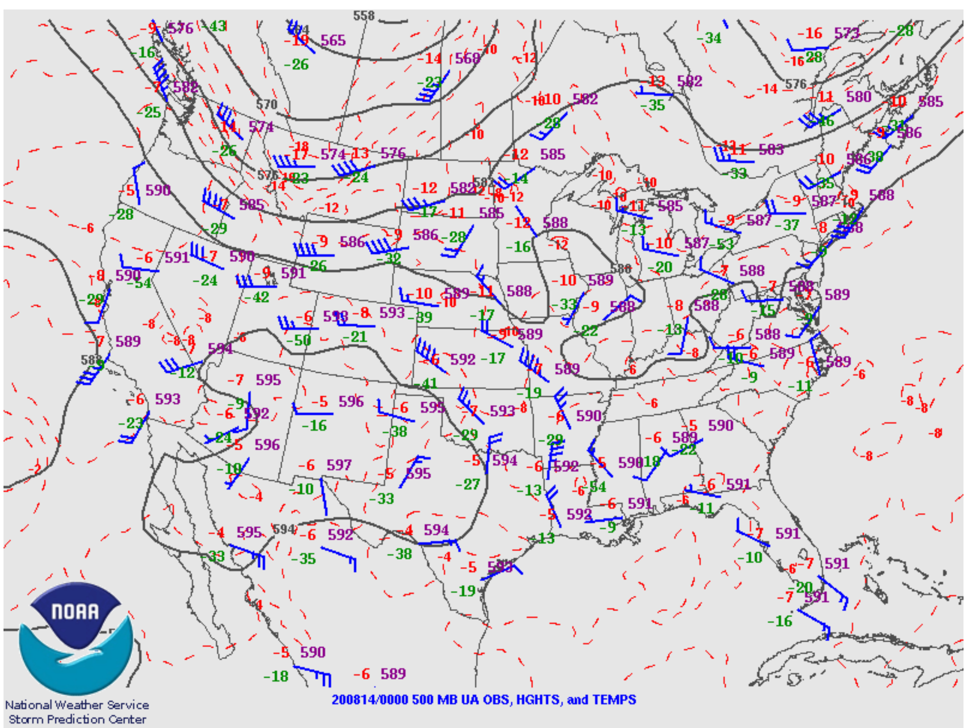

Figure 1-7: NOAA 500 mb Height and Wind Analysis at 6:00 PM CST August 13, 2020

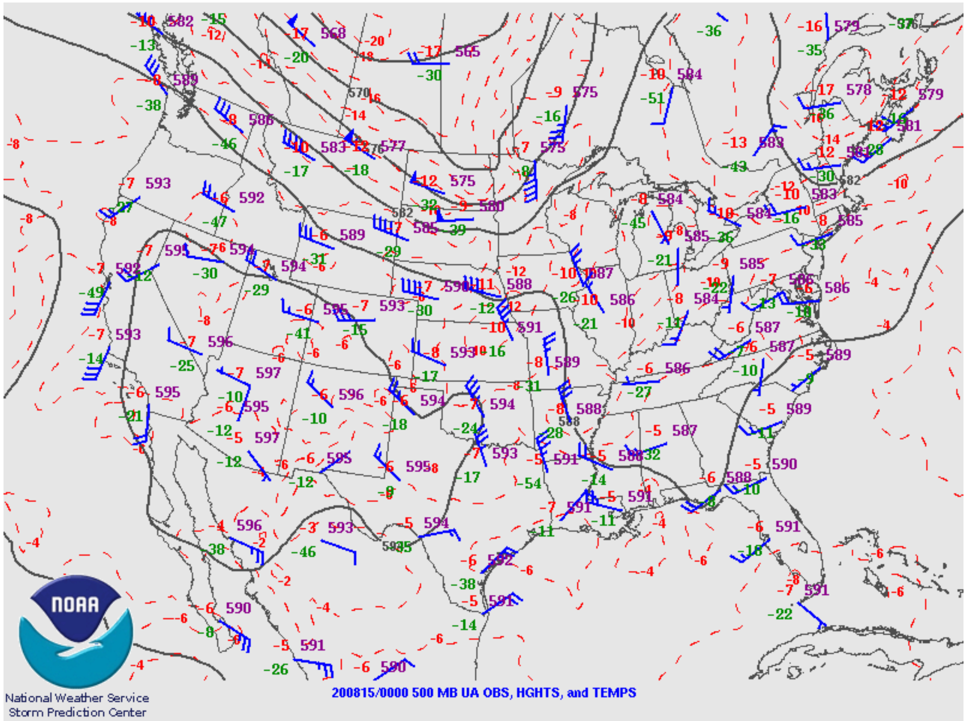

Figure 1-8: NOAA 500 mb Height and Wind Analysis at 6:00 PM CST August 14, 2020

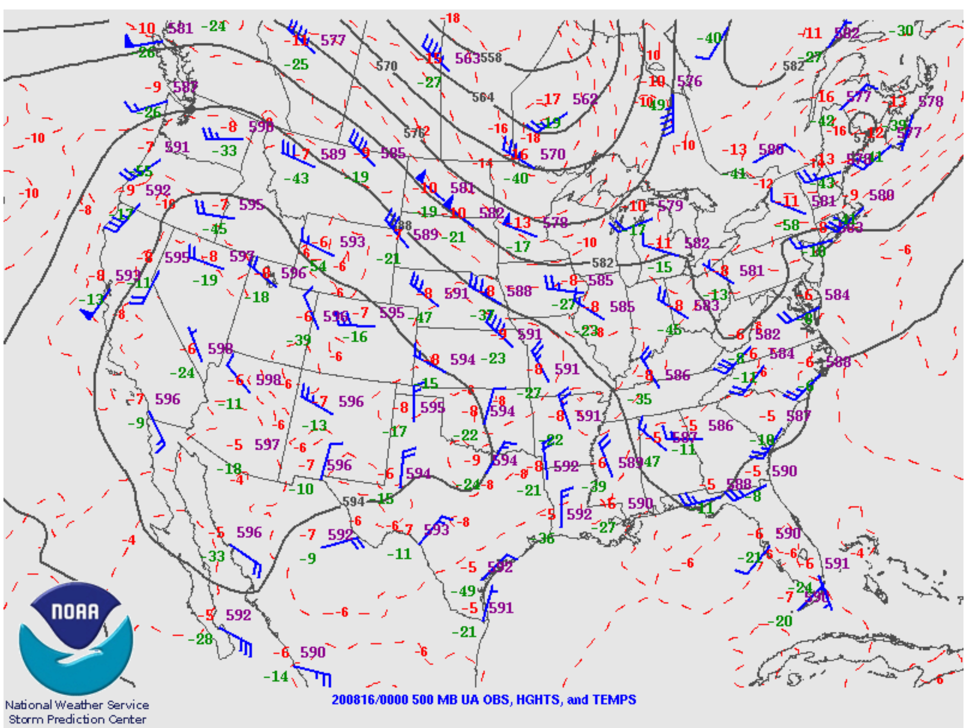

Figure 1-9: NOAA 500 mb Height and Wind Analysis at 6:00 PM CST August 15, 2020

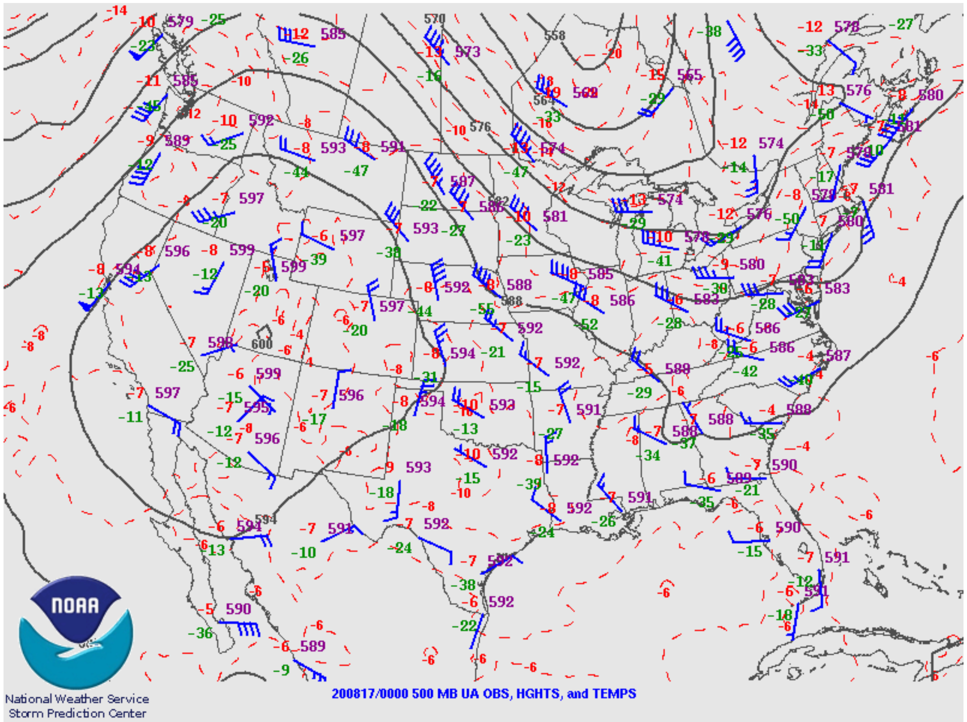

Figure 1-10: NOAA 500 mb Height and Wind Analysis at 6:00 PM CST August 16, 2020

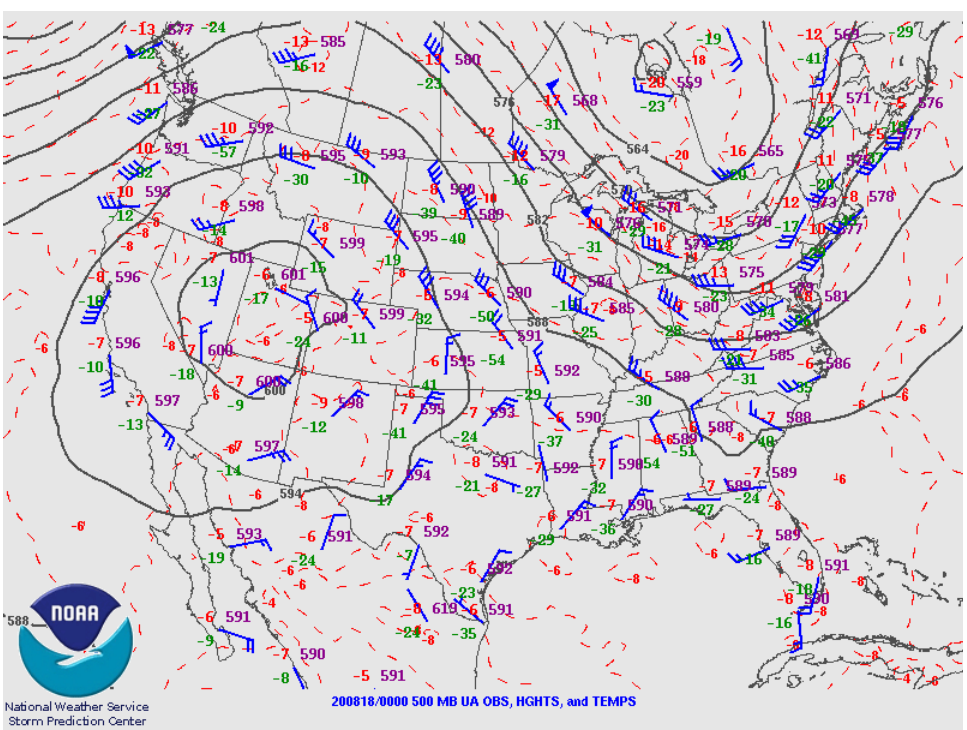

Figure 1-11: NOAA 500 mb Height and Wind Analysis at 6:00 PM CST August 17, 2020

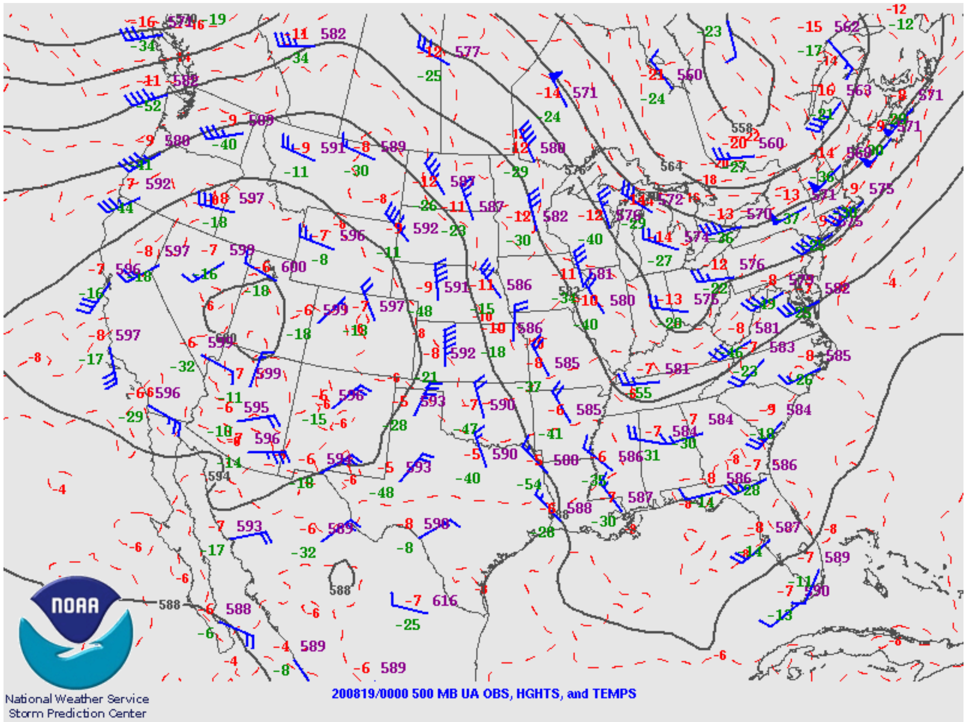

Figure 1-12: NOAA 500 mb Height and Wind Analysis at 6:00 PM CST August 18, 2020

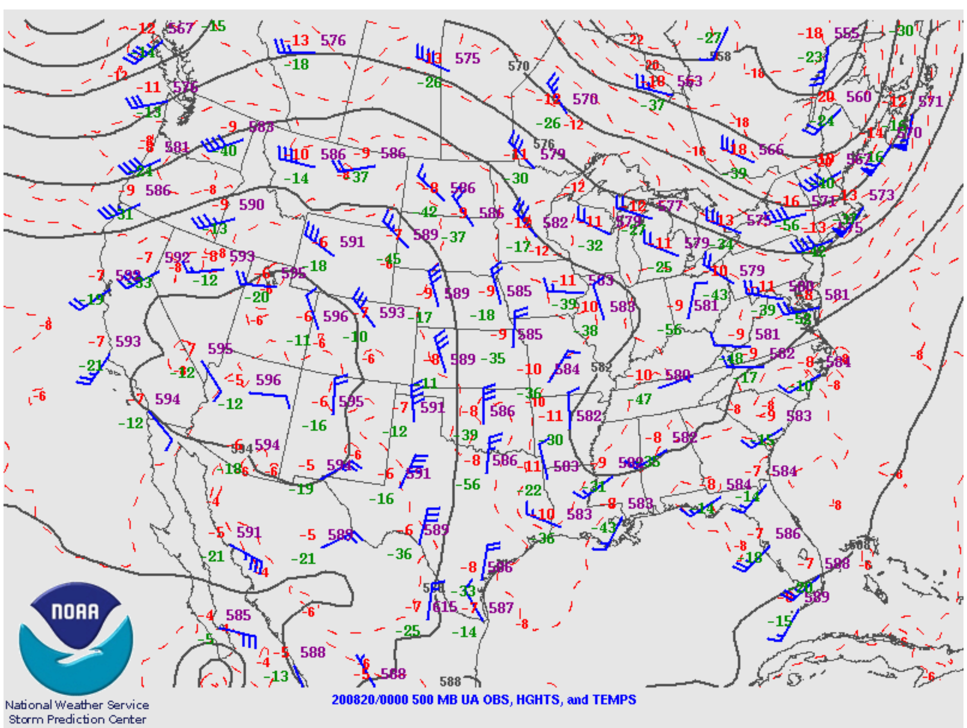

Figure 1-13: NOAA 500 mb Height and Wind Analysis at 6:00 PM CST August 19, 2020

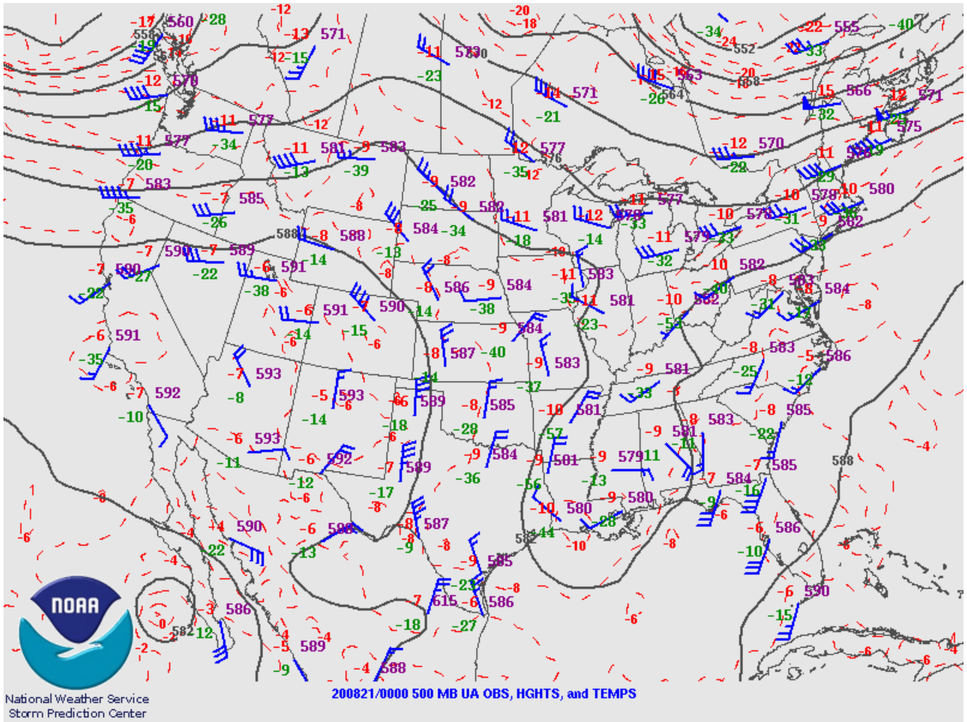

Figure 1-14: NOAA 500 mb Height and Wind Analysis at 6:00 PM CST August 20, 2020

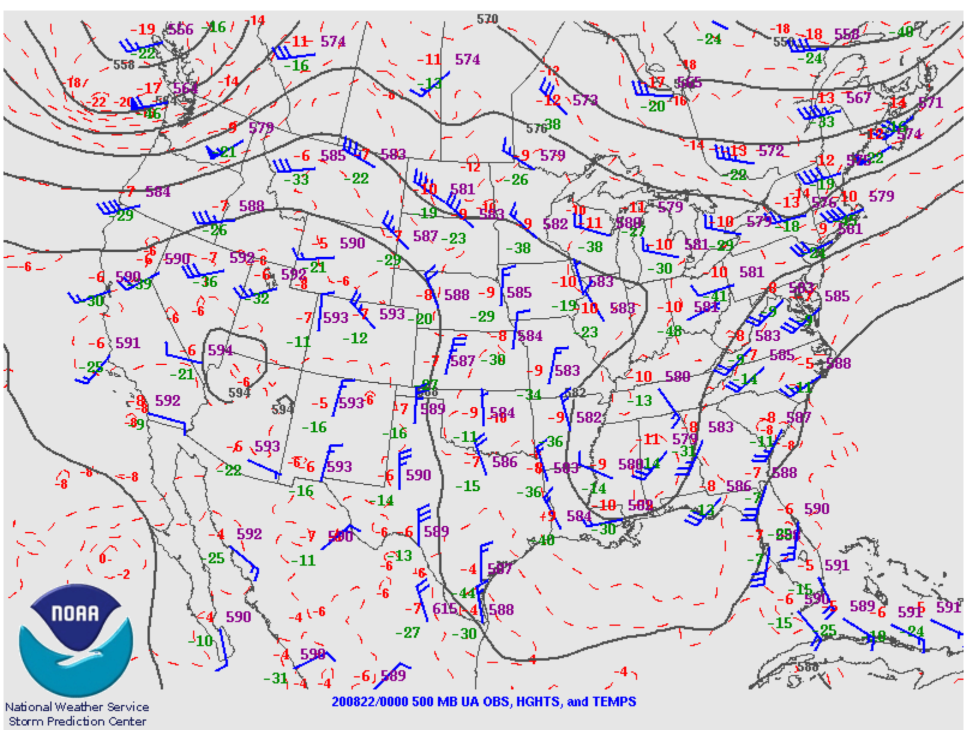

Figure 1-15: NOAA 500 mb Height and Wind Analysis at 6:00 PM CST August 21, 2020

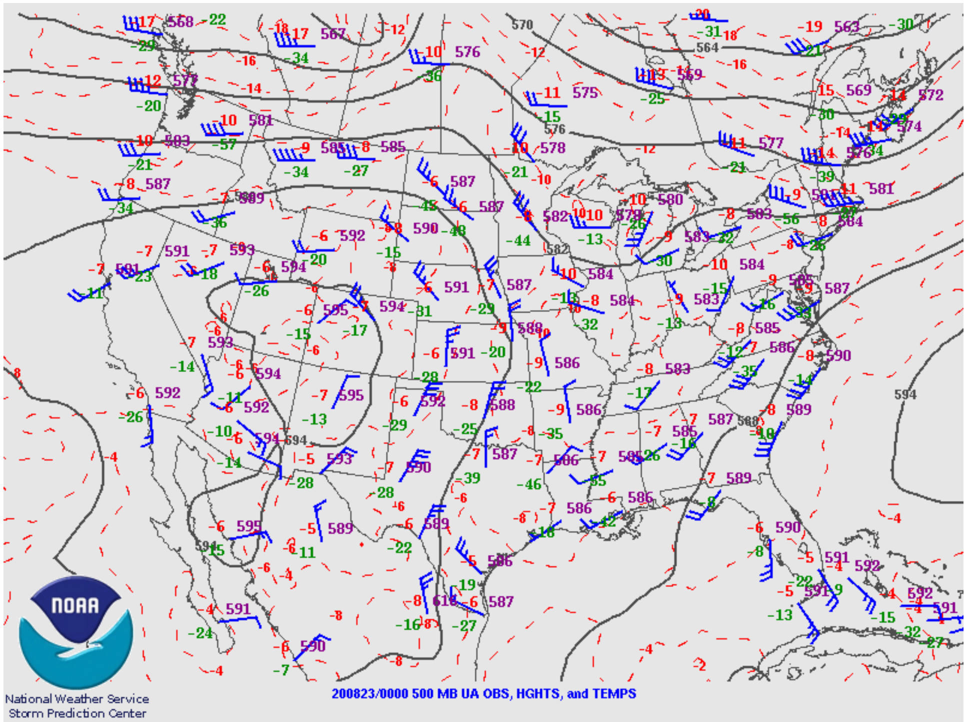

Figure 1-16: NOAA 500 mb Height and Wind Analysis at 6:00 PM CST August 22, 2020

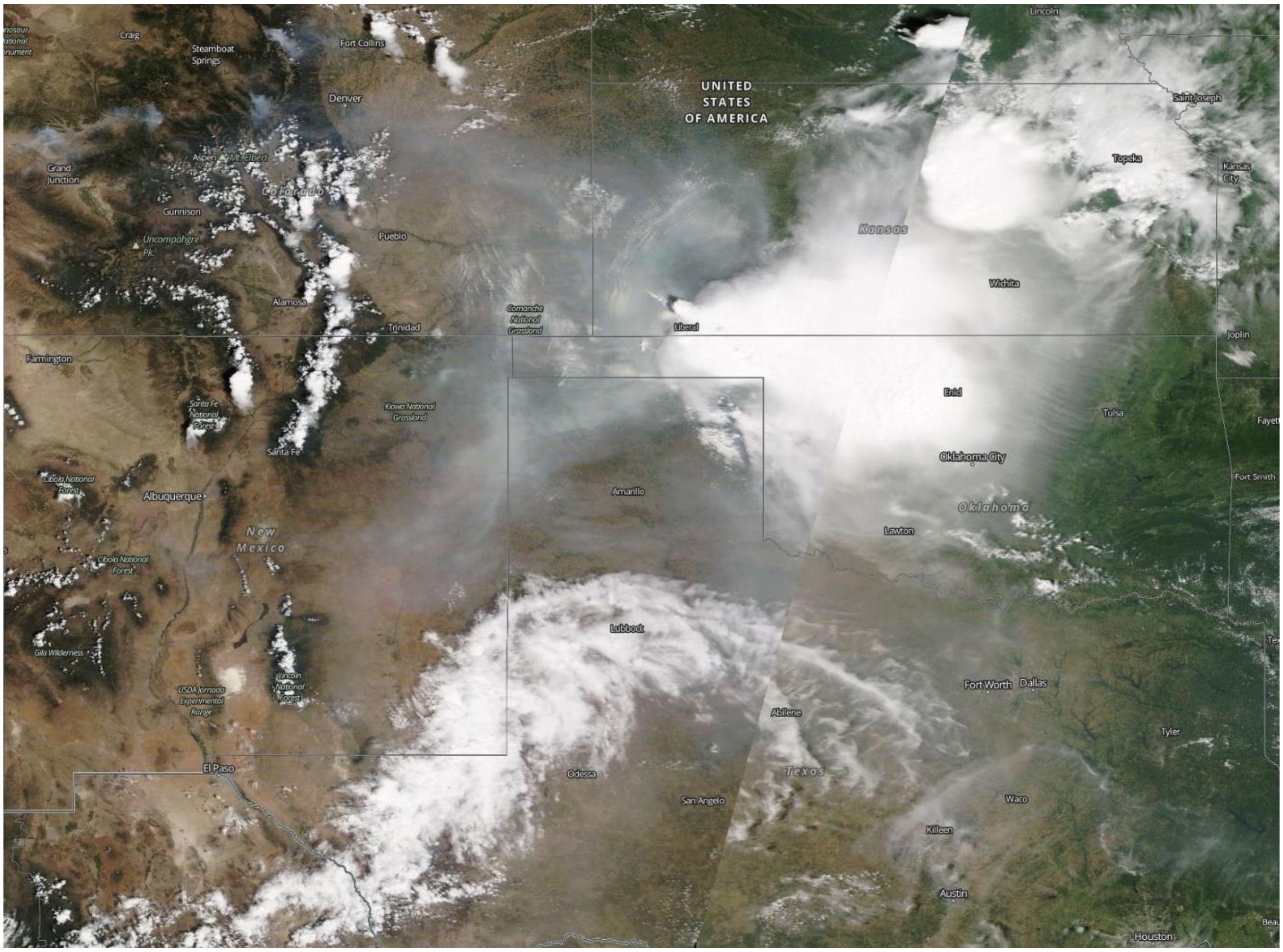

Figure 1-17: MODIS Terra True Color Satellite Image on August 16, 2020

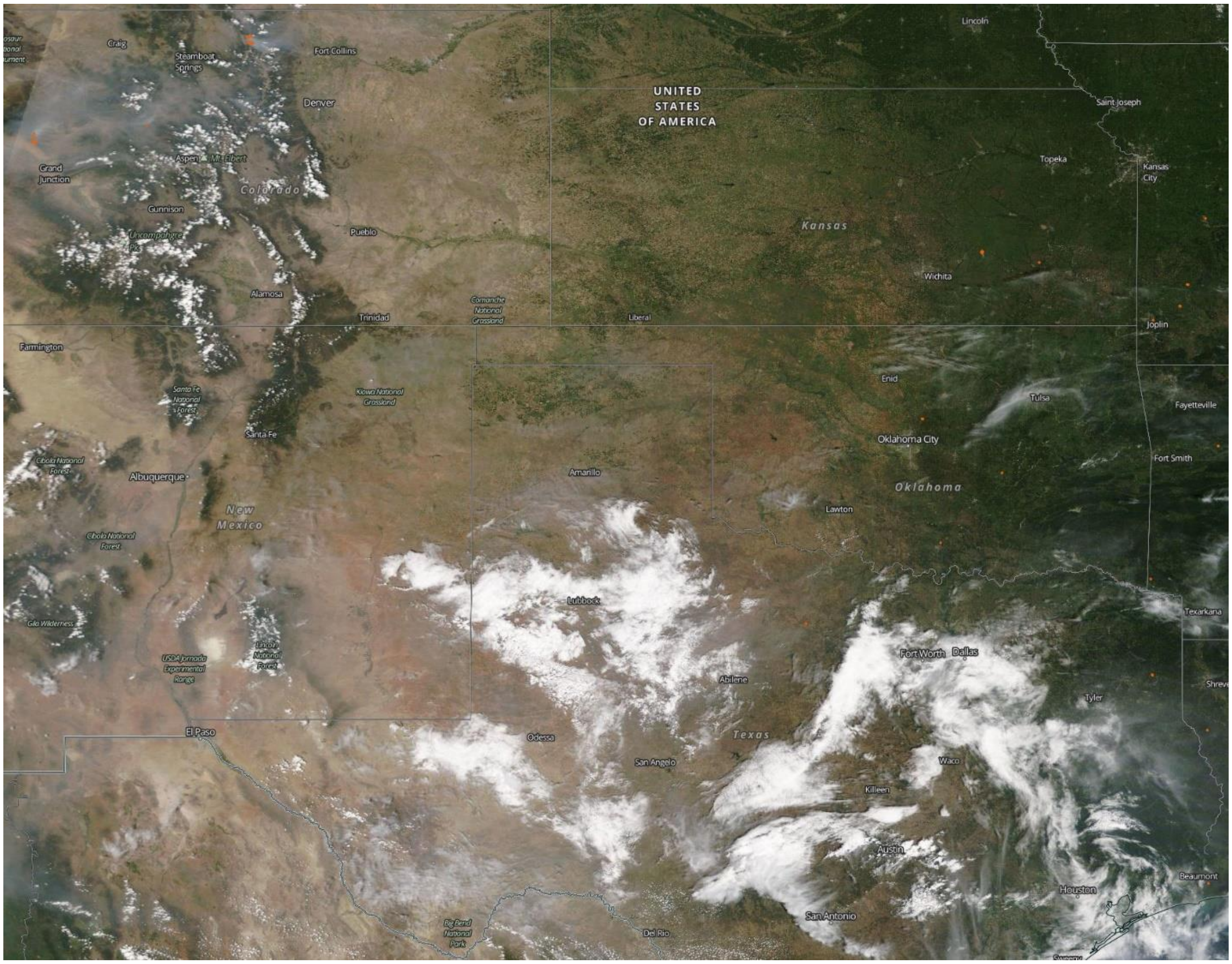

Figure 1-18: MODIS Terra True Color Satellite Image on August 17, 2020

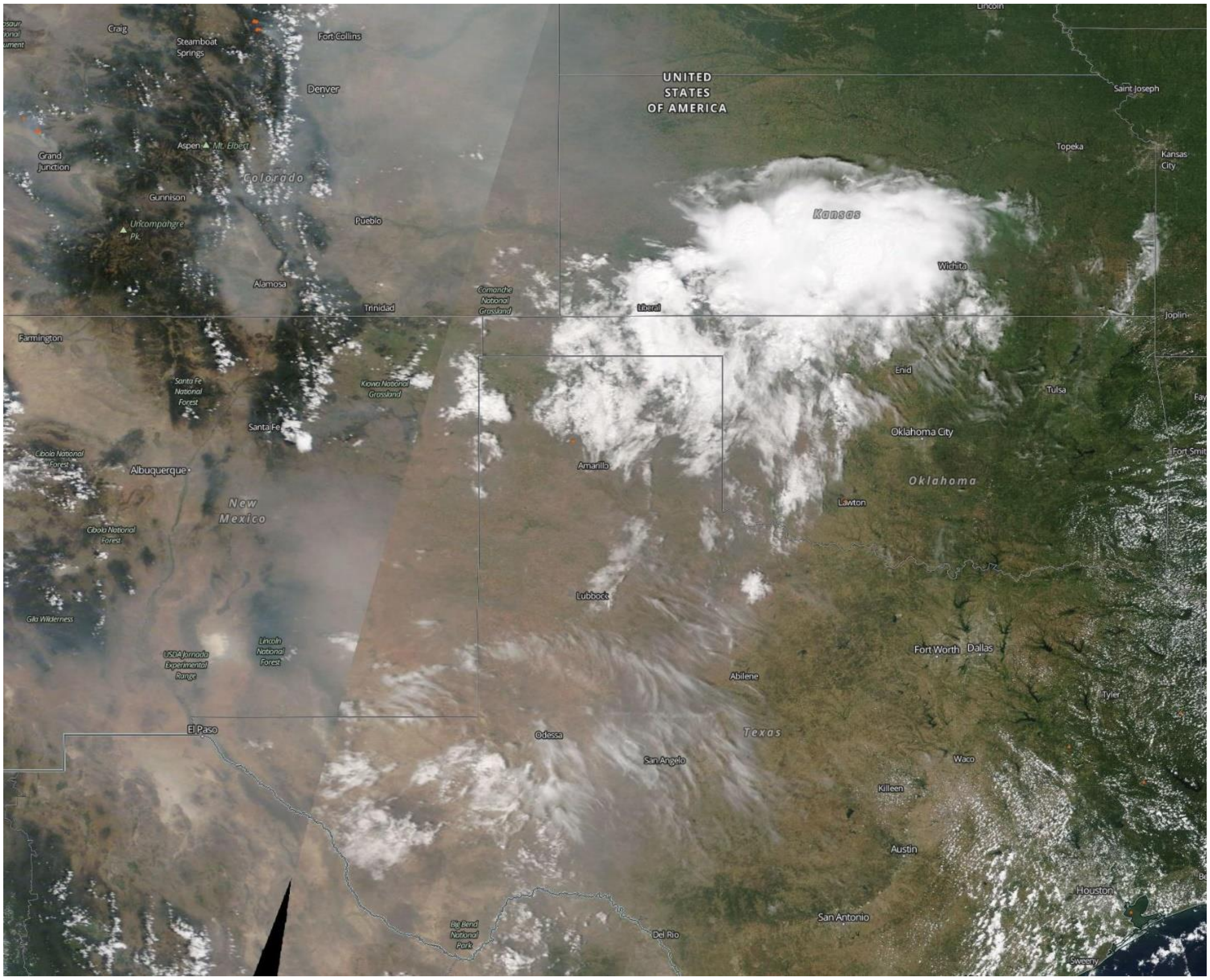

Figure 1-19: MODIS Terra True Color Satellite Image on August 21, 2020

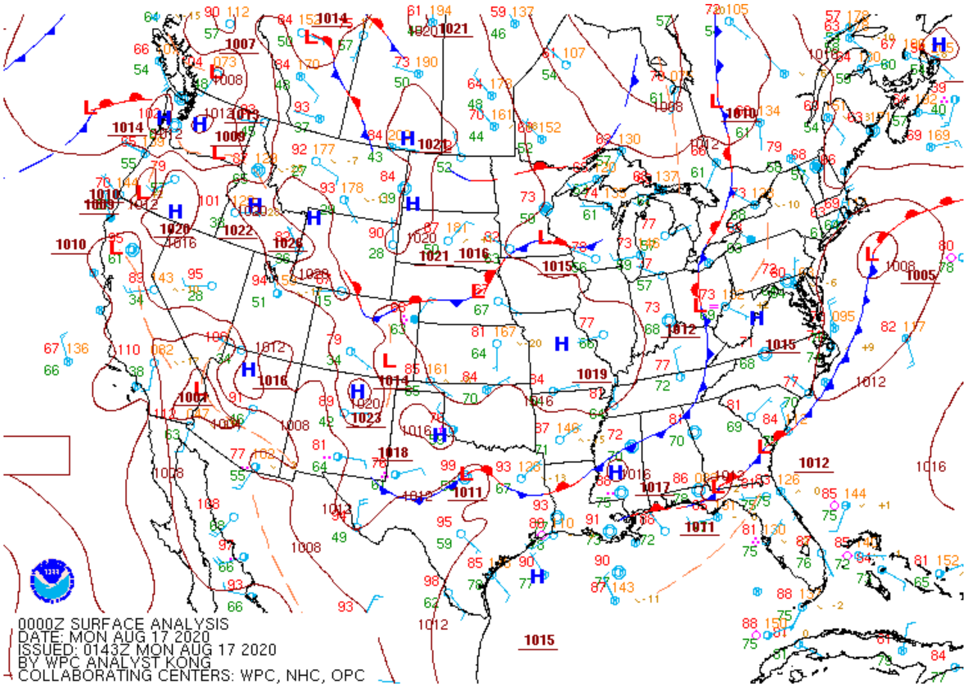

Figure 1-20: NOAA Surface Analysis at 6:00 PM CST August 16, 2020

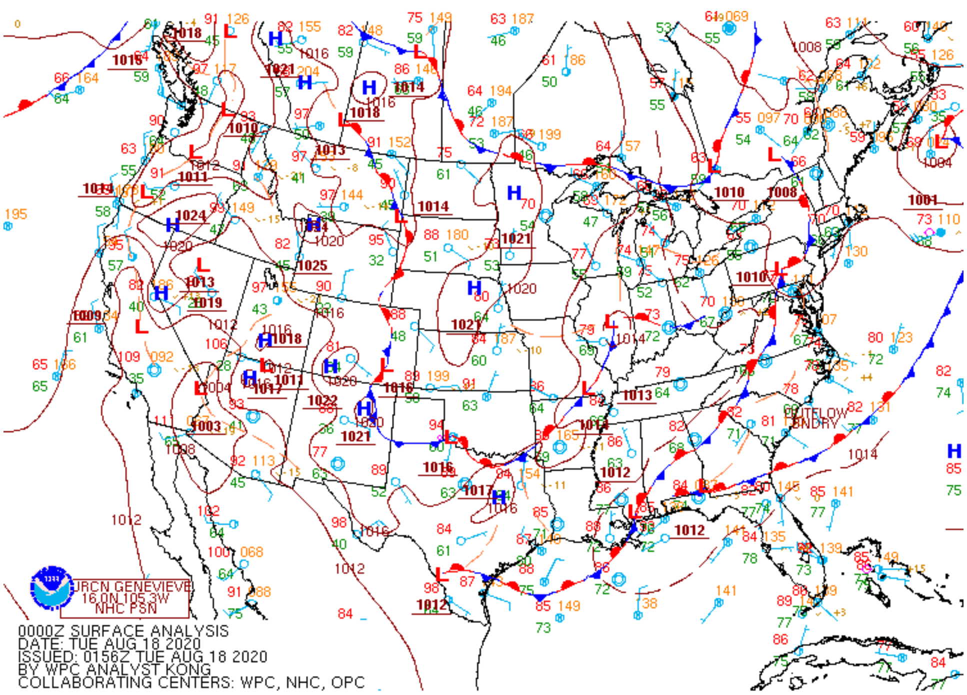

Figure 1-21: NOAA Surface Analysis at 6:00 PM CST August 17, 2020

1.4 FIRES INFLUENCING AUGUST 2020 EXCEEDANCES IN THE DFW AREA

During the mid-August 2020 period, there were three regions in the western United States with wildfires that affected the DFW area: northern/western Colorado, southern California, and northern California. While there were closer fires in Texas and other states in August 2020, those fires did not influence air quality in the DFW area due to the lack of smoke plumes in the hazard mapping system (HMS). The four wildfire complexes identified in Figure 1-22: *Significant Colorado Wildfires That Impacted DFW* influenced DFW air quality on August 16 and 17, 2020. Table 1-2: *Significant Colorado Wildfires That Impacted DFW* contains additional information on these fire complexes. Appendix A: *Detailed Information on Colorado and Northern California Wildfires* contains additional information relating to NO_X and VOC emissions from these fires.

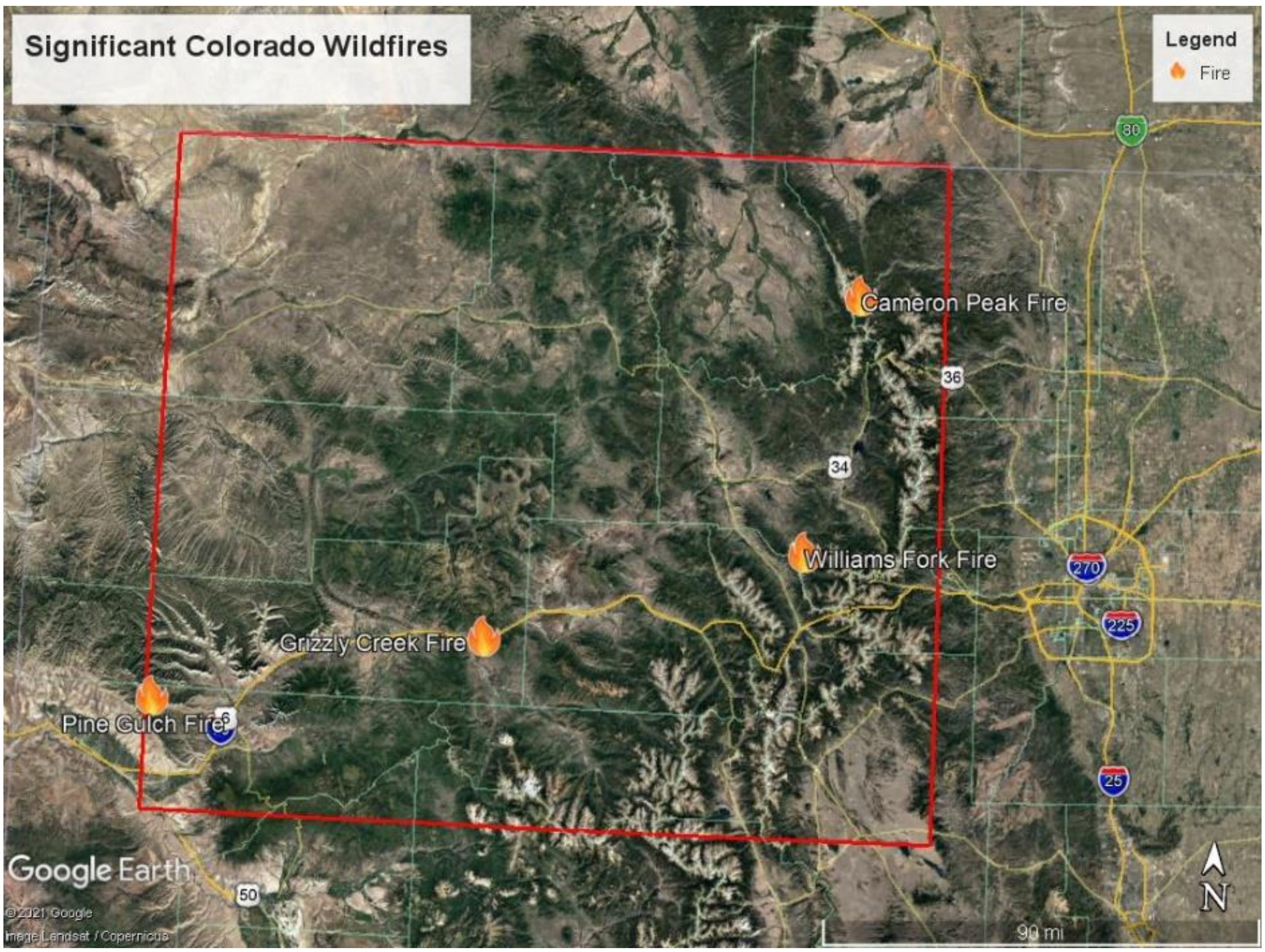

Figure 1-22: Significant Colorado Wildfires That Impacted DFW

Table 1-2: Significant Colorado Wildfires That Impacted DFW

Wildfire	Start Date	Acreage on close of August 14	Reference Latitude	Reference Longitude	Cause
Pine Gulch Fire	7/31/2020	73,713	39.336	-108.526	Lightning
Grizzly Creek Fire	8/10/2020	13,441	39.567	-107.271	Human
Cameron Peak Fire	8/13/2020	5,100	40.609	-105.879	Suspected Human
Williams Fork Fire	8/14/2020	1,300	39.851	-106.065	Human

The TCEQ also identified 22 wildfires throughout California in mid-August 2020 that influenced DFW air quality on August 21, 2020. General locations of these fires are shown in Figure 1-23: *Significant California Wildfires That Impacted DFW* and

Table *1-3: Significant California Wildfires That Impacted* DFW provides more detailed information relating to size, causation, and start dates. Appendix A contains additional information relating to NO_x and VOC emissions from these fires.

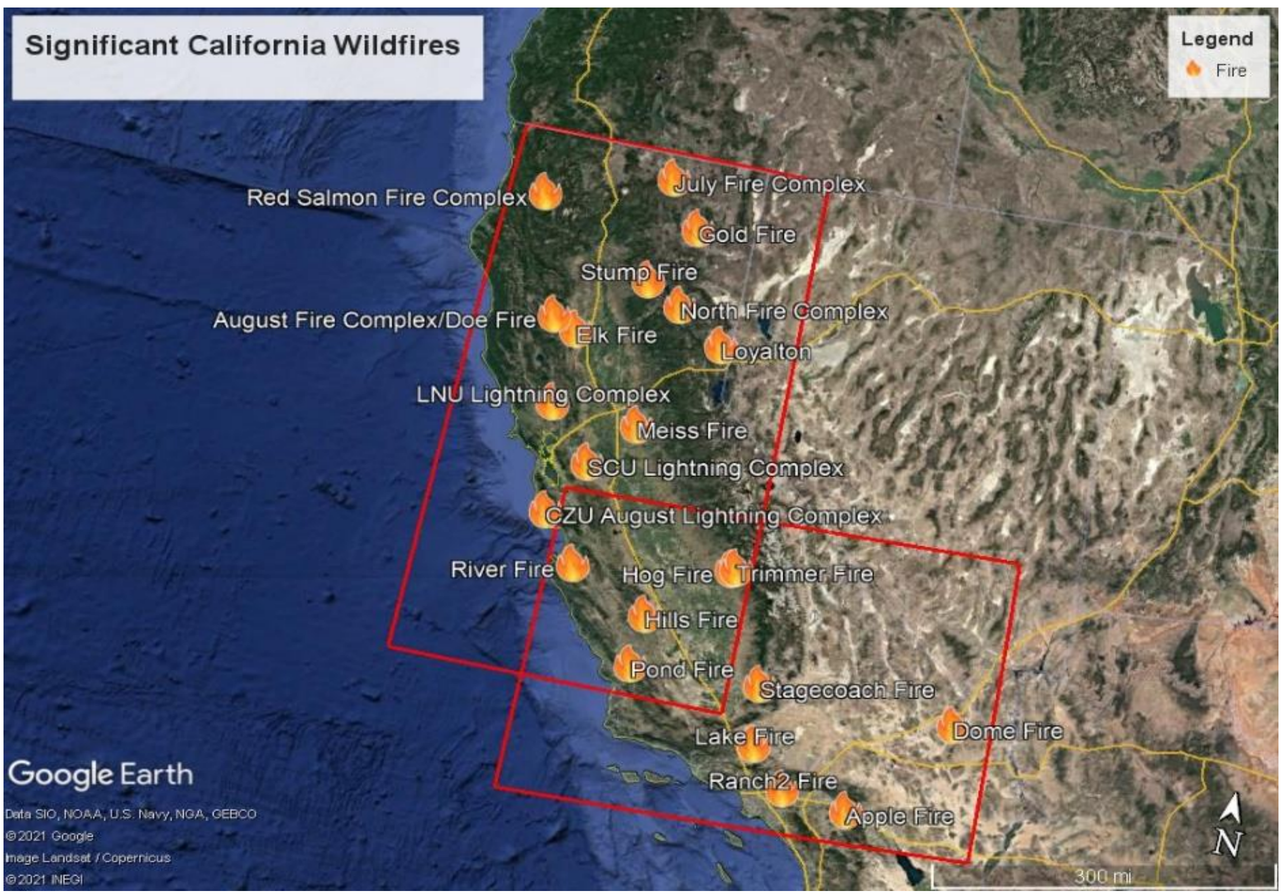

Figure 1-23: Significant California Wildfires That Impacted DFW

Table 1-3: Significant California Wildfires That Impacted DFW

Wildfire	Region	Start Date	Acreage on close of August 16	Reference Latitude	Reference Longitude	Cause
Apple Fire	Southern California	7/31/2020	33,424	33.998	-116.933	Human
Trimmer Fire	Southern California	8/3/2020	594	36.899	-119.240	Unknown
Stagecoach Fire	Southern California	8/3/2020	7,760	35.465	-118.544	Unknown
Lake Fire	Southern California	8/12/2020	18,361	34.679	-118.452	Unknown
Ranch2 Fire	Southern California	8/13/2020	2,557	34.157	-117.911	Human
Dome Fire	Southern California	8/15/2020	25,000	35.301	-115.598	Lightning
Hills Fire	Southern California	8/15/2020	800	36.099	-120.427	Unknown
River Fire	Southern California	8/16/2020	2,000	36.563	-121.640	Lightning
Hog Fire	Northern California	6/12/2020	9,564	36.875	-119.305	Unknown
Gold Fire	Northern California	7/20/2020	22,634	41.113	-120.921	Unknown
July Fire Complex	Northern California	7/22/2020	83,261	41.699	-121.477	Lightning
Red Salmon Fire Complex	Northern California	7/27/2020	12,856	41.185	-123.433	Lightning
Stump Fire	Northern California	8/1/2020	684	40.336	-121.510	Lightning
Meiss Fire	Northern California	8/13/2020	512	38.475	-121.173	Unknown
Loyalton	Northern California	8/14/2020	29,828	39.681	-120.171	Lightning
SCU Lightning Complex (final size)	Northern California	8/16/2020	9,400	37.882	-121.777	Lightning
CZU August Lightning Complex	Northern California	8/16/2020	722	37.172	-122.223	Lightning
Elk Fire	Northern California	8/16/2020	725	39.525	-122.427	Lightning
North Fire Complex	Northern California	8/17/2020	1,481	40.091	-120.931	Lightning

Wildfire	Region	Start Date	Acreage on close of August 16	Reference Latitude	Reference Longitude	Cause
August Fire Complex/Doe Fire	Northern California	8/17/2020	1,000	39.659	-122.809	Lightning
LNU Lightning Complex	Northern California	8/17/2020	3,311	38.549	-122.506	Lightning

CHAPTER 2: EXCEPTIONAL EVENT REQUIREMENTS FOR STATES

2.1 RELEVANT REGULATORY DOCUMENTS

The United States Environmental Protection Agency (EPA) has provided several documents that address exceptional event demonstration requirements, including:

- The 2016 revisions to the 2007 Exceptional Events Rule (EER) (U.S. EPA, 2016a);
- “Guidance on the Preparation of Exceptional Events Demonstrations for Wildfire Events that May Influence Ozone Concentrations” (U.S. EPA, 2016b); and
- “2016 Revisions to the Exceptional Events Rule: Update to Frequently Asked Questions Update to Frequently Asked Questions” (U.S. EPA, 2020).

2.2 REQUIREMENTS FOR AN EXCEPTIONAL EVENT

On October 3, 2016, the EPA revised its EER (40 Code of Federal Regulations (CFR) §50.14(c)(3)), to specify six fundamental elements that a state’s demonstration must contain. Those elements and the parts of this demonstration that fulfill those requirements are shown in Table 2-1: *40 CFR §50.14(c)(3) Exceptional Event Demonstration Requirements*.

Table 2-1: 40 CFR §50.14(c)(3) Exceptional Event Demonstration Requirements

40 CFR §50.14(c)(3) Requirement	Demonstration Chapter
A narrative conceptual model that describes the event(s) causing the exceedance or violation and a discussion of how emissions from the event(s) led to the exceedance or violation at the affected monitor(s).	Chapter 1.3
A demonstration that the event affected air quality in such a way that there exists a clear causal relationship between the specific event and the monitored exceedance or violation.	Chapter 1.2, Chapter 1.3, Chapter 3
Analyses comparing the claimed event-influenced concentration(s) to concentrations at the same monitoring site at other times. The Administrator shall not require a State to prove a specific percentile point in the distribution of data.	Chapter 1.2
A demonstration that the event was both not reasonably controllable and not reasonably preventable.	Chapter 2.3
A demonstration that the event was caused by human activity that is unlikely to recur at a particular location or was a natural event.	Chapter 2.4
Documentation that the submitting air agency followed the public comment process.	Chapter 2.5, Appendix B

The Texas Commission on Environmental Quality (TCEQ) documents compliance with the EER mitigation requirements in 40 CFR §51.930 with respect public notification, public education, and implementation of appropriate measures to protect health in Table 2-2: *40 CFR §51.930 Exceptional Event Demonstration Requirements*.

Table 2-2: 40 CFR §51.930 Exceptional Event Demonstration Requirements

40 CFR §51.930 Requirement	Demonstration Chapter
Provide for prompt public notification whenever air quality concentrations exceed or are expected to exceed an applicable ambient air quality standard.	Chapter 2.6.1
Provide for public education concerning actions that individuals may take to reduce exposures to unhealthy levels of air quality during and following an exceptional event.	Chapter 2.6.2
Provide for public education concerning actions that individuals may take to reduce exposures to unhealthy levels of air quality during and following an exceptional event.	Chapter 2.6.3

2.3 THE EVENT IS NOT REASONABLY CONTROLLABLE OR PREVENTABLE

Having occurred outside of the State of Texas, these wildfires were not controllable or preventable by Texas. The states of Colorado and California both maintain robust programs aimed at responding to wildfires and preventing future ones.

Information on the California Department of Forestry and Fire Protection programs is available at https://www.fire.ca.gov/.

Information on the Colorado State Forest Service education and wildfire mitigation and measures is available at https://csfs.colostate.edu/.

2.4 THE EVENT IS NOT LIKELY TO RECUR OR IS NATURAL

The wildfires determined to have caused the subject ozone exceedance were a mix of natural cause (lightning strikes) and human caused. Once an area has been burned out, the likelihood of that area burning again declines for an extended period (assuming that the fire was completely extinguished), and the biomass available to burn is significantly reduced such that a fire in the same area in the next several years would likely yield significantly fewer emissions. Any of the fires attributable to human causes that occur outside of Texas are not controllable or preventable by the State of Texas.

2.5 THE TCEQ FOLLOWED THE PUBLIC COMMENT PROCESS

The TCEQ provided for stakeholders and the public to comment on this document for 30 days as required by federal rules. All comments received will be submitted to the EPA with this demonstration.

2.6 MITIGATION REQUIREMENTS OF 40 CFR §51.930

The EER (40 CFR §51.930) requires that "a State requesting to exclude air quality data due to exceptional events must take appropriate and reasonable actions to protect public health from exceedances or violations of the national ambient air quality standards." The TCEQ addresses each of the specific requirements individually below.

2.6.1 Prompt Public Notification

The first mitigation requirement is to "provide for prompt public notification whenever air quality concentrations exceed or are expected to exceed an applicable ambient air quality standard." The TCEQ provided (and continues to provide) ozone, Fine Particulate Matter ($PM_{2.5}$), and Particulate Matter less than or equal to 10 microns in diameter (PM_{10}) Air Quality Index (AQI) forecasts for the current day and the next three days for 14 areas in Texas including the Dallas-Fort Worth (DFW) area. These forecasts are available to the public on the Today's Texas Air Quality Forecast webpage of the TCEQ website (http://www.tceq.texas.gov/airquality/monops/forecast_today.html), and on the EPA's AirNow website (http://airnow.gov/).

The TCEQ provides near real-time hourly ozone measurements from monitors across the state, including the DFW area, which the public may access on the Current Ozone Levels page of the TCEQ website (http://www.tceq.texas.gov/cgi-bin/compliance/monops/select_curlev.pl). The TCEQ also publishes an AQI Report for many Texas metropolitan areas including the DFW area on the AQI page of the TCEQ website (https://www.tceq.texas.gov/airquality/monops/data-reports), which displays current and historical daily AQI measurements. Finally, the TCEQ publishes daily updates to its air quality forecast to interested parties through electronic mail and Twitter. Any person wishing to receive these updates may register on the TCEQ website (http://www.tceq.texas.gov/airquality/monops/ozone_email.html). These measures provide daily and near real-time notification to the public of current, expected, and changing air quality conditions.

2.6.2 Public Education

The second mitigation requirement is to "provide for public education concerning actions that individuals may take to reduce exposures to unhealthy levels of air quality during and following an exceptional event." Through its website, the TCEQ provides the public with technical, health, personal activity, planning, and legal information and resources concerning ozone pollution.

The TCEQ maintains an ozone fact sheet (http://www.tceq.texas.gov/airquality/monops/ozonefacts.html), which provides important information regarding the health effects of ozone, steps that individuals can take to limit ozone formation, and actions they may wish to take to reduce their exposure to higher levels of ozone. A hyperlink to this fact sheet is located on the TCEQ daily air quality forecast page. The fact sheet points individuals towards additional health-related information from the Centers for Disease Control, the Texas Department of State Health Services, and the EPA.

The TCEQ's main webpage for air (http://www.tceq.texas.gov/agency/air_main.html) provides air quality information on topics such as advisory groups, emissions inventories, air quality modeling and data analysis, scientific field studies, state implementation plan (SIP) revisions, air permits, rules, air monitoring data, and how to file complaints.

The TCEQ provides a specific "Air Pollution from Ozone" webpage (http://www.tceq.texas.gov/airquality/sip/criteria-pollutants/sip-ozone), which provides the latest information on air quality planning activities by both the TCEQ and the EPA.

The TCEQ's website provides a hyperlink to the Texas "AirNow" website operated by the EPA (https://www.airnow.gov/). This website links the public to additional information regarding health effects of ozone, strategies for reducing one's exposure to ozone, and actions that individuals can take to reduce pollution levels.

The Texas Department of Transportation sponsors the public education and awareness campaign, "Drive Clean Across Texas" (http://www.drivecleanacrosstexas.org). The campaign raises awareness about the impact of vehicle emissions on air quality and motivates drivers to take steps to reduce air pollution. The campaign's activities are concentrated during the summer months when ozone levels rise.

The TCEQ sponsors the "Take Care of Texas" program (http://takecareoftexas.org/air-quality), which addresses air quality and provides the public with proactive steps to reduce air pollution particularly on days when air quality forecasts are issued predicting greater potential for ozone formation.

2.6.3 Implementation of Measures to Protect Public Health

The DFW area is designated as marginal nonattainment for the 2015 eight-hour ozone NAAQS and serious nonattainment for the 2008 eight-hour ozone NAAQS. The TCEQ adopted a revised attainment demonstration SIP revision for the DFW area for the 2008 eight-hour ozone NAAQS. The DFW SIP Section 4.2 contains information on existing control measures. The SIP revision can be accessed via the link (https://www.tceq.texas.gov/assets/public/implementation/air/sip/dfw/dfw_ad_sip_2016/DFWAD_15014SIP_ado.pdf). More detailed information about the state's ozone reduction strategies can be found on the following webpages:

- Control Strategies for Stationary Sources: http://www.tceq.texas.gov/airquality/stationary-rules/ozone;
- Control Strategies for On-Road Mobile Sources: http://www.tceq.texas.gov/airquality/mobilesource/mobile_source.html;
- Air Permitting: http://www.tceq.texas.gov/permitting/air; and
- Texas Emissions Reduction Plan Program: http://www.tceq.texas.gov/airquality/terp/erig.html.

CHAPTER 3: CAUSAL RELATIONSHIP

In this chapter, the Texas Commission on Environmental Quality (TCEQ) developed analyses of meteorological, pollutant, and remote sensing data that support the position that a clear causal relationship between Colorado and California wildfires and exceedances of the 2008 eight-hour ozone National Ambient Air Quality Standard (NAAQS) at the Grapevine Fairway monitor in the Dallas-Fort Worth (DFW) area on August 16, 17, and 21, 2020. The exceedances on August 16 and 17, 2020 were caused by the wildfires in Colorado and the exceedance on August 21, 2020 were caused by large wildfires in California. The TCEQ's analysis of data at the Dallas Hinton monitor indicates that wildfire emissions affected ground-level air quality in the DFW area.

3.1 PERIOD OF ANALYSIS

When considering the amount of data that states should use in an exceptional event demonstration, the United States Environmental Protection Agency (EPA) (2020, p. 14) notes that "For seasonal comparisons, an approvable demonstration will ideally include all available seasonal data from at least 5 years, if available." For this demonstration, the TCEQ used the 2016 through 2020 a five-year period. The TCEQ's monitoring from 2020 has not been certified and should be viewed as preliminary. Exceptions to this time-period will be noted on a case-by-case basis.

3.2 TIERED ANALYSIS

In its September 2016 guidance for exceptional event demonstrations related to wildfire events the EPA (U.S. EPA, 2016a, p. 4) introduced a tiered approach for addressing the causal relationship in a wildfire-caused ozone exceptional event demonstration.

"Tier 1 clear causal analyses should be used for wildfire events that cause clear ozone impacts in areas or during times of year that typically experience lower ozone concentrations and are thus simpler and less resource intensive than analyses for other events. Tier 2 clear causal analyses are likely appropriate when the impacts of the wildfire on ozone levels are less clear and require more supportive documentation than Tier 1 analyses. Tier 3 clear causal analyses should be used for events in which the relationship between the wildfire and the ozone exceedance or violation is more complicated than the relationship in a Tier 2 analysis, and thus would require more supportive documentation than Tier 2 analyses." (U.S EPA, 2016a, p. 4)

As a result of discussions between the TCEQ and the EPA, this demonstration provides a Tier 3 analysis.

3.3 HAZARD MAPPING SYSTEM PLUME

As part of its Hazard Mapping System (HMS), the National Oceanic and Atmospheric Administration (NOAA) produces daily fire and smoke plume maps depicting the location of fires and smoke plumes detected by satellites (NOAA, 2003). The maps for August 16 through August 17, 2020 and August 21, 2020 are shown below in Figure 3-1: *NOAA Hazard Mapping System Plume Map for August 16, 2020,*

Figure 3-2: *NOAA Hazard Mapping System Plume Map for August 17,* **2020***,* and Figure 3-3: *NOAA Hazard Mapping System Plume Map for August 21, 2020*. The location of the Grapevine Fairway and Eagle Mountain Lake monitors are shown by green pins in the DFW area. All three figures clearly show the presence of smoke plumes over the Grapevine Fairway monitor.

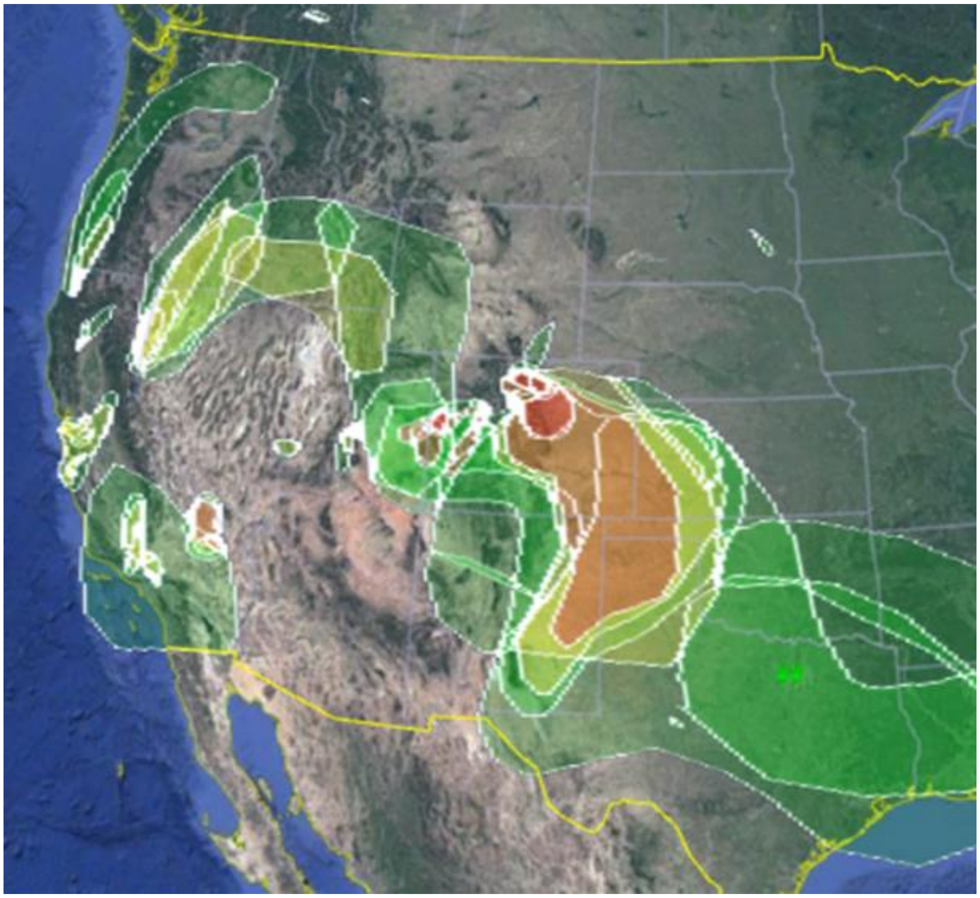

Figure 3-1: NOAA Hazard Mapping System Plume Map for August 16, 2020

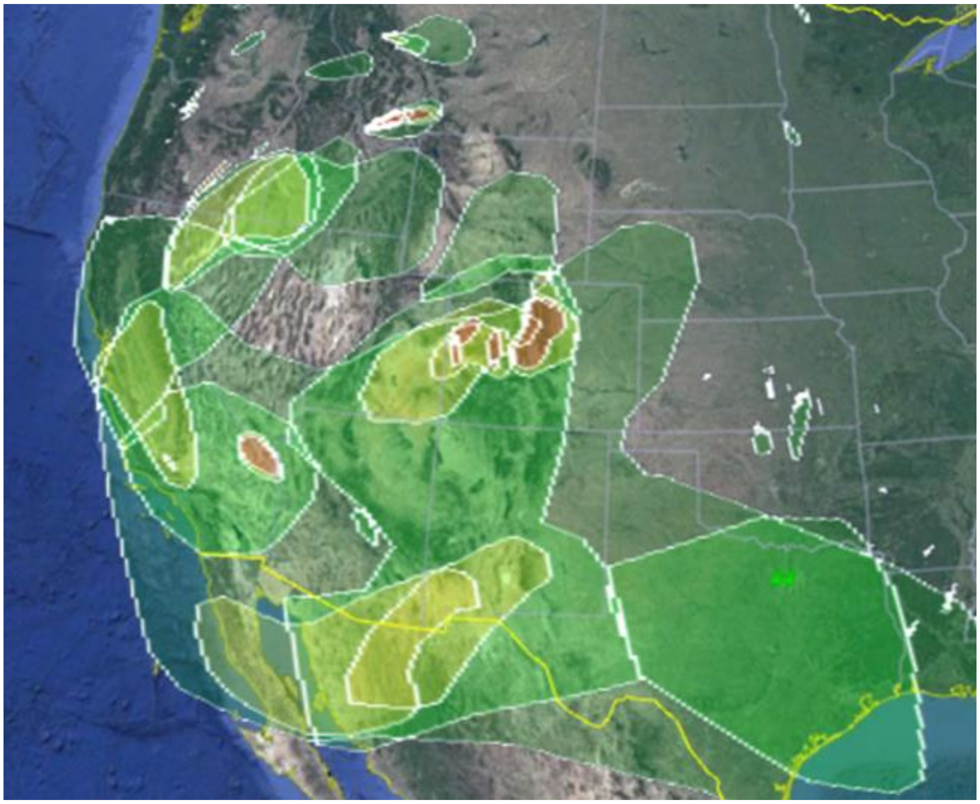

Figure 3-2: NOAA Hazard Mapping System Plume Map for August 17, 2020

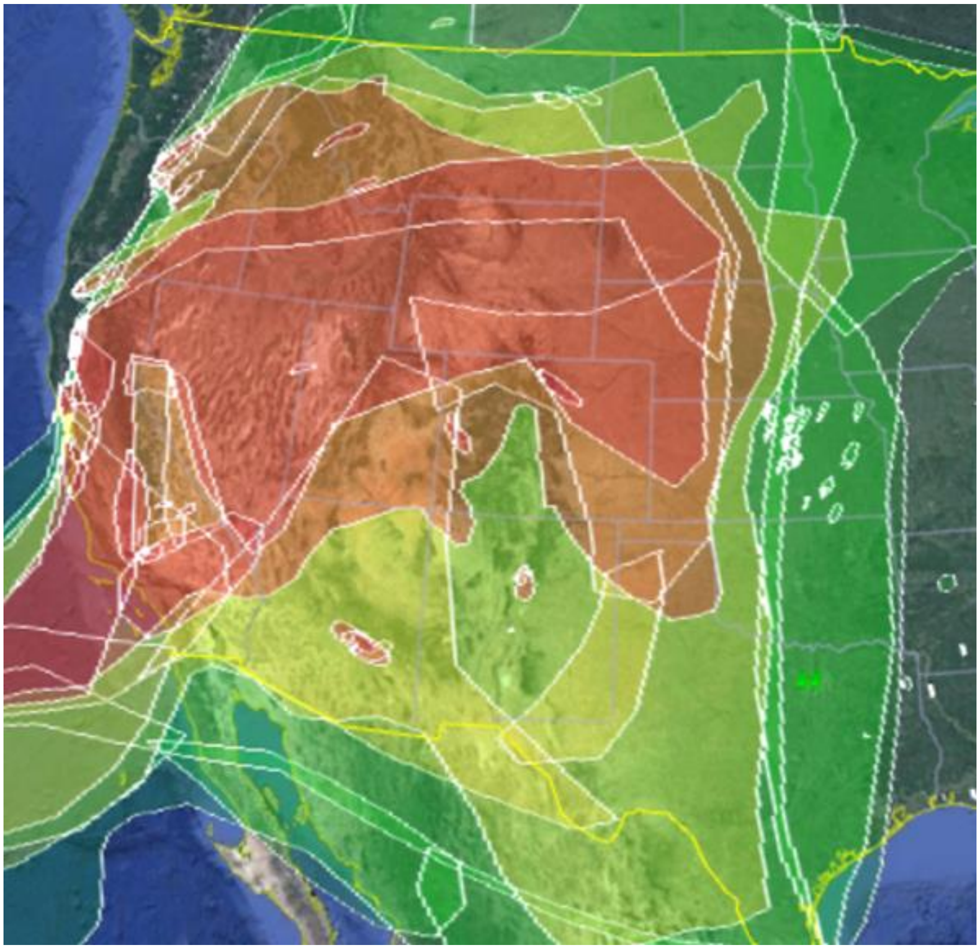

Figure 3-3: NOAA Hazard Mapping System Plume Map for August 21, 2020

3.4 TRUE COLOR SATELLITE IMAGERY SHOWS TRANSPORT TO GRAPEVINE FAIRWAY

The TCEQ used satellite imagery available through the National Aeronautics and Space Administration's (NASA) Worldview website (NASA, 2020) to analyze the transport of wildfire emissions from Colorado and California to the Grapevine Fairway monitor.

The Visible Infrared Imaging Radiometer Suite (VIIRS) instrument on the joint NASA/NOAA Suomi National Polar-orbiting Partnership (Suomi-NPP) satellite uses three wavelength bands in the visible portion of the electromagnetic spectrum (red, green, and blue) to create "true color" images of the Earth's surface. Suomi-NPP is a near-polar-orbiting satellite that provides near-daily coverage of the globe, with a single daily daytime overpass of any location.

The daily progress of smoke and emissions transported from northern Colorado wildfires to the Grapevine Fairway monitor beginning August 13, 2020 and ending August 17, 2020 is shown in Figure 3-4: *Suomi VIIRS True Color Imagery on August 13, 2020,* Figure 3-5: *Suomi VIIRS True Color Imagery on August 14, 2020, Figure 3-6: Suomi VIIRS True Color Imagery on August 15, 2020, Figure 3-7: Suomi VIIRS True Color Imagery on August 16, 2020,* and Figure 3-8: *Suomi VIIRS True Color Imagery on August 17, 2020*. With this series of images, the progress of wildfire smoke and its arrival in the DFW area on August 16 and 17, 2020 is evident. Additional information, including enlarged versions of some figures, is available at the following TCEQ webpage https://www.tceq.texas.gov/airquality/airmod/docs/ozone-data-exceptional-event-flag-demonstrations.

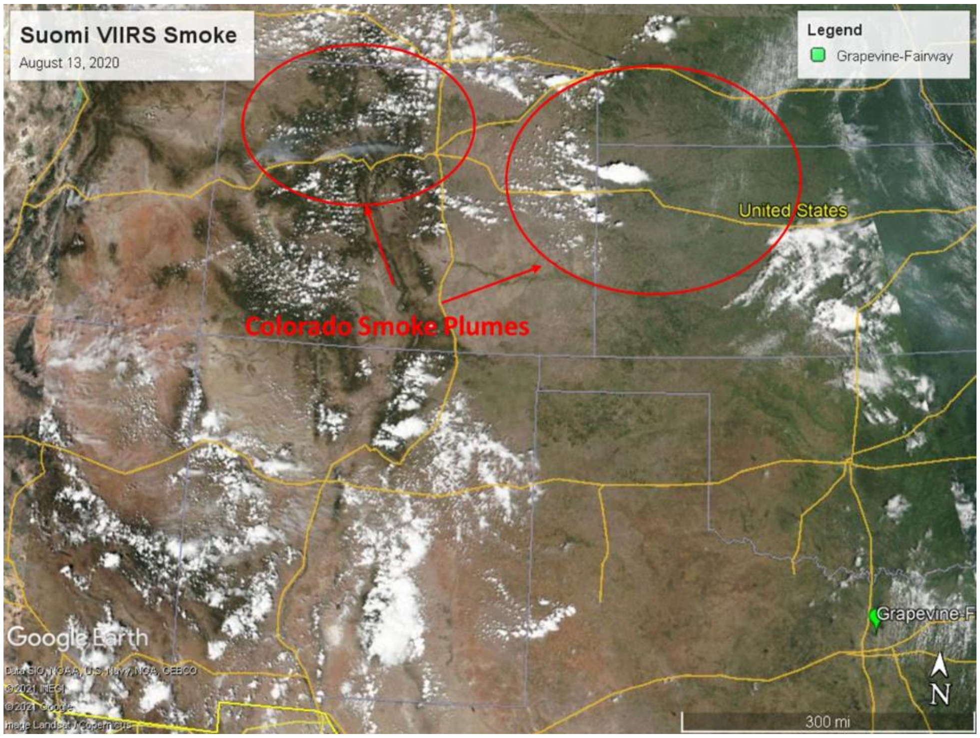

Figure 3-4: Suomi VIIRS True Color Imagery on August 13, 2020

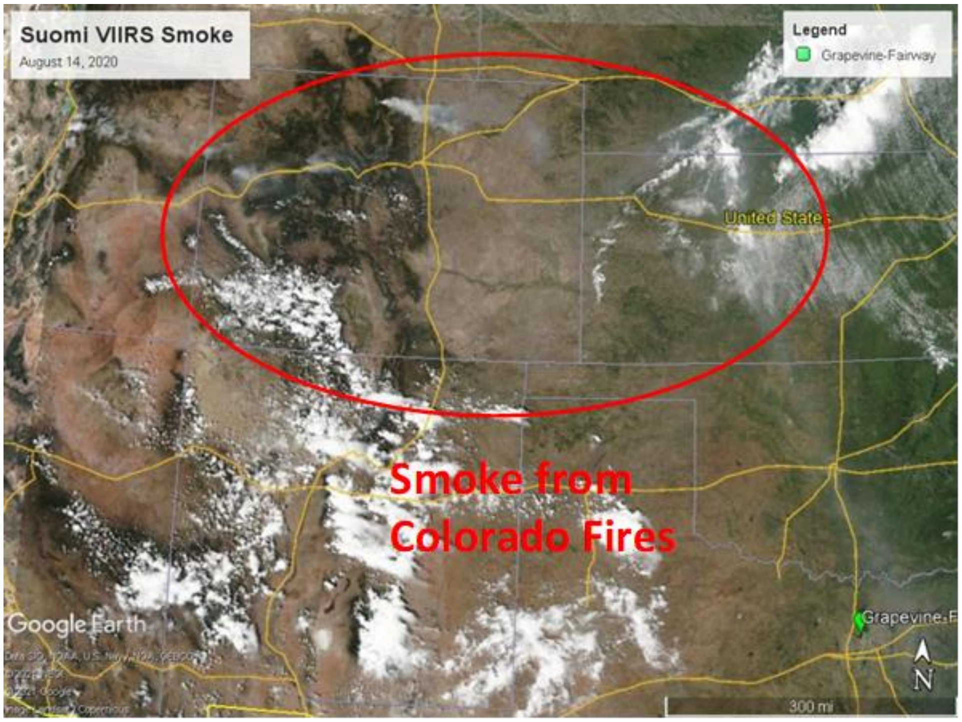

Figure 3-5: Suomi VIIRS True Color Imagery on August 14, 2020

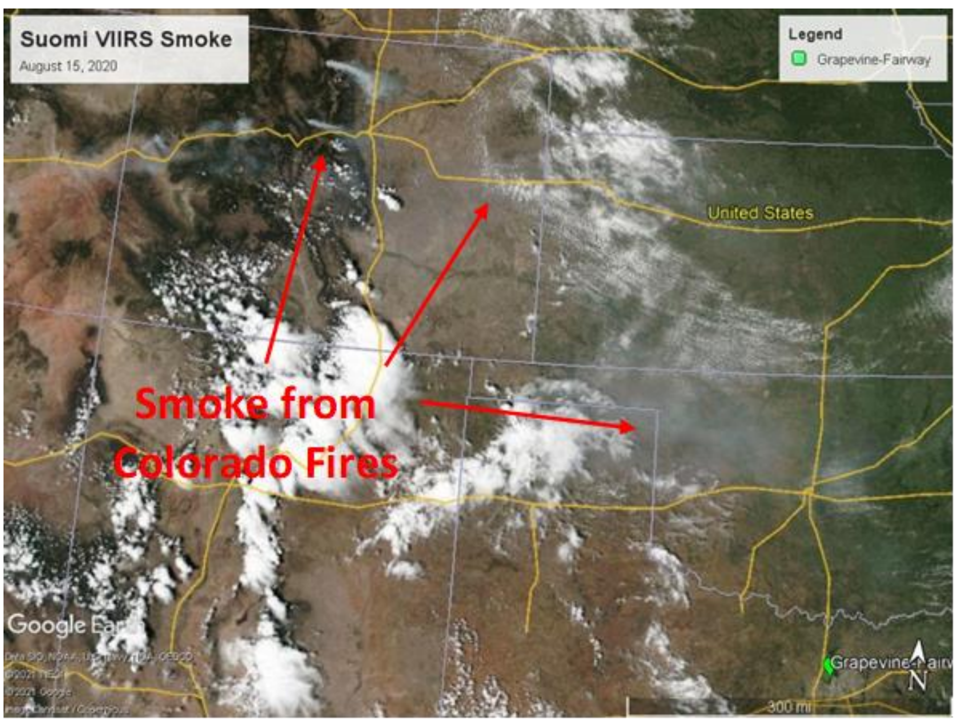

Figure 3-6: Suomi VIIRS True Color Imagery on August 15, 2020

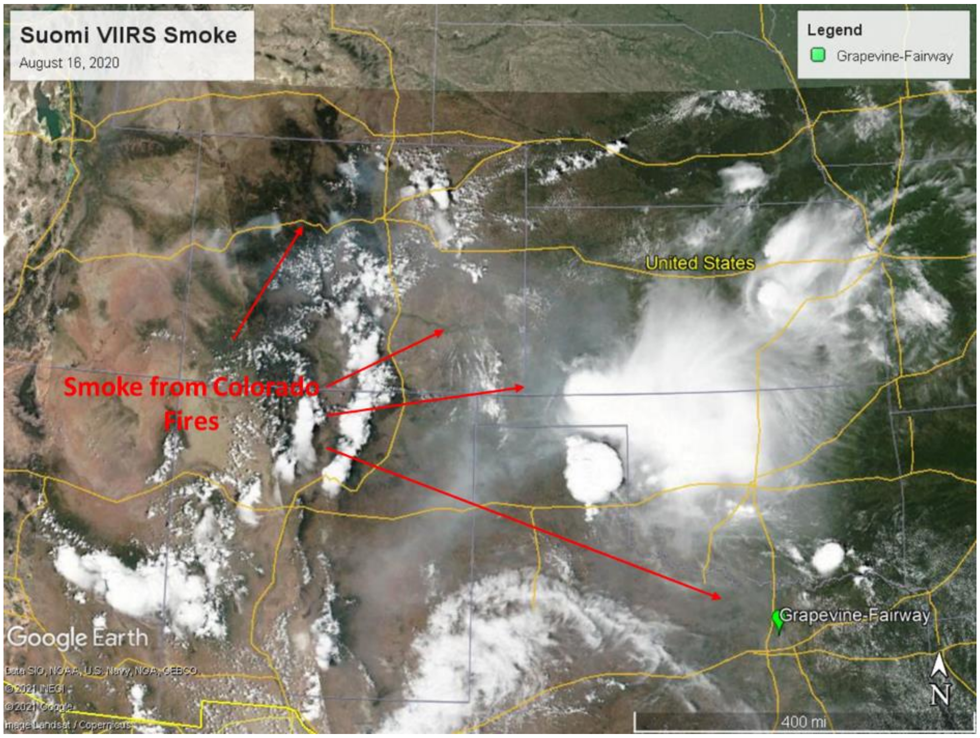

Figure 3-7: Suomi VIIRS True Color Imagery on August 16, 2020

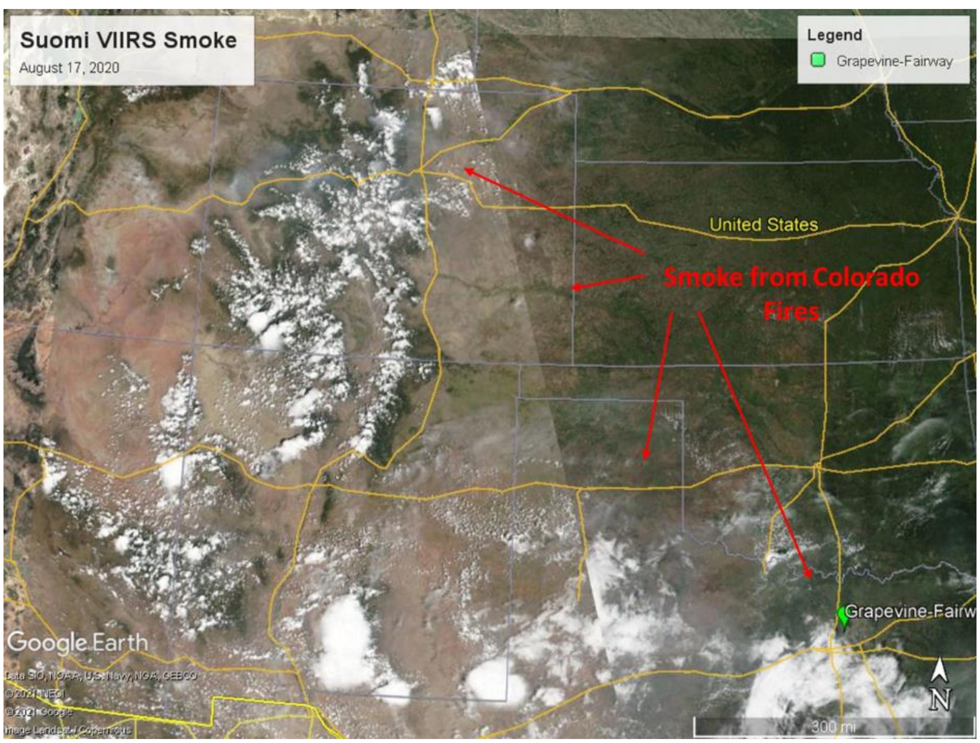

Figure 3-8: Suomi VIIRS True Color Imagery on August 17, 2020

The Terra satellite uses five instruments to observe Earth's atmosphere, ocean, land, snow and ice, and energy budget. Similar to Suomi-NPP, Terra follows a circular sun-synchronous polar orbit that takes it from north to south (on the daylight side of the

Earth) every 99 minutes. One of Terra's instruments, the Moderate Resolution Imaging Spectroradiometer (MODIS) has imaging bands very sensitive to fires. The bands can distinguish flaming from smoldering burns and provide more accurate estimates of the amounts of aerosols and gases that fires release into the atmosphere. With its 2,330-kilometer-wide imaging swath, MODIS captures every point on the earth's surface every one or two days. True color imagery from this instrument shows transport of California wildfire smoke to the Grapevine Fairway monitor in Figure 3-9: *Terra MODIS True Color Imagery on August 16, 2020,* Figure 3-10: *Terra MODIS True Color Imagery on August 17, 2020,* Figure 3-11: *Terra MODIS True Color Imagery on August 18, 2020,* Figure 3-12: *Terra MODIS True Color Imagery on August 19, 2020,* Figure 3-13: *Terra MODIS True Color Imagery on August 20, 2020,* and Figure 3-14: *Terra MODIS True Color Imagery on August 21, 2020.* Additional information, including enlarged versions of some figures, is available at the following TCEQ webpage https://www.tceq.texas.gov/airquality/airmod/docs/ozone-data-exceptional-event-flag-demonstrations.

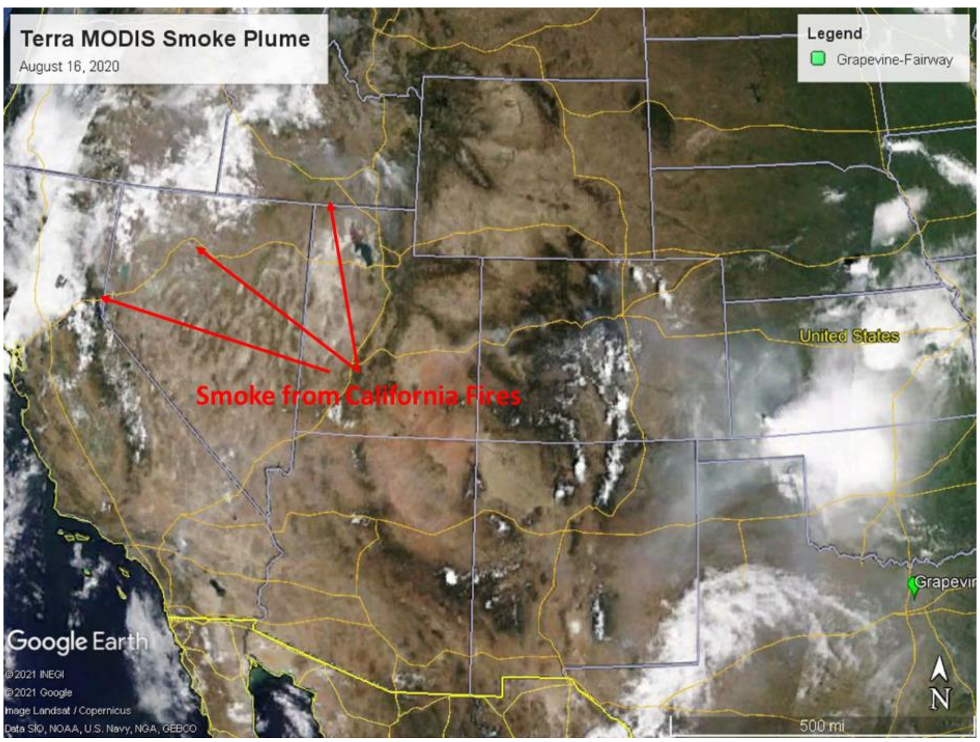

Figure 3-9: Terra MODIS True Color Imagery on August 16, 2020

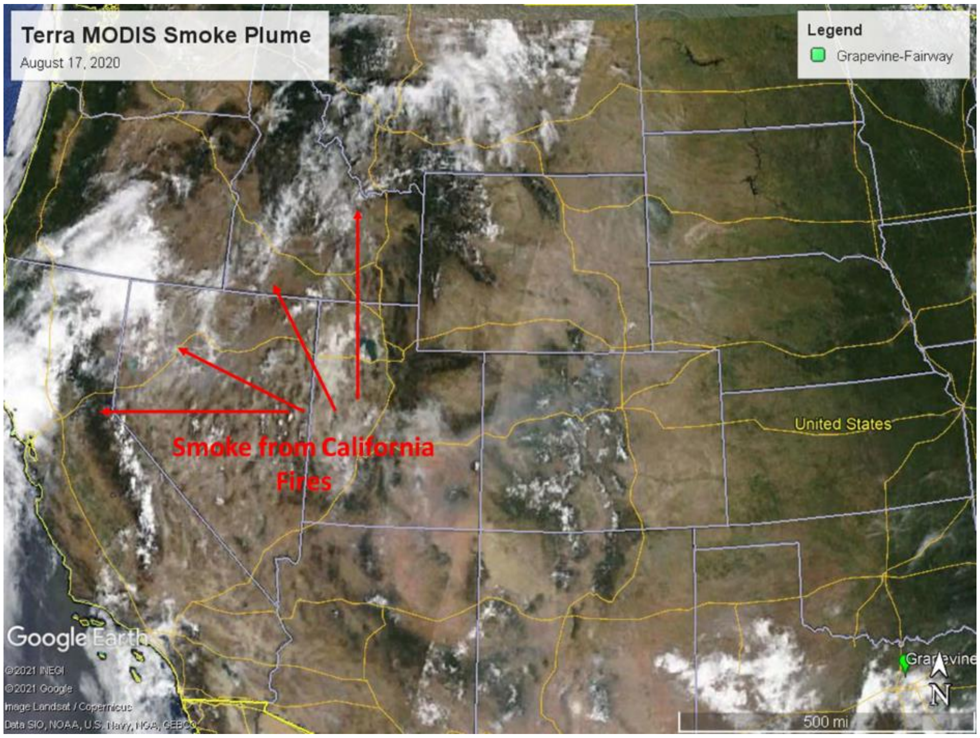

Figure 3-10: Terra MODIS True Color Imagery on August 17, 2020

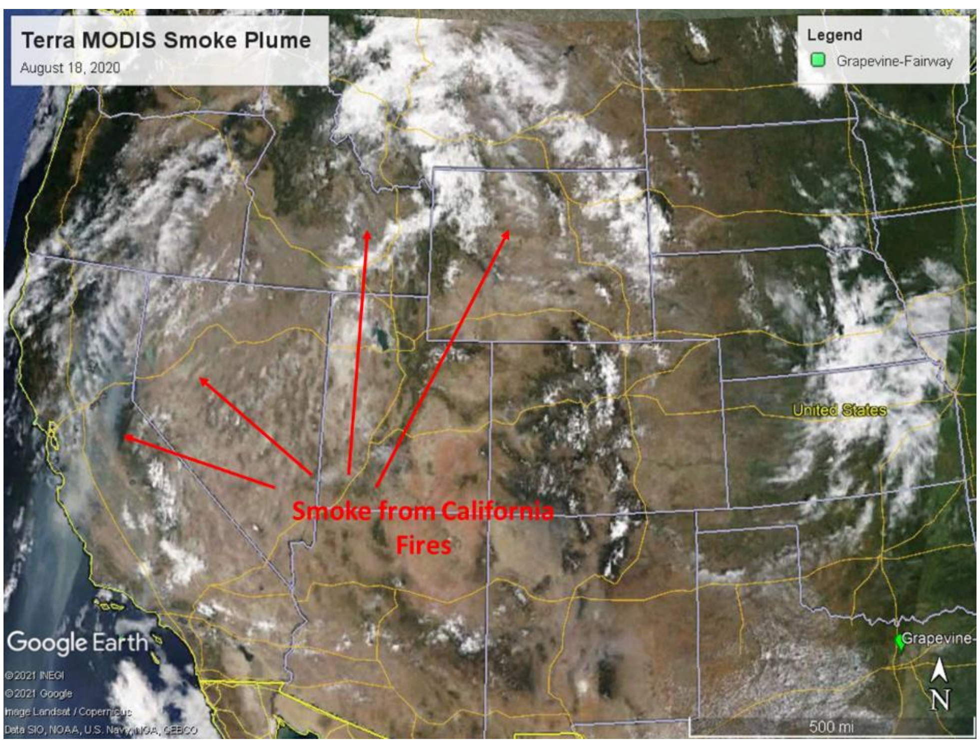

Figure 3-11: Terra MODIS True Color Imagery on August 18, 2020

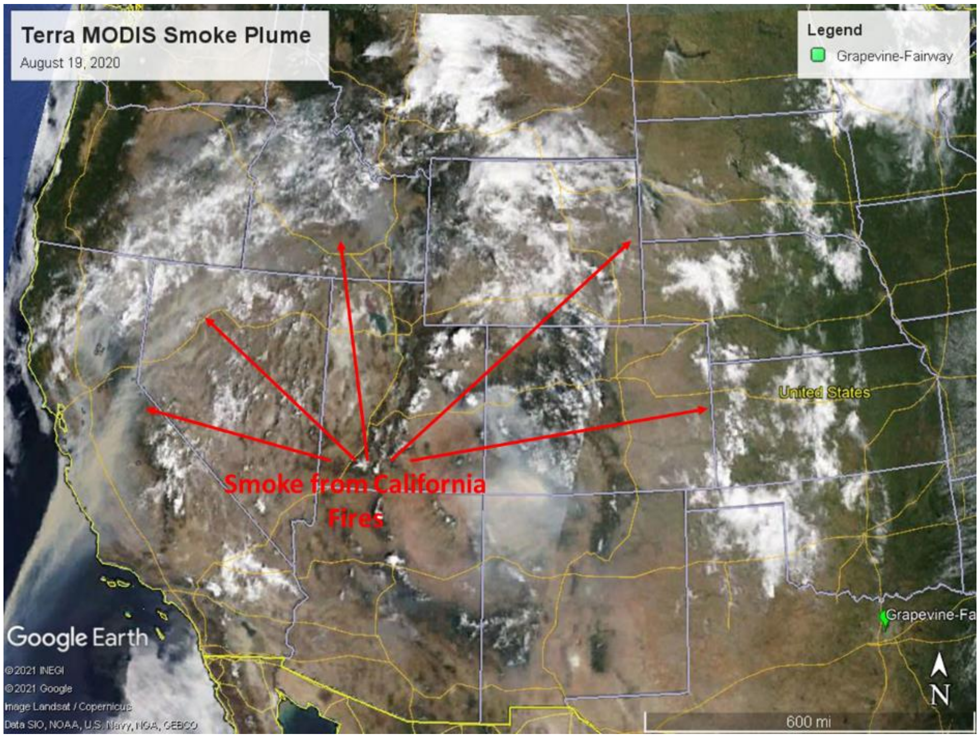

Figure 3-12: Terra MODIS True Color Imagery on August 19, 2020

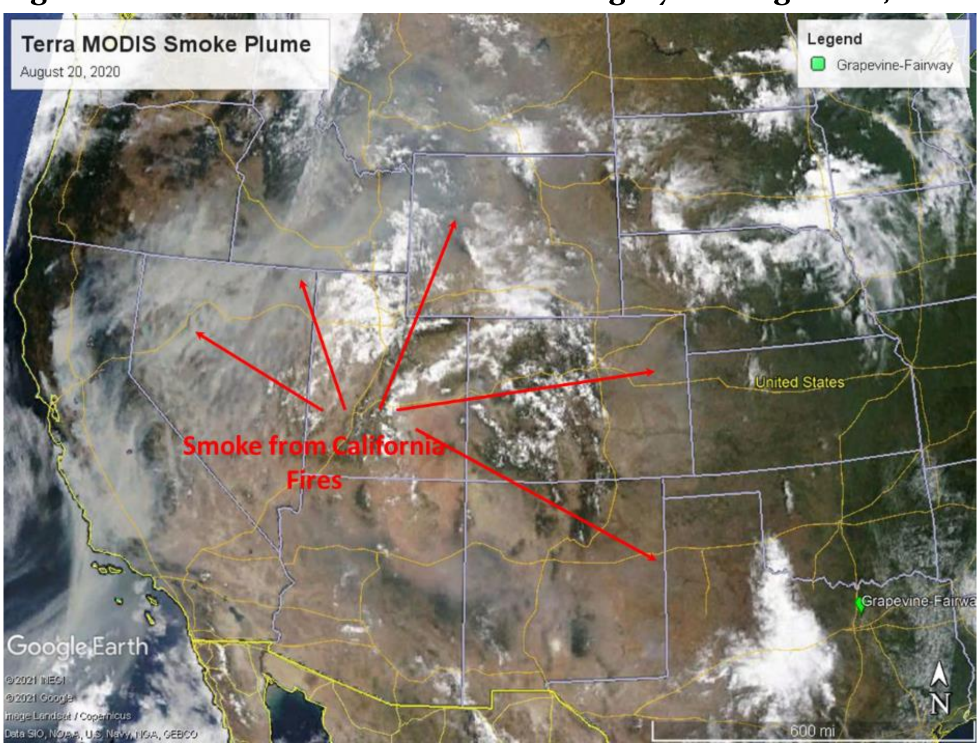

Figure 3-13: Terra MODIS True Color Imagery on August 20, 2020

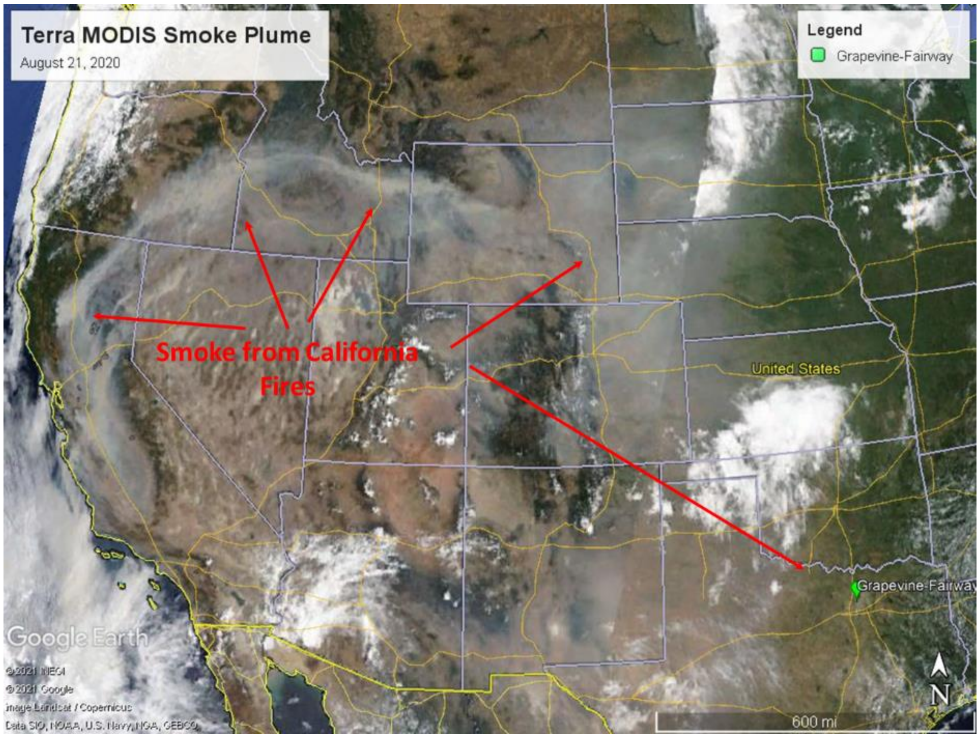

Figure 3-14: Terra MODIS True Color Imagery on August 21, 2020

3.5 AEROSOL OPTICAL DEPTH MEASUREMENTS OVER THE DALLAS-FORT WORTH AREA

Aerosol optical depth (AOD) is a unitless measure of extinction of radiation by particles in the atmosphere, such as dust, smoke, and other constituents of air pollution, known as aerosols. Aerosols are a complex mixture of many atmospheric compounds, which can have adverse human health effects when breathed. In addition, constituents in aerosols, such as nitrogen compounds (e.g., NO_2) and volatile organic compounds (VOC) can contribute to ozone formation, especially downwind of fires.

Aerosol particles block radiation by absorbing or scattering specific wavelengths. AOD can be determined remotely using instruments on the ground by observing incoming solar radiation, or satellites, by observing radiation emitted or reflected from the Earth's surface. Use of instruments to detect aerosols from a distance is referred to as "remote sensing", in contrast to methods that directly sample discrete parcels of air to determine their constituents.

One limitation of AOD is that estimation algorithms cannot retrieve values where radiation in the column is obscured ("attenuated"), such as by clouds, or where other factors such as sun glint or background noise prevent the algorithms from computing values with sufficiently low uncertainty as to be reliable. In these instances, the algorithms report no data, that is, missing values, which are indistinguishable from actual absence of aerosols. Aerosol is likely to exist at those locations, but AOD cannot be estimated.

The TCEQ obtained MODIS AOD imagery from both the Terra and Aqua satellites at NASA's Worldview website. Figure 3-15*: Terra MODIS Atmospheric Optical Depth on*

August 16, 2020, Figure 3-16: *Aqua MODIS Atmospheric Optical Depth on August 17, 2020,* and Figure 3-17: *Terra MODIS Atmospheric Optical Depth on August 21, 2020* clearly show a strong presence of aerosols in the air above the DFW area. This is another piece of evidence for the transport of wildfire emissions to the Grapevine Fairway monitor.

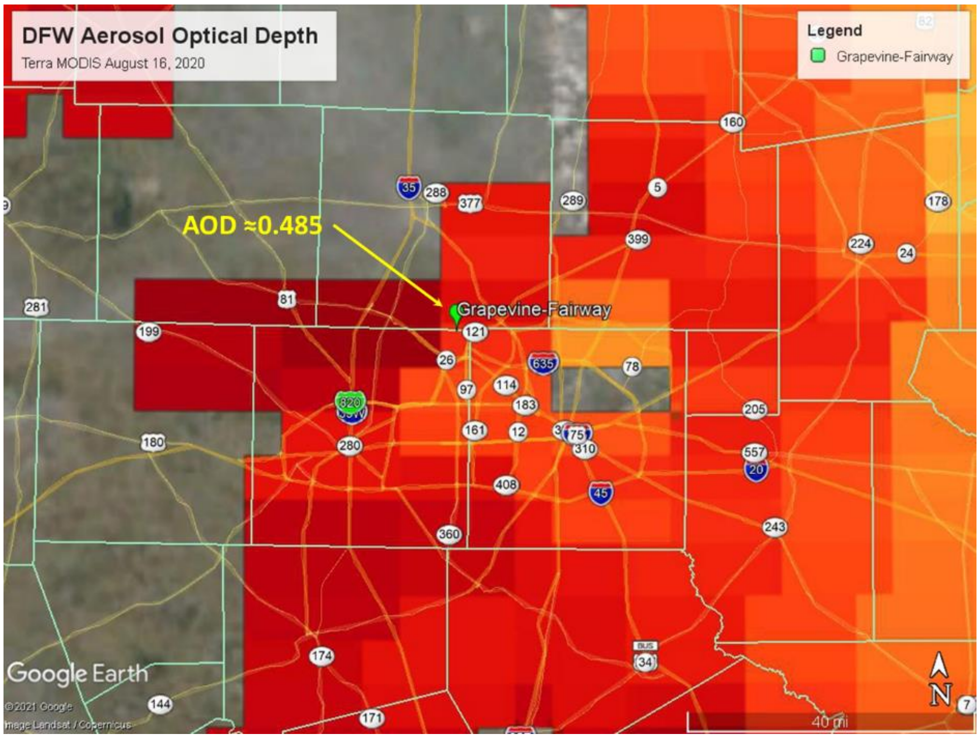

Figure 3-15: Terra MODIS Atmospheric Optical Depth on August 16, 2020

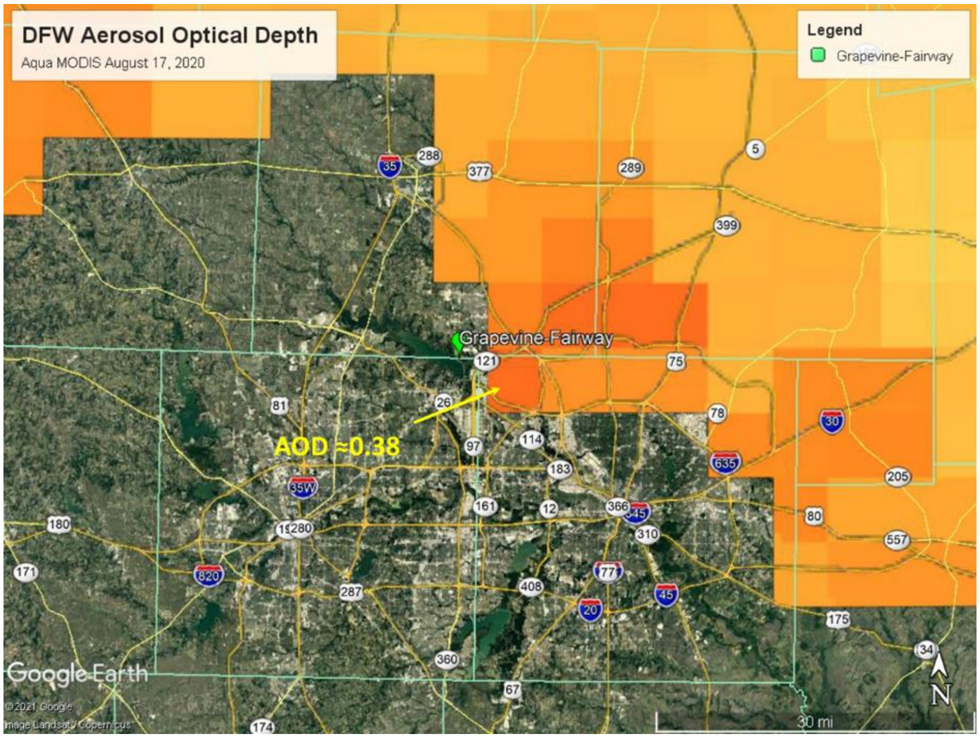

Figure 3-16: Aqua MODIS Atmospheric Optical Depth on August 17, 2020

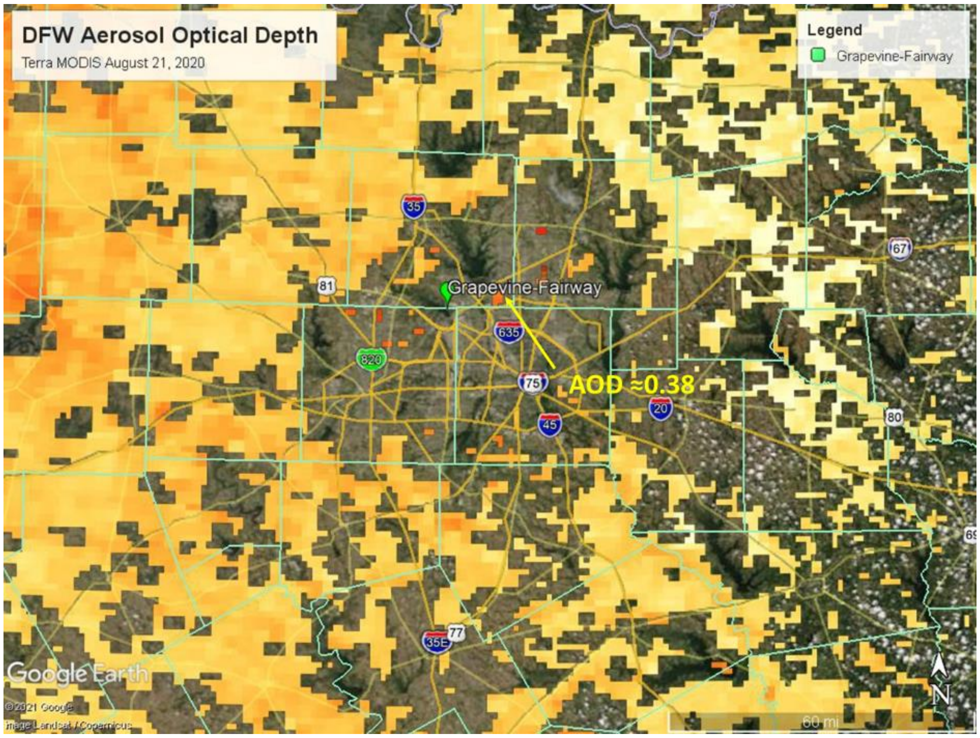

Figure 3-17: Terra MODIS Atmospheric Optical Depth on August 21, 2020

3.6 WILDFIRE EMISSIONS TRANSPORTED TO GRAPEVINE FAIRWAY

As shown by remote-sensing data presented above and trajectory analysis presented below, wildfire emissions from Colorado and California were transported to the Grapevine Fairway monitor and caused exceedances on August 16, 17, and 21, 2020.

The TCEQ generated a series of backward (in time from the Grapevine Fairway monitor towards the wildfire locations) and forward (in time from the wildfire locations towards the Grapevine Fairway monitor) air parcel trajectories that show how wildfire emissions were transported to the Grapevine Fairway monitor. The NOAA HYSPLIT (NOAA, 2020) (Stein, *et al.*, 2015) was used to compute the trajectories.

The meteorological input to HYSPLIT was a subset of model output from NOAA's North American Mesoscale Forecast System (NAM). The NAM system is a major forecast model run by NOAA's National Center for Environmental Prediction for the North American continent at several different resolutions. The subset used has a horizontal resolution of 12 kilometers (km) and comprises 26 vertical layers ranging from the surface to 50 hectopascals (hPa).

Backward trajectories from the Grapevine Fairway monitor were calculated using an option in the HYSPLIT model that allows the user to specify starting heights as a fraction of mixing height over the starting point. The TCEQ used the following fractional heights: 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.2, 1.5, and 1.8. Starting heights for forward trajectories were chosen as explicit elevations (meters) above ground level. Other information about the HYSPLIT configuration used is presented in Table 3-1: *HYSPLIT Model Information*.

Table 3-1: HYSPLIT Model Information

Model Parameter	Configuration
HYSPLIT Version	5.0.0 (April 2020)
Model Top	10,000 meters
Vertical Motion Method	Input model data
Input Meteorology	NAM 12 km

Figure 3-18: *Backward HYSPLIT Trajectories on August 16, 2020* shows 80-hour back trajectories from the Grapevine Fairway monitor to the northern part of Colorado where four significant wildfires were burning. These trajectories go back in time to 8:00 AM Central Standard Time (CST) on August 13, 2020 from 4:00 PM CST on August 16, 2020. Together with NOAA's Hazard Management System smoke plume maps shown above, it is clear that smoke and emissions from the Colorado wildfires were transported to the DFW area, and to the Grapevine Fairway monitor specifically.

Figure 3-19: *Backward HYSPLIT Trajectories on August 17, 2020* shows the same evidence of transport from Colorado wildfires to the Grapevine Fairway monitor. These trajectories, starting at 3:00 PM CST and going back to 7:00 AM CST on August 14, 2020, provide clear evidence that smoke and emissions from Colorado wildfires were transported to the DFW area and to the Grapevine Fairway monitor. The backward trajectories show wildfire smoke and emissions arriving within the mixing layer above the Grapevine Fairway monitor at approximately 90% of the mixing height.

Figure 3-20: *Backward HYSPLIT Trajectories on August 21, 2020* shows similar evidence that wildfire smoke and emissions were transported to the Grapevine Fairway monitor from northern California starting on August 16, 2020.

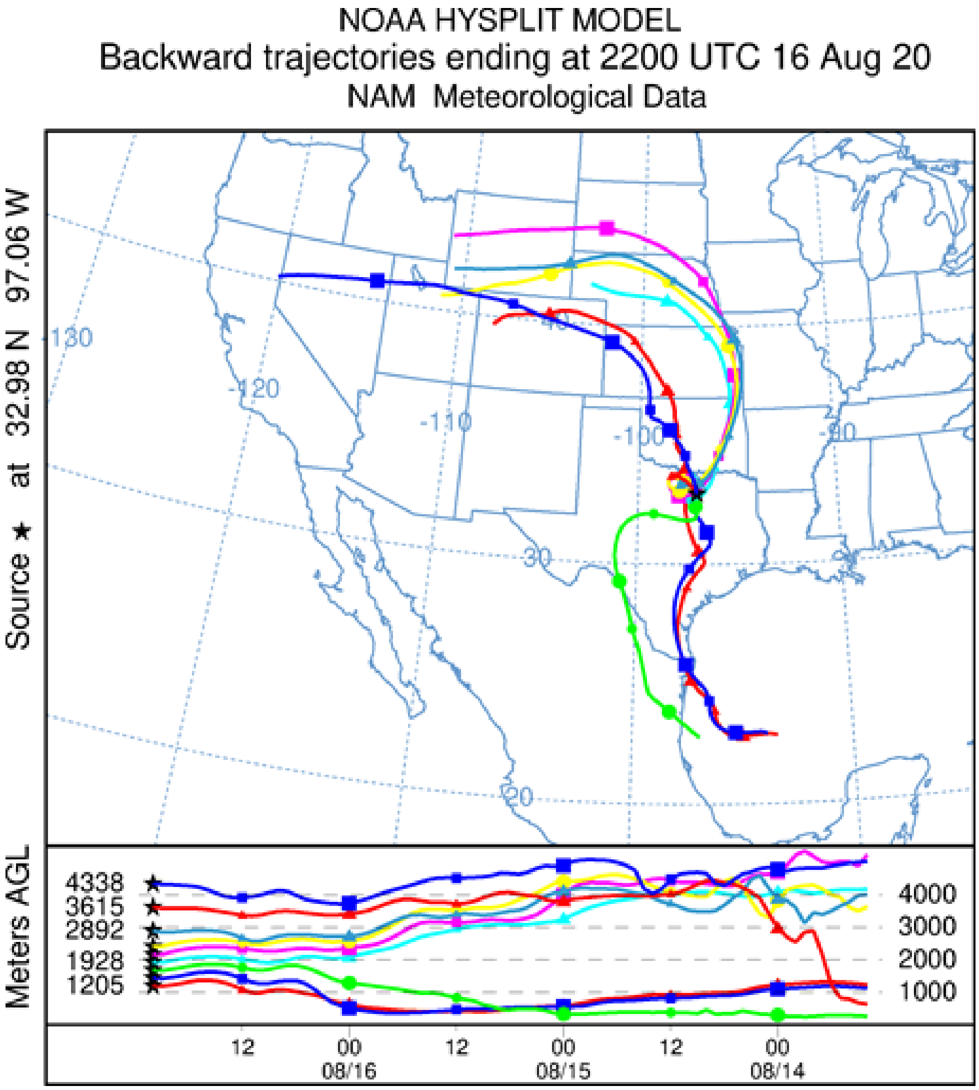

Figure 3-18: Backward HYSPLIT Trajectories on August 16, 2020

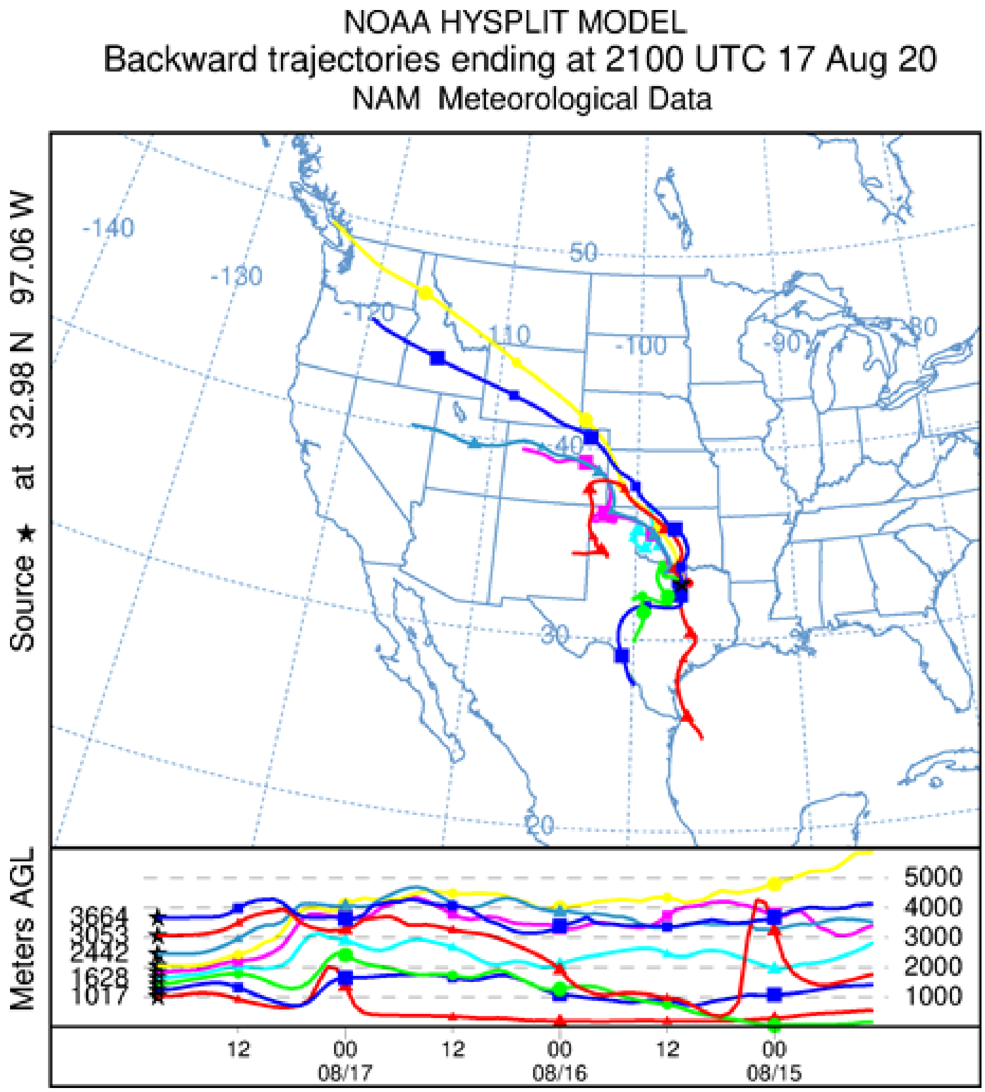

Figure 3-19: Backward HYSPLIT Trajectories on August 17, 2020

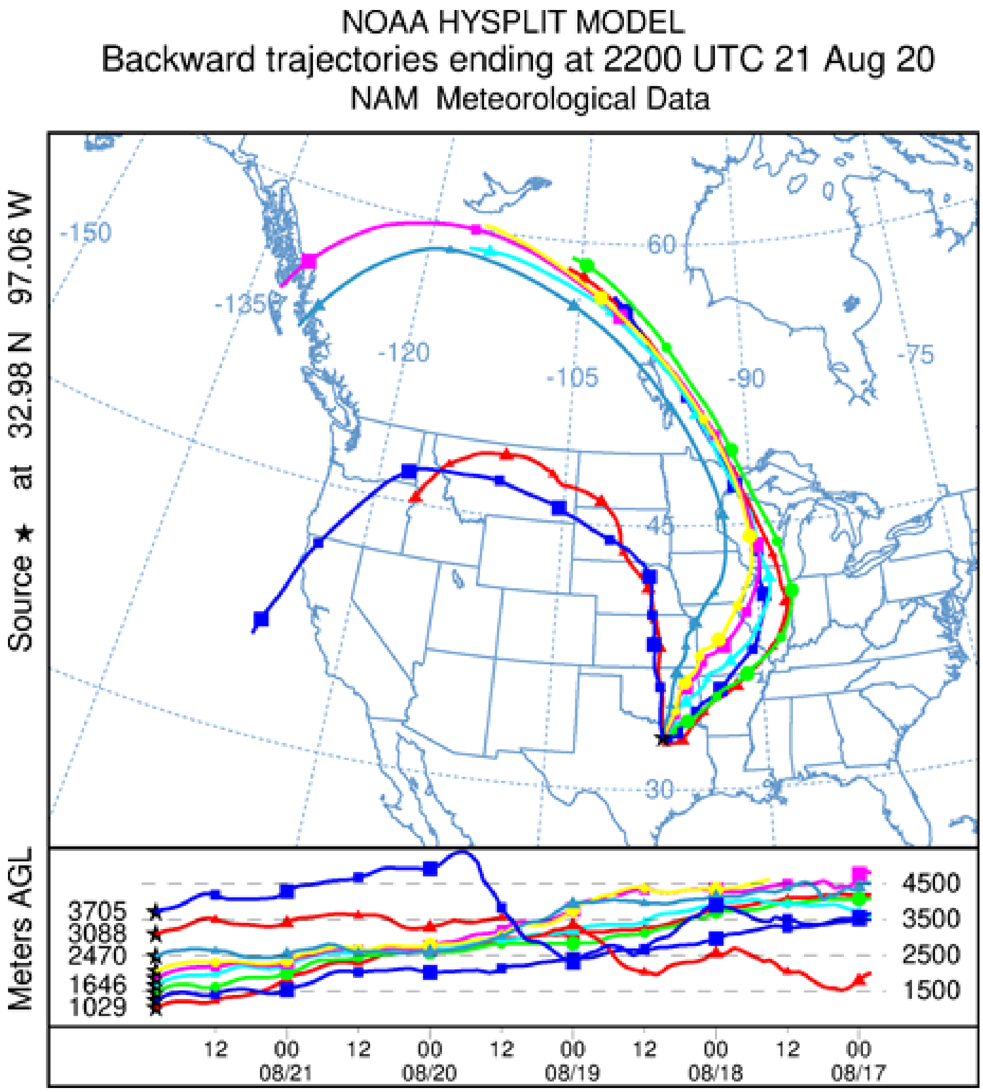

Figure 3-20: Backward HYSPLIT Trajectories on August 21, 2020

The TCEQ also created forward trajectories with the HYSPLIT model as shown in *Figure 3-21: Colorado Forward HYSPLIT Trajectories on August 13, 2020*, Figure 3-22: *Colorado Forward HYSPLIT Trajectories on August 14, 2020*, and Figure 3-23: *Northern California Forward Trajectories on August 16, 2020*. Although the forward trajectories from Colorado on August 14th and California on August 16th do not intersect with the monitor location for all heights, these trajectories support transport of fire emissions to the DFW area. As HYSPLIT trajectory time increases, so does the uncertainty in the precise path of air parcels. For this reason, these results should be interpreted as representing a central estimate of the forward trajectories. The trajectories are consistent with the backward trajectories shown above and demonstrate that wildfire emissions and smoke were transported to the Grapevine Fairway monitor. While the forward trajectories as shown on the map may not pass exactly over the Grapevine Fairway monitor, they can still indicate that air quality was affected because the plotted trajectories are a representation of the air mass and the line shown is the average path, roughly showing the central portion of the air mass. If the line shown for the trajectory is in the vicinity of the monitor, it is valuable evidence that the air quality around the monitor was affected.

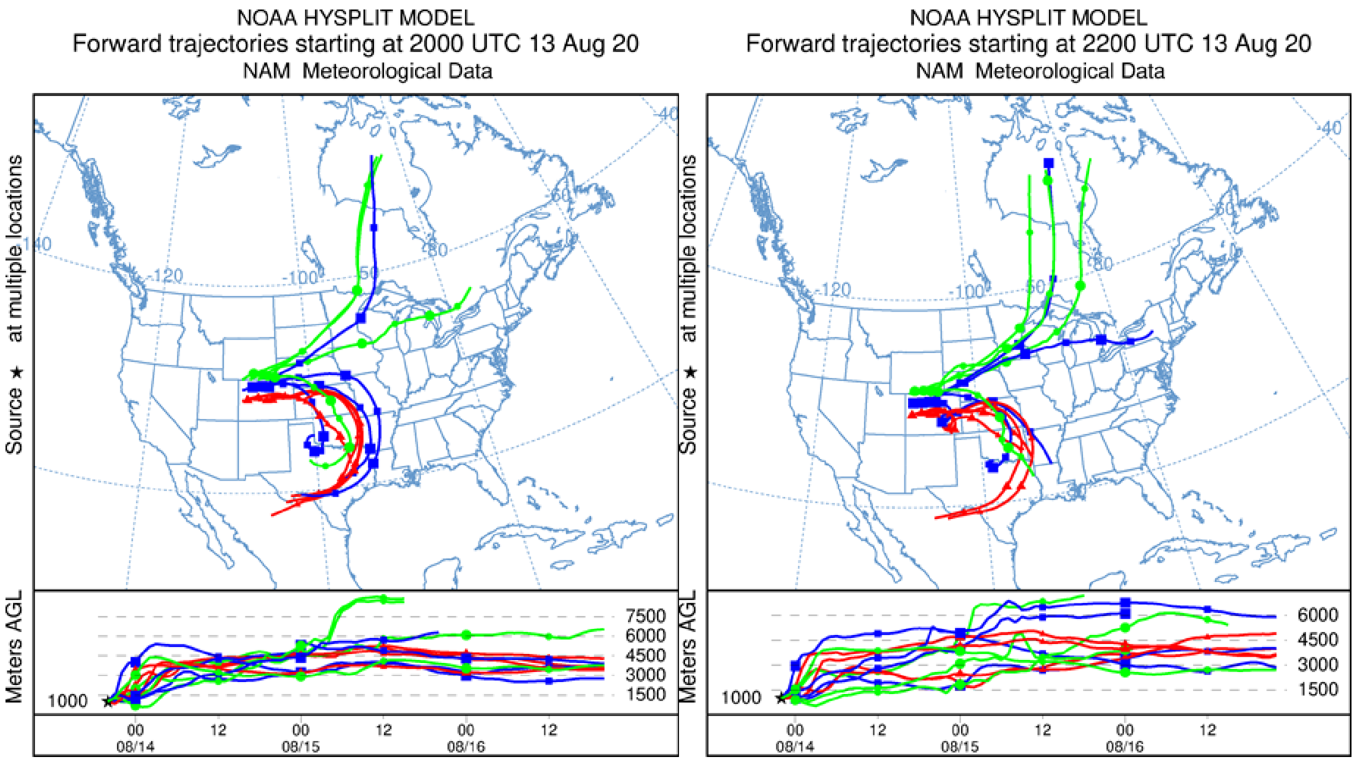

Figure 3-21: Colorado Forward HYSPLIT Trajectories on August 13, 2020

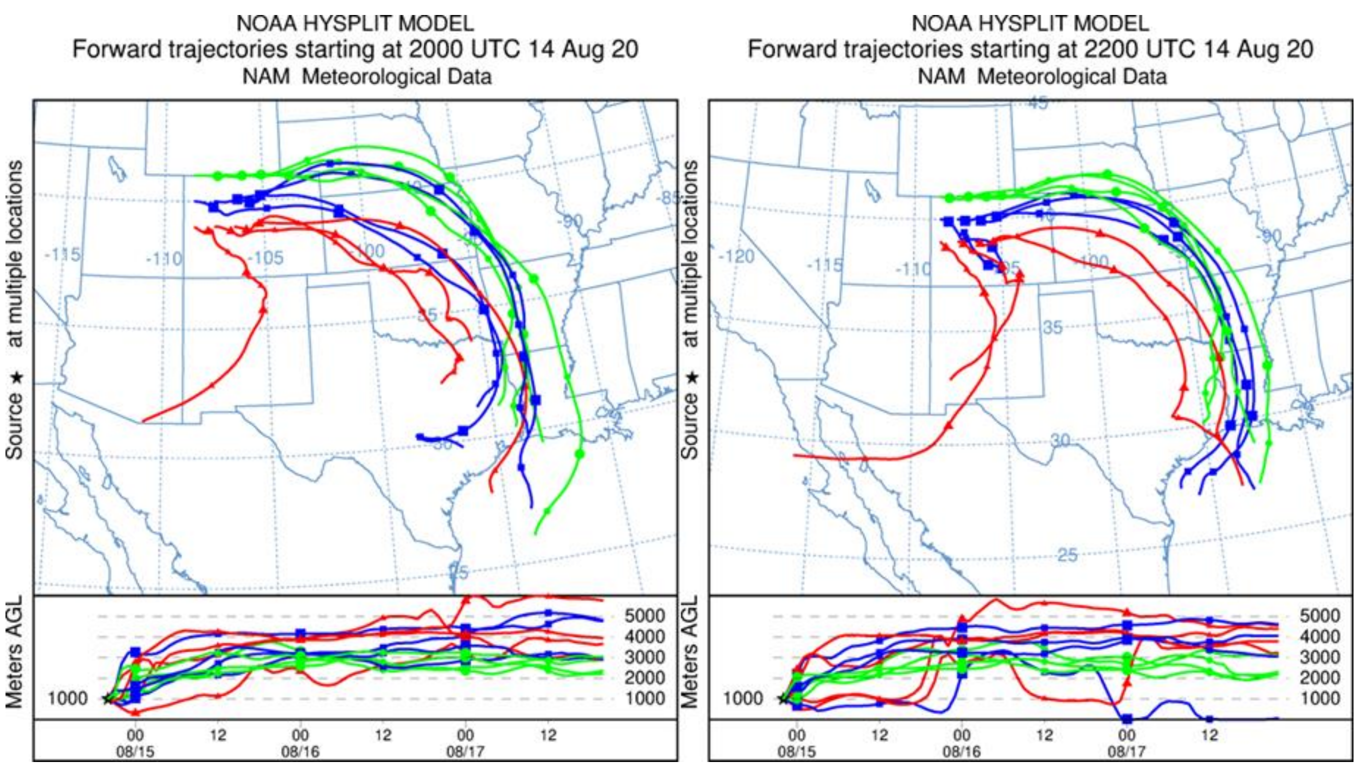

Figure 3-22: Colorado Forward HYSPLIT Trajectories on August 14, 2020

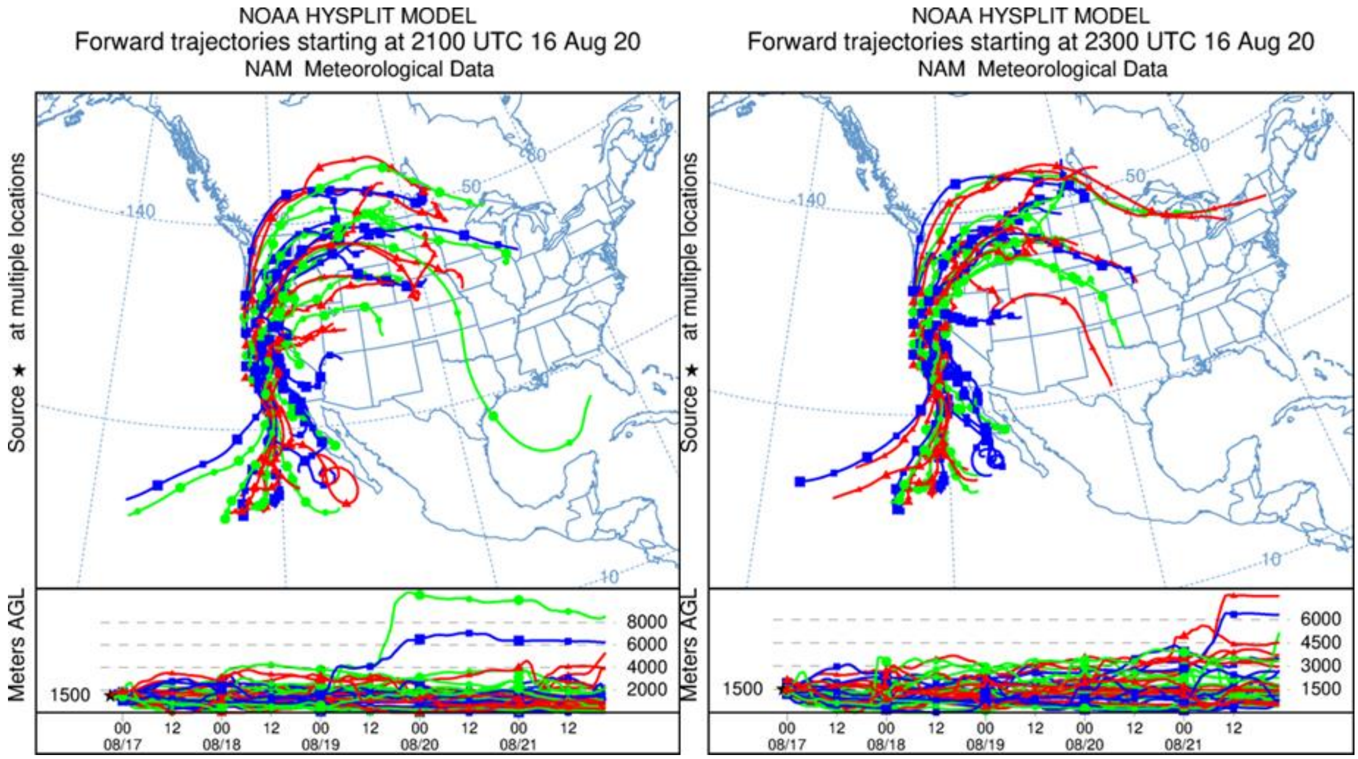

Figure 3-23: Northern California Forward Trajectories on August 16, 2020

3.7 ANALYSIS OF MEASURED POLLUTANTS

In Section 1.2 , the maximum daily eight-hour ozone concentrations on August 16 through 17, 2020 and August 21, 2020 were demonstrated to be above the Grapevine Fairway monitor's historical 99th percentile. This section presents additional supporting evidence for ozone and other pollutants.

3.7.1 The Regional Effect of Wildfire Emissions

The EPA Exceptional Event Rule (EER) requires states that submit demonstrations to compare ozone measurements on candidate exceptional event days to historical measurements to obtain the percentile of the candidate measurements over the historical period. To assess how widely wildfire emissions affected the DFW area, the TCEQ expanded this historical comparison to include all 20 regulatory ozone monitors across the region.

For each day from January 1, 2016 through December 31, 2020, the TCEQ evaluated how many sites reported a maximum daily eight-hour ozone at or above the 95th percentile for that site. It is uncommon for large numbers of monitoring sites across an area to measure ozone values above their respective 95th percentile. This metric provides an indicator of how widespread the impact of wildfire emissions was because exceedances of the 95th percentile across multiple monitors are rare.

Table 3-2: *Dallas-Fort Worth Area Monitoring Sites Above the 95th Percentile*, shows the results of this analysis. On August 16, 2020, four monitoring sites measured ozone concentrations above their 95th percentile. Because almost 90% of all days had three or fewer monitors measuring ozone above the 95th percentile, August 16, 2020 is in the top 10% of all days for this historical period. On August 17, 2020, 16 monitoring sites measured ozone concentrations above the 95th percentile. There were only 22 days (out of a total 1827) over this historical period that had more than 15 monitors measuring more than the 95th percentile. This means that August 17, 2020 was in the top one percent of all days for the entire DFW area. On August 21, 2020, 12 monitoring sites measured ozone concentrations above the 95th percentile places above the 97th percentile for all days in this period.

Table 3-2: Dallas-Fort Worth Area Monitoring Sites Above the 95th Percentile

Number of Monitors	Days Above 95th Percentile	Percentage	Cumulative Percentage
0	1499	82.05%	82.05%
1	60	3.28%	85.33%
2	44	2.41%	87.74%
3	33	1.81%	89.55%
4	32	1.75%	91.30%
5	29	1.59%	92.88%
6	19	1.04%	93.92%
7	20	1.09%	95.02%
8	9	0.49%	95.51%
9	14	0.77%	96.28%
10	12	0.66%	96.93%
11	7	0.38%	97.32%
12	8	0.44%	97.76%
13	5	0.27%	98.03%
14	7	0.38%	98.41%
15	7	0.38%	98.80%
16	4	0.22%	99.01%
17	7	0.38%	99.40%
18	5	0.27%	99.67%
19	2	0.11%	99.78%
20	4	0.22%	100.00%
Total Days	1827	100.00%	

As plumes travel, they tend to disperse, so the fact that many air quality monitors are influenced in the DFW area is consistent with what would be expected when wildfire emissions have transported over a long distance (Jaffe *et al.*, 2020). Figure 3-24: *Monitoring Sites Above Their 95th Percentile on August 16, 2020* shows four monitoring sites on August 16, 2020 with measurements above their 95th percentile. These four monitoring sites are widely distributed from Granbury in the far southwest corner of the DFW area to Frisco in the northeast. Figure 3-25: *Monitoring Sites Above Their 95th Percentile on August 17, 2020* shows how widespread the effects of wildfire emissions are on August 17, 2020. The historically high values at the Italy and Kaufman monitoring sites to the South and Southeast of the DFW area are particularly important because they are located upwind of the DFW area, where they would not be affected by a typical high ozone day in DFW. Figure 3-26: *Monitoring Sites Above Their 95th Percentile on August 21, 2020* also shows the widespread nature of the historically high ozone values measured on August 21, 2020.

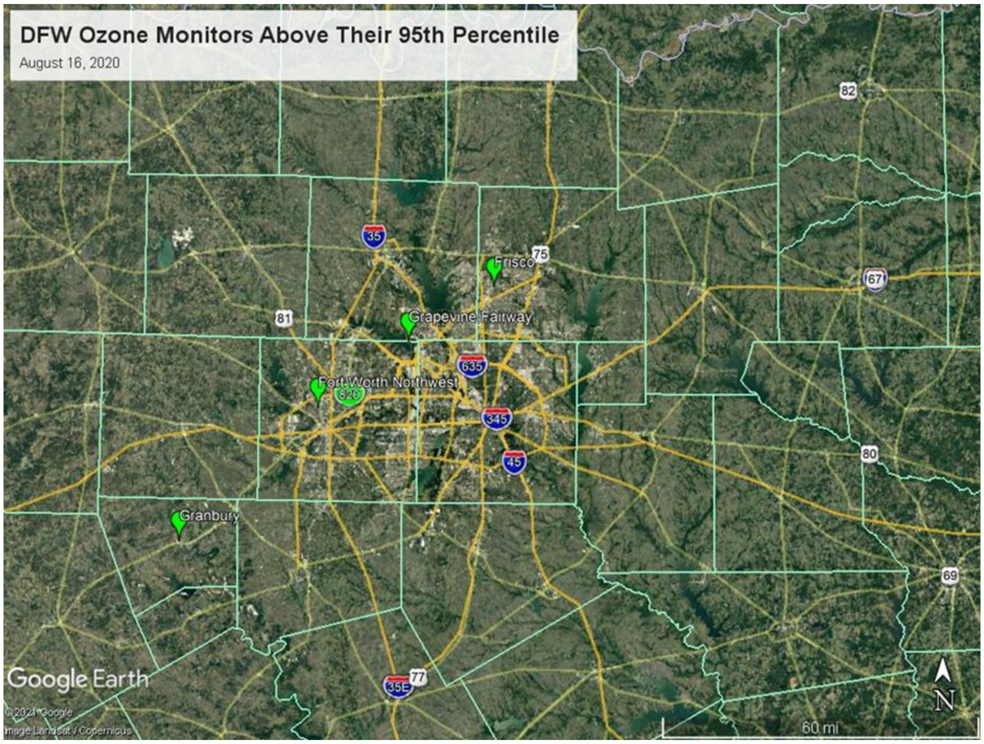

Figure 3-24: Monitoring Sites Above Their 95th Percentile on August 16, 2020

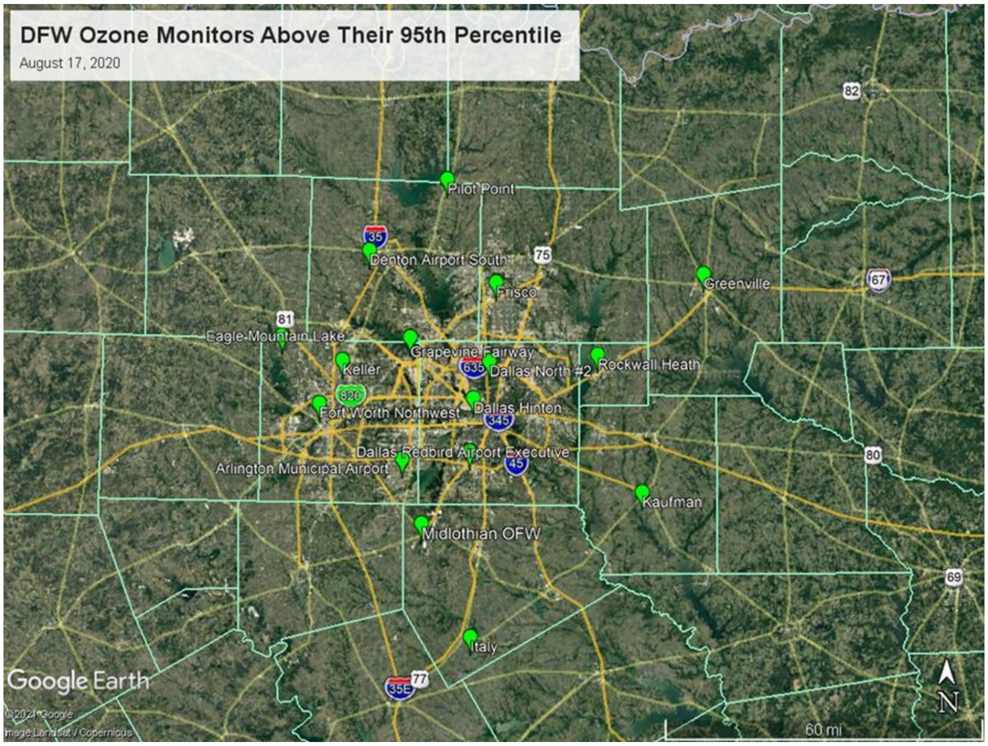

Figure 3-25: Monitoring Sites Above Their 95th Percentile on August 17, 2020

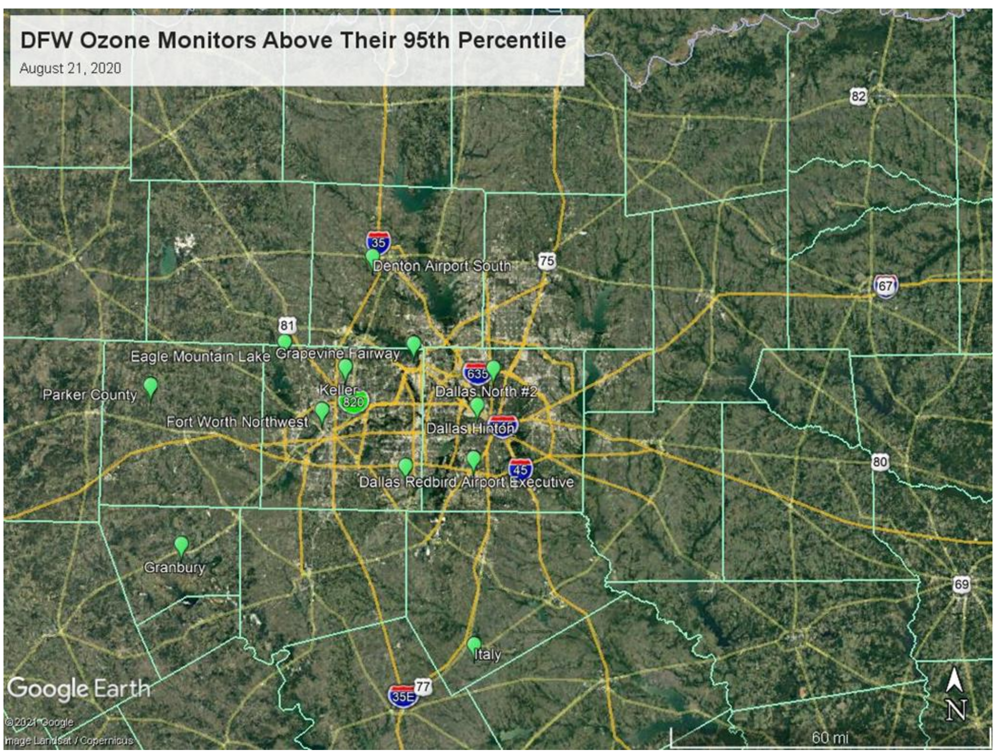

Figure 3-26: Monitoring Sites Above Their 95th Percentile on August 21, 2020

3.7.2 Analysis of Data from the Dallas Hinton Monitor

Located northwest of downtown Dallas, the Dallas Hinton monitor is designated as a Photochemical Assessment Monitoring Station (PAMS) and Chemical Speciation Network monitoring site. Instruments at this monitoring site collect data for a variety of meteorological and pollutant parameters including ozone, NO_X, reactive oxides of nitrogen (NO_y), fine particulate matter less than or equal to 2.5 microns in diameter ($PM_{2.5}$), carbon monoxide (CO), and VOCs.

3.7.2.1 Analysis of Speciated Fine Particulate Matter Data

The TCEQ collects speciated $PM_{2.5}$ data at the Dallas Hinton monitor as part of the EPA's Chemical Speciation Network. The monitoring site collects 24-hour samples every three days. The organic carbon species is frequently associated with biomass burning and can be used as an indicator of wildfire emissions/smoke affecting a monitoring site. Figure 3-27: *Grapevine Fairway Ozone and Organic Carbon August 10 - 25, 2020* comparing organic carbon samples from the Dallas Hinton monitor in mid-August with maximum daily eight-hour ozone averages at the Grapevine Fairway monitor reveals a strong positive correspondence between two pollutants. This association between ozone and organic carbon suggests the two are related to one another and caused by biomass burning.

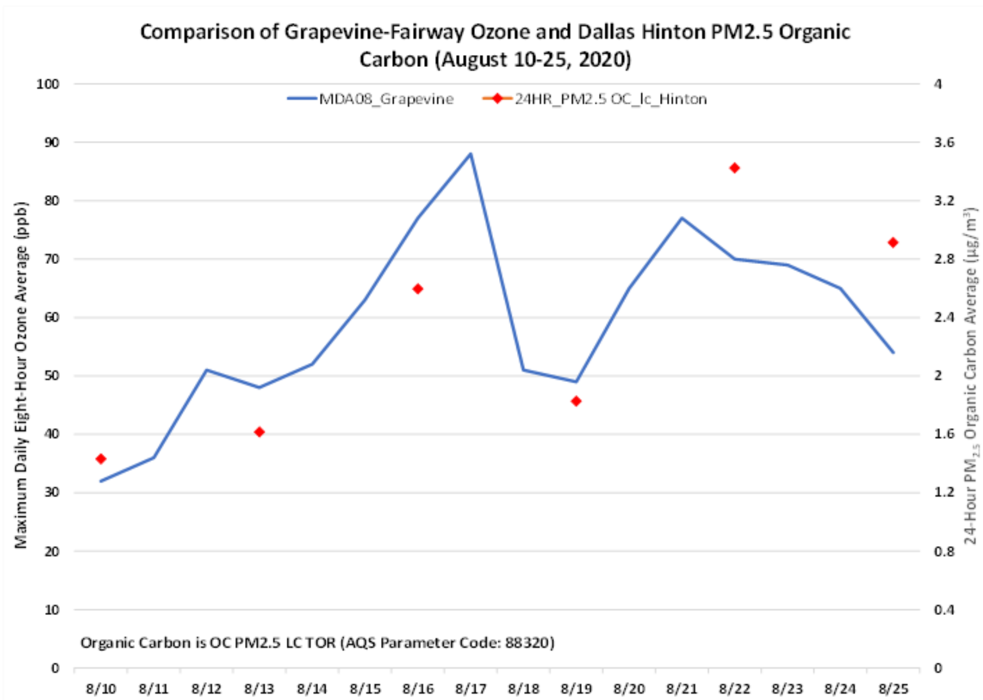

Figure 3-27: Grapevine Fairway Ozone and Organic Carbon August 10 - 25, 2020

3.7.2.2 Fine Particulate Matter and Carbon Monoxide Enhancement Ratios

Laing, *et al.* (2017) conclude that $\Delta PM_{2.5}/\Delta CO$ normalized enhancement ratios (NER) can be appropriately used to indicate the presence of smoke (as opposed to vehicle exhaust) in urban areas. During a wildfire event, where ambient concentrations of pollutants (X and Y) increase significantly above background levels, NERs "relate the excess concentrations of target species X with that of a reference species Y" (Laing *et* *al*., 2017). Looking at 25 wildfire events, they found that $\Delta PM_{2.5}/\Delta CO$ normalized enhancement ratios ranged from 0.057 – 0.228 $\mu gm^{-3}ppbv^{-1}$ (Laing *et al*., 2017). In contrast, "$PM_{2.5}/CO$ ratios from measurements near major highways and urban background range from 0.021 to 0.045 $\mu gm^{-3}ppbv^{-1}$." (Laing *et al*., 2017). The TCEQ performed this analysis for all three candidate days using daytime hours from 10:00 AM to 7:00 PM CST (hours 10 through 18). The results of this analysis are shown in Table 3-3: *Results of ΔPM2.5/ΔCO Normalized Enhancement Ratio Analysis*. The results for August 17, 2020 demonstrate that the air measured at the Dallas Hinton monitor is inconsistent with emissions originating in a mobile source dominated urban area. Combined with the lack of local fires, this analysis provides a strong indication that wildfire emissions affected air quality in the DFW area that day.

Table 3-3: Results of ΔPM2.5/ΔCO Normalized Enhancement Ratio Analysis

Date	Slope (NER)	Y-Intercept	R^2	Significant?
August 16, 2020	-.1637	29.43	0.2354	No
August 17, 2020	.0798	-3.36	0.8298	Yes
August 21, 2020	.0185	-9.48	0.0009	No

3.8 MATCHING DAY ANALYSIS

Ozone formation and transport depend greatly on meteorology. Consequently, a comparison of ozone meteorologically similar days with and without fire impacts can support a clear causal relationship between wildfires and monitored ozone concentrations. Because days with similar meteorology and seasonality usually have similar ozone concentrations, large differences in measured ozone concentrations with similar meteorology indicate influences from non-typical sources.

A typical approach to a "Matching Day" analysis involves meteorological parameters that strongly affect ozone concentrations near the monitor location. The parameters should be matched to the candidate day(s) within an appropriate tolerance. Matching days are usually chosen from a similar time of year as the candidate day(s). The EPA (U.S. EPA, 2016a, p. 27) notes that "A similar day analysis of this type, when combined with a comparison of the qualitative description of the synoptic scale weather pattern (e.g., cold front location, high pressure system location), can show that the fire contributed to the elevated ozone concentrations."

In undertaking its matching day analysis, the TCEQ chose to compare days according to synoptic conditions, backward trajectories, and the following parameters:

- average morning resultant wind speed (mph) and direction (˚from North). Vector components of resultant wind speed and direction are averaged for the 7:00 AM through the 10:00 AM hours Central Standard Time (CST);
- average afternoon resultant wind speed (mph) and direction (˚from North); Vector components of resultant wind speed and direction are averaged for the 1:00 PM through the 4:00 PM hours Central Standard Time (CST);
- daily Maximum Temperature (˚F). The maximum hourly average temperature for each day;
- daily Maximum Solar Radiation (Langley/minute). The maximum hourly solar radiation measurement for each day;
- average Relative Humidity (%). The average of all hourly relative humidity measurements for each day;

- morning geopotential height (meters) and temperature (˚K) at the 850 millibar pressure level. Taken from daily 1200 UTC rawinsonde launches at the Fort Worth launch site; and
- morning geopotential height (meters) and temperature (˚K) at the 7000 millibar pressure level. Taken from daily 1200 UTC rawinsonde launches at the Fort Worth launch site.

3.8.1 August 16, 2020

In reviewing information for August 16, 2020, the TCEQ identified a meteorologically similar day without smoke effects. On September 12, 2017, the Grapevine Fairway monitor measured a maximum daily eight-hour ozone average of 70 parts per billion (ppb) and had no smoke plumes overhead. Table 3-4: *Meteorological Matching Parameters for August 16, 2020* shows the similarities of individual parameters. September 12, 2017 occurs at the same time of year as August 17 and shares many of the same general characteristics.

Table 3-4: Meteorological Matching Parameters for August 16, 2020

Meteorological Parameter	August 16, 2020	September 12, 2017
Maximum Daily 8-hour O_3 Average (ppb)	77	70
Average Resultant Wind Direction AM (hours 7-10)	143	173
Average Resultant Wind Speed AM (hours 7-10) (mph)	2.6	1.9
Average Resultant Wind Direction PM (hours 13-16)	204	173
Average Resultant Wind Speed PM (hours 13-16) (mph)	2	1
Maximum Temperature (˚F)	101.9	91.4
Maximum Solar Radiation (Langley/minute)	1.1975	1.1592
Average Relative Humidity (%) (24-hour)	55.38	55.98
850mb Height (m)	1,563	1,552
850mb Temperature (˚K)	296.7	291.6
700mb Height (m)	3,229	3,189
700mb Temperature (˚K)	285.6	282.7

Figure 3-28: *Backward Trajectories from the Grapevine Fairway monitor on August 16, 2020, and September 2, 2017* compares backward HYSPLIT trajectories initiated from the Grapevine Fairway monitor at the hour of maximum one-hour ozone on August 16, 2020 (left) to September 2, 2017 (right). The back trajectories are released at five heights equivalent to fractions of the mixing height: 50%, 100%, 120%, 150%, and 180%. Higher trajectories on both days all approach from the north and west of the Grapevine Fairway monitor, indicating the influence of substantially similar synoptic conditions. This conclusion is confirmed by the NOAA (2003) Surface and 500-Millibar Weather Charts in Figure 3-29: *Surface Weather Chart for August 16, 2020*, Figure 3-30: *Surface Weather Chart for September 2, 2017*, Figure 3-31*: 500-Millibar Weather Chart*

for August 16, 2020, and Figure 3-32*: 500-Millibar Weather Chart for September 2, 2017* which show the larger scale meteorological similarities.

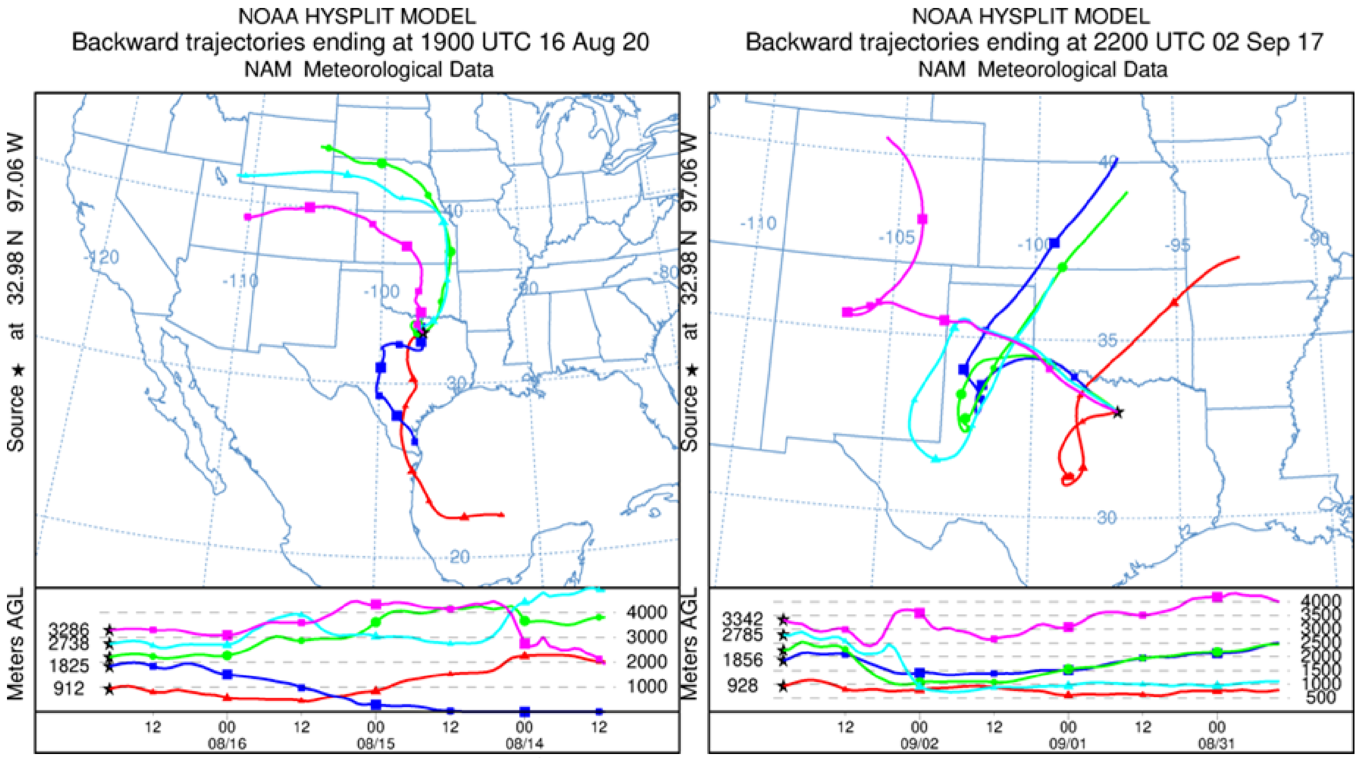

Figure 3-28: Backward Trajectories from the Grapevine Fairway monitor on August 16, 2020, and September 2, 2017

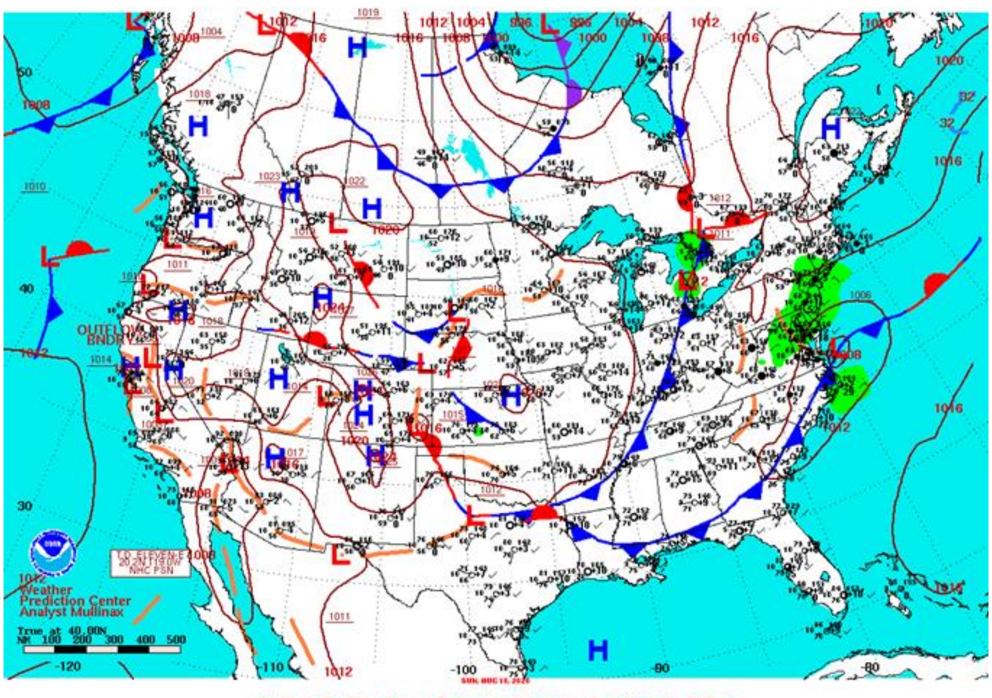

Figure 3-29: Surface Weather Chart for August 16, 2020

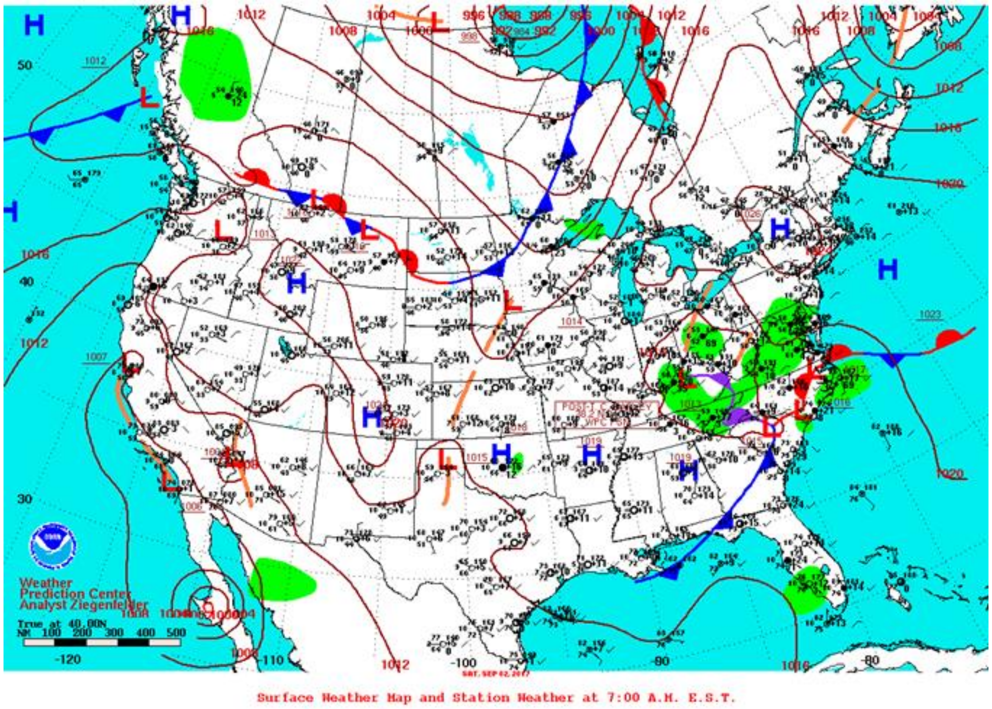

Figure 3-30: Surface Weather Chart for September 2, 2017

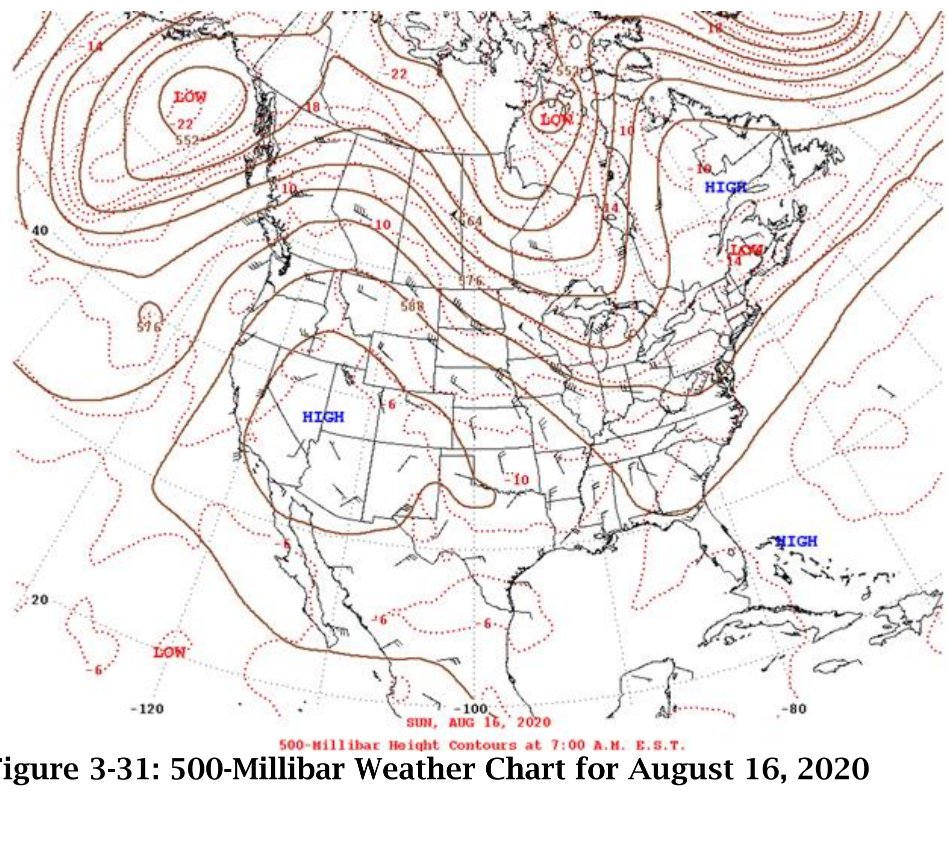

Figure 3-31: 500-Millibar Weather Chart for August 16, 2020

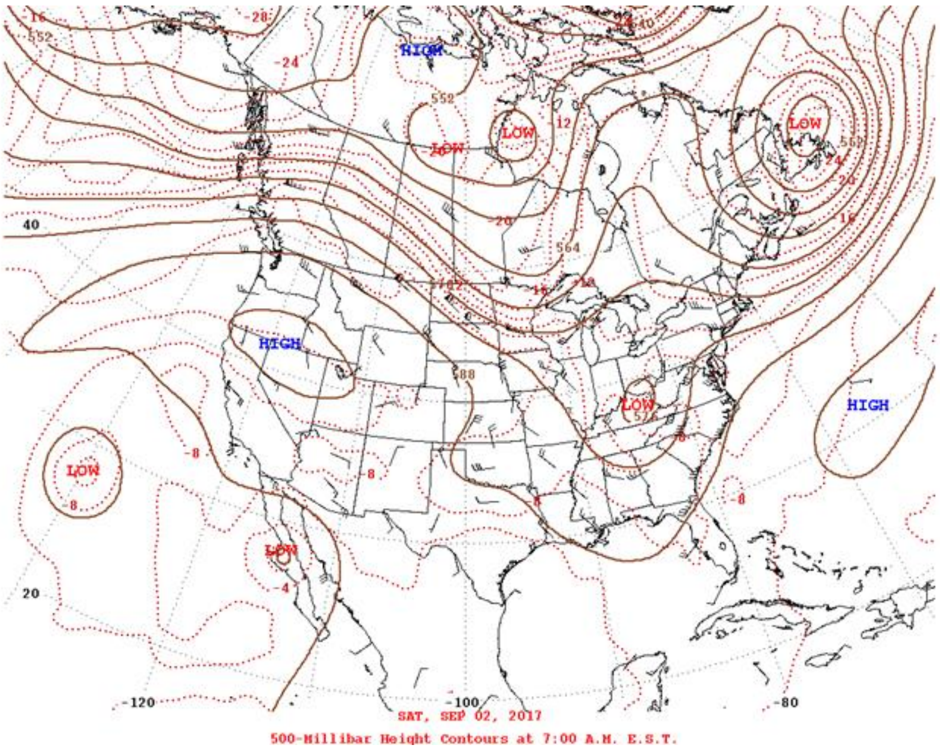

Figure 3-32: 500-Millibar Weather Chart for September 2, 2017

3.8.2 August 17, 2020

In reviewing information for August 17, 2020, the TCEQ identified a meteorologically similar day without smoke effects. On August 14, 2019, the Grapevine Fairway monitor measured a maximum daily eight-hour ozone average of 53 ppb and had no smoke plumes overhead. Table 3-5: *Meteorological Matching Parameters for August 17,* 2020 shows the similarities of individual parameters. August 14, 2019 occurs at the same time of year as August 17 and shares many of the same general characteristics. While an average morning wind speed of 2.3 mph on August 14, 2019 is 0.8 mph faster than the 1.5 mph experienced on August 17, 2020, both wind speeds are considered slow and are therefore comparable.

Figure 3-33: *Backward Trajectories from the Grapevine Fairway Monitor on August 17, 2020, and August 14, 2019* compares backward HYSPLIT trajectories initiated from the Grapevine Fairway monitor at the hour of maximum one-hour ozone on August 17, 2020 (left) to August 14, 2019 (right). The back trajectories are released at five heights equivalent to fractions of the mixing height: 50%, 100%, 120%, 150%, and 180%. Higher trajectories on both days all possess similar characteristics indicating the influence of substantially similar synoptic conditions. This conclusion is confirmed by the NOAA (2003) Surface and 500-Millibar Weather Charts in Figure 3-34: Surface Weather Chart for August 17, 2020, Figure 3-35: *Surface Weather Chart for August 14, 2019*, Figure 3-36: *500-Millibar Weather Chart for August 17, 2020*, and Figure 3-37: *500-Millibar Weather Chart for August 14, 2019* which show the larger scale meteorological similarities.

Table 3-5: Meteorological Matching Parameters for August 17, 2020

Meteorological Parameter	August 17, 2020	August 14, 2019
Maximum Daily 8-hour O3 Average (ppb)	88	53
Average Resultant Wind Direction AM (hours 7-10)	83	29
Average Resultant Wind Speed AM (hours 7-10) (mph)	1.5	2.3
Average Resultant Wind Direction PM (hours 13-16)	249	223
Average Resultant Wind Speed PM (hours 13-16) (mph)	3.1	3.2
Maximum Temperature (˚F)	91.2	90.1
Maximum Solar Radiation (Langley/minute)	1.31	1.12
Average Relative Humidity (%) (24-hour)	59.5	66.9
850mb Height (m)	1,581	1,560
850mb Temperature (˚K)	294.1	292
700mb Height (m)	3,224	3,209
700mb Temperature (˚K)	282.5	283.5

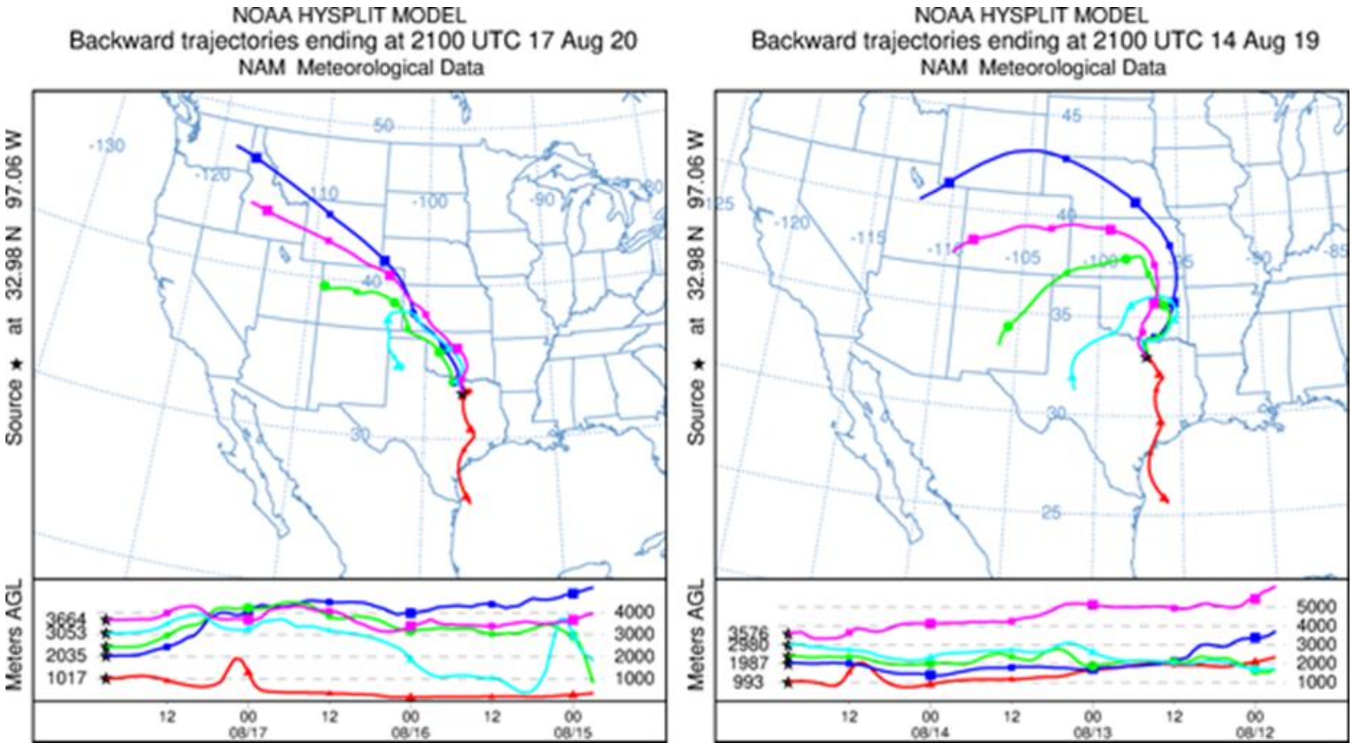

Figure 3-33: Backward Trajectories from the Grapevine Fairway Monitor on August 17, 2020, and August 14, 2019

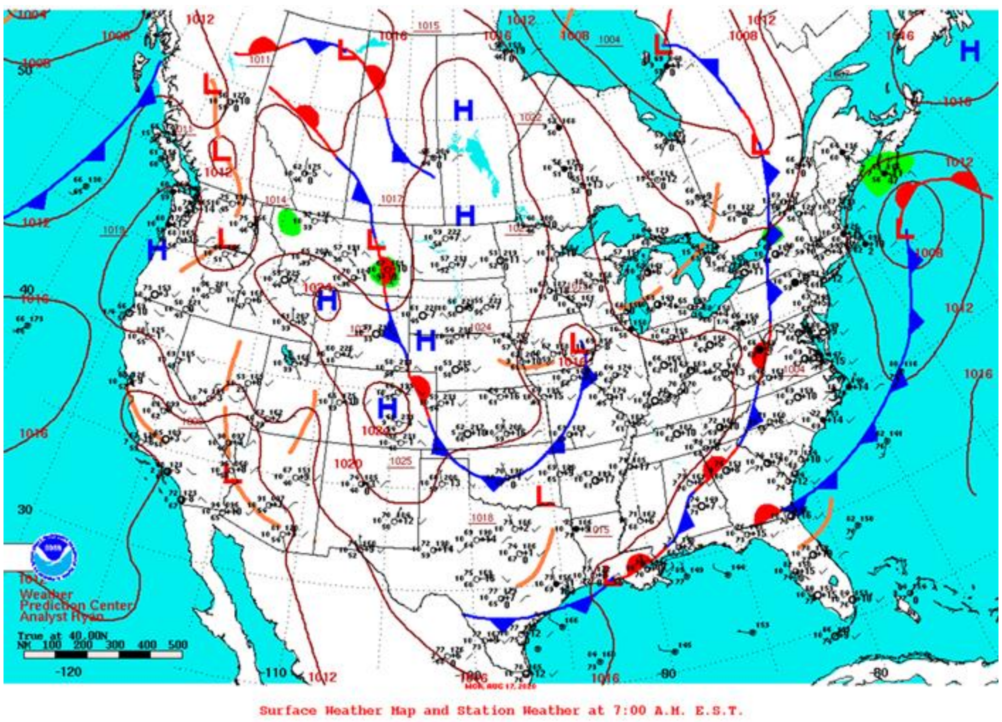

Figure 3-34: Surface Weather Chart for August 17, 2020

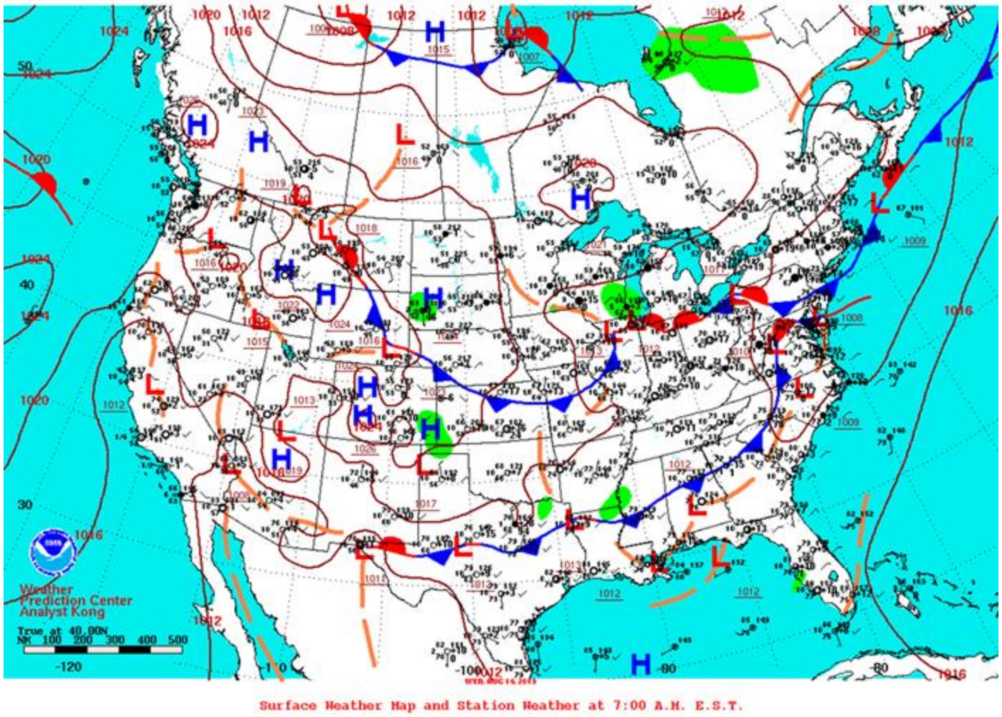

Figure 3-35: Surface Weather Chart for August 14, 2019

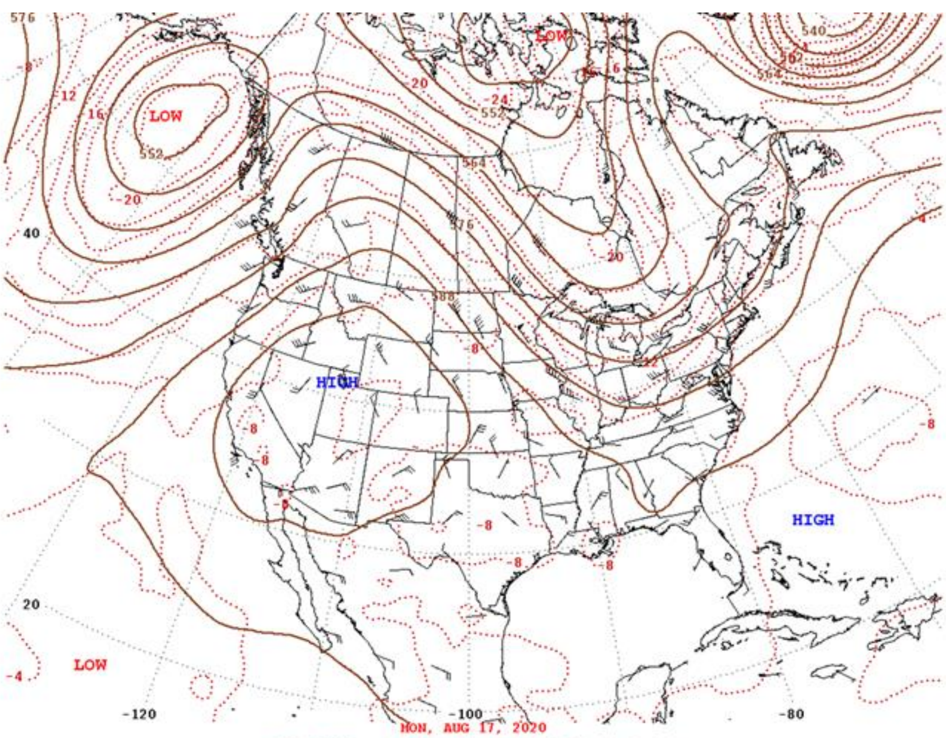

Figure 3-36: 500-Millibar Weather Chart for August 17, 2020

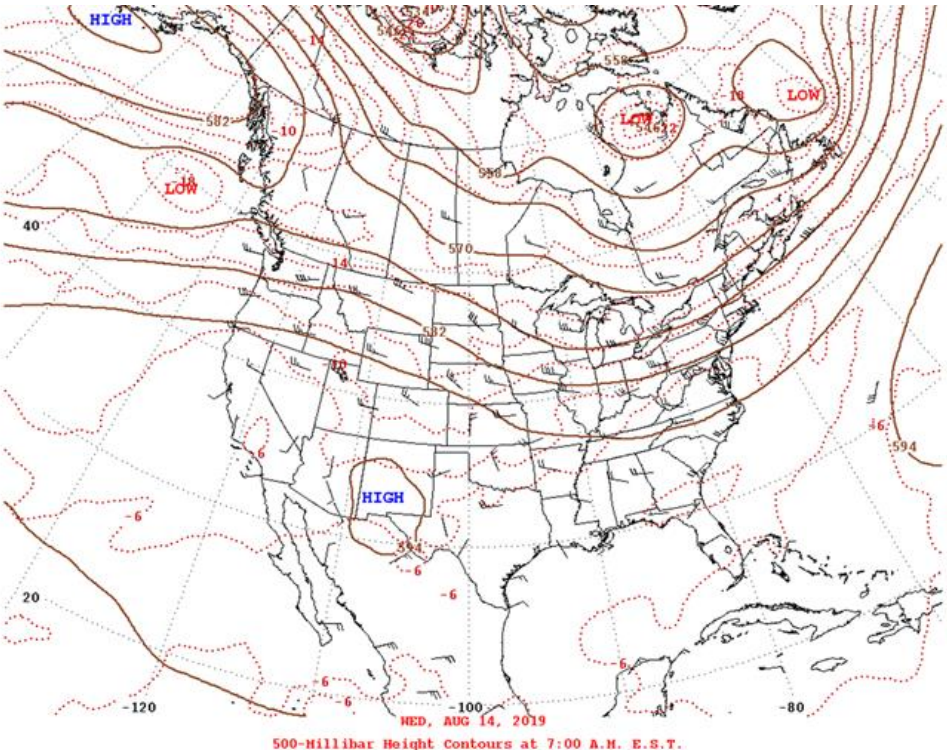

Figure 3-37: 500-Millibar Weather Chart for August 14, 2019

3.8.3 August 21, 2020

In reviewing information for August 21, 2020, the TCEQ identified a meteorologically similar day without smoke effects. August 15, 2019 experienced a maximum daily eight-hour ozone average of 71 ppb and did not have overhead smoke plumes. Table 3-6: *Meteorological Matching Parameters for August 21,* 2020 shows the similarities of individual parameters. Seasonally, August 15, 2019 occurs within one month of August 21 and share many of the same general characteristics. While an average afternoon wind speed of 3.1 mph on August 14, 2019 is 1.1 mph faster than the 2.0 mph experienced on August 21, 2020, both wind speeds are considered slow and are therefore comparable.

Table 3-6: Meteorological Matching Parameters for August 21, 2020

Meteorological Parameter	August 21, 2020	August 15, 2019
Maximum Daily 8-hour ozone Average (ppb)	77	71
Average Resultant Wind Direction AM (hours 7-10)	122	115
Average Resultant Wind Speed AM (hours 7-10) (mph)	3.5	2.7
Average Resultant Wind Direction PM (hours 13-16)	91	107
Average Resultant Wind Speed PM (hours 13-16) (mph)	2	3.1

Meteorological Parameter	August 21, 2020	August 15, 2019
Maximum Temperature (˚F)	92.2	95.1
Maximum Solar Radiation (Langley/minute)	1.16	1.16
Average Relative Humidity (%) (24-hour)	45.4	55.8
850mb Height (m)	1,513	1,558
850mb Temperature (˚K)	290.2	293.2
700mb Height (m)	3,144	3,209
700mb Temperature (˚K)	282.1	284.9

Figure 3-38: *Backward Trajectories from the Grapevine Fairway Monitor on August 21, 2020, and August 15, 2019* compares backward HYSPLIT trajectories initiated from the Grapevine Fairway monitor at the hour of maximum one-hour ozone on August 21, 2020 (left) to August 15, 2019 (right). The back trajectories are released at five heights equivalent to fractions of the mixing height: 50%, 100%, 120%, 150%, and 180%. Higher trajectories on both days possess similar characteristics indicating the influence of substantially similar synoptic conditions. This conclusion is confirmed by the NOAA Surface and 500-Millibar Weather Charts in Figure 3-39*: Surface Weather Chart for August 21, 2020*, Figure 3-40: *Surface Weather Chart for August 15, 2019*, Figure 3-41: *500-Millibar Weather Chart for August 21, 2020*, and Figure 3-42*: 500-Millibar Weather Chart for August 15, 2019* which show the larger scale meteorological similarities.

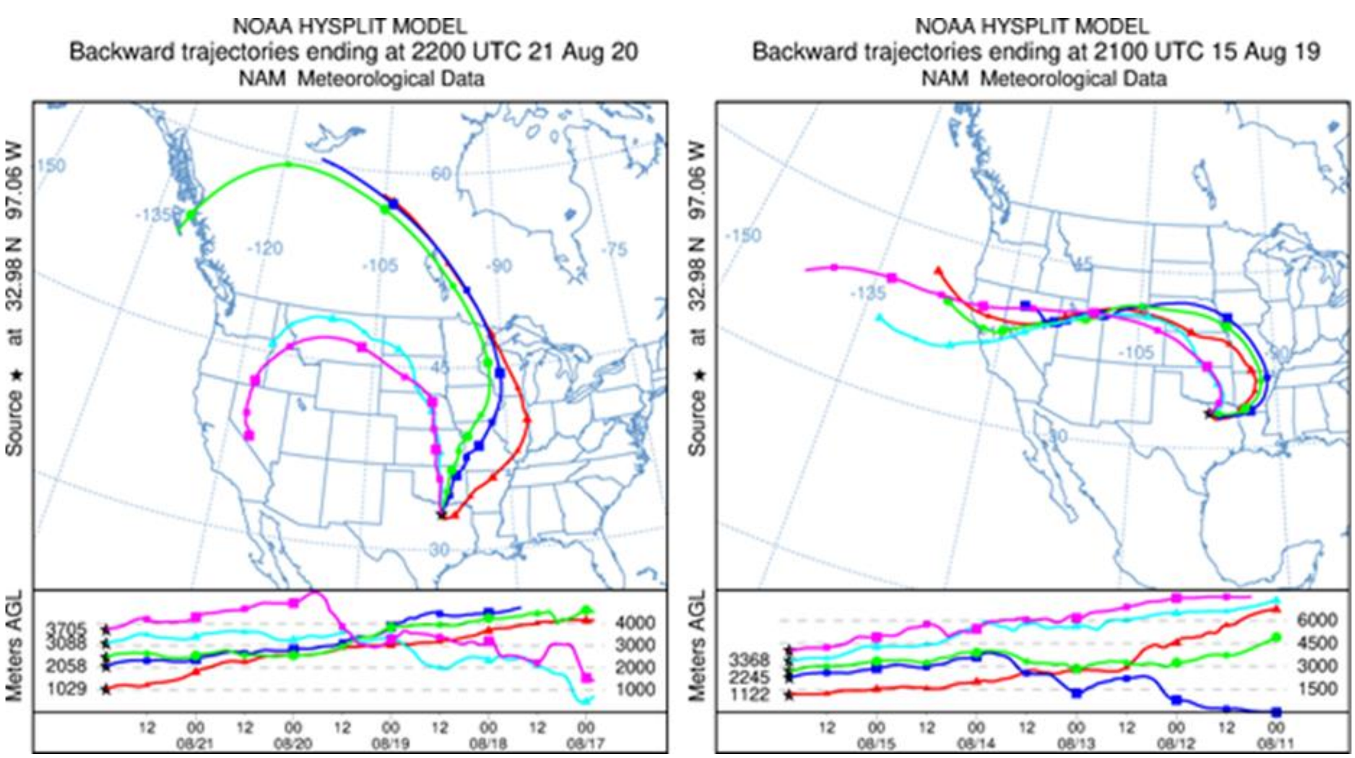

Figure 3-38: Backward Trajectories from the Grapevine Fairway Monitor on August 21, 2020, and August 15, 2019

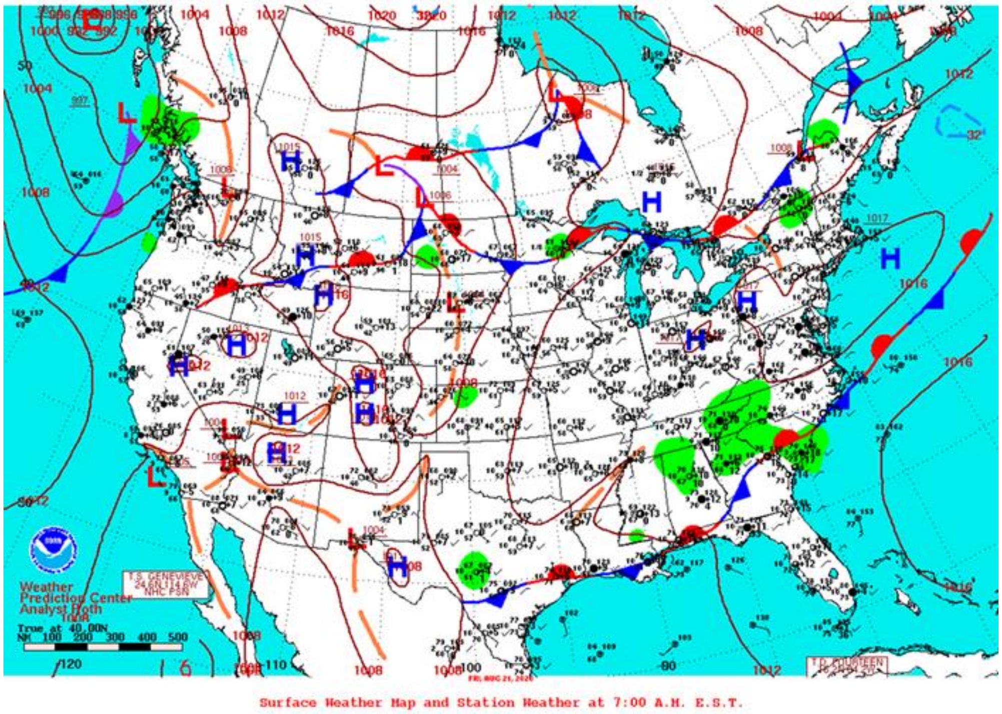

Figure 3-39: Surface Weather Chart for August 21, 2020

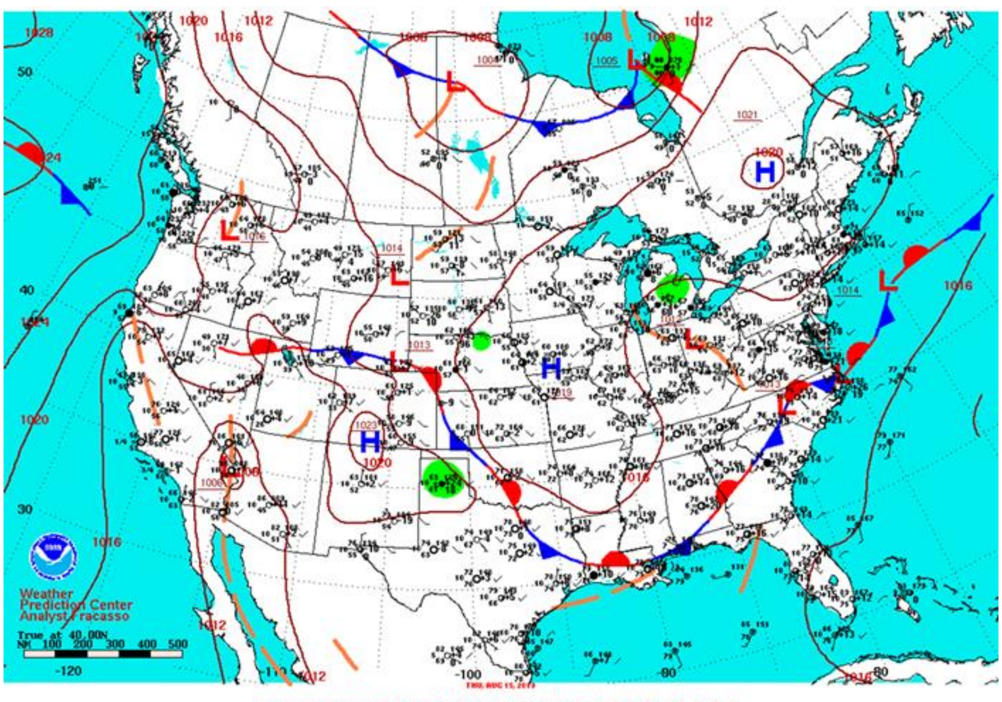

Figure 3-40: Surface Weather Chart for August 15, 2019

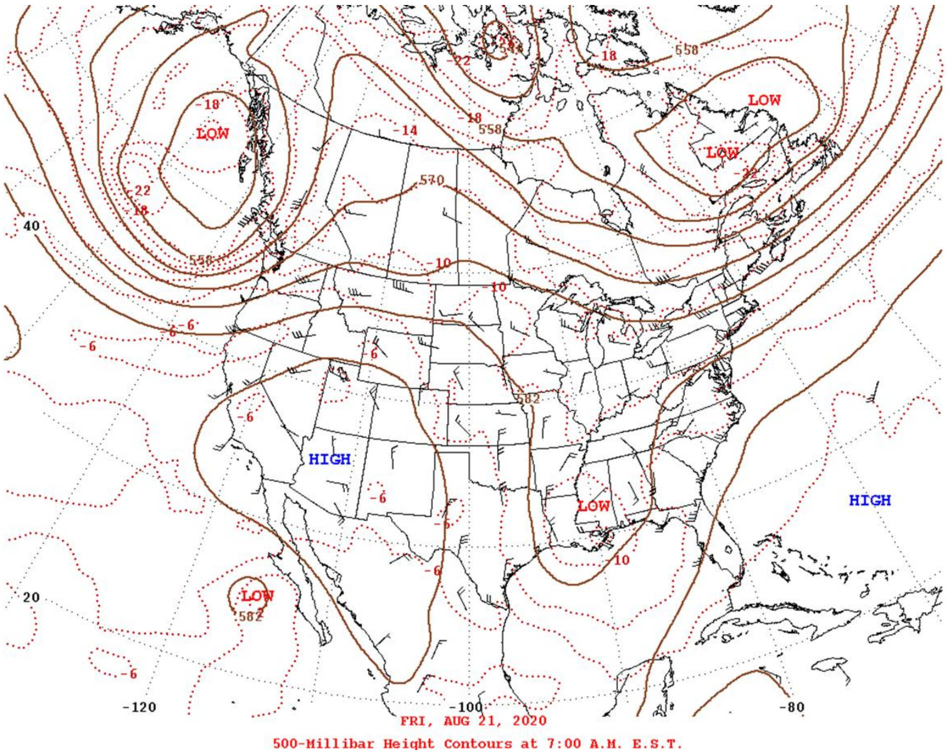

Figure 3-41: 500-Millibar Weather Chart for August 21, 2020

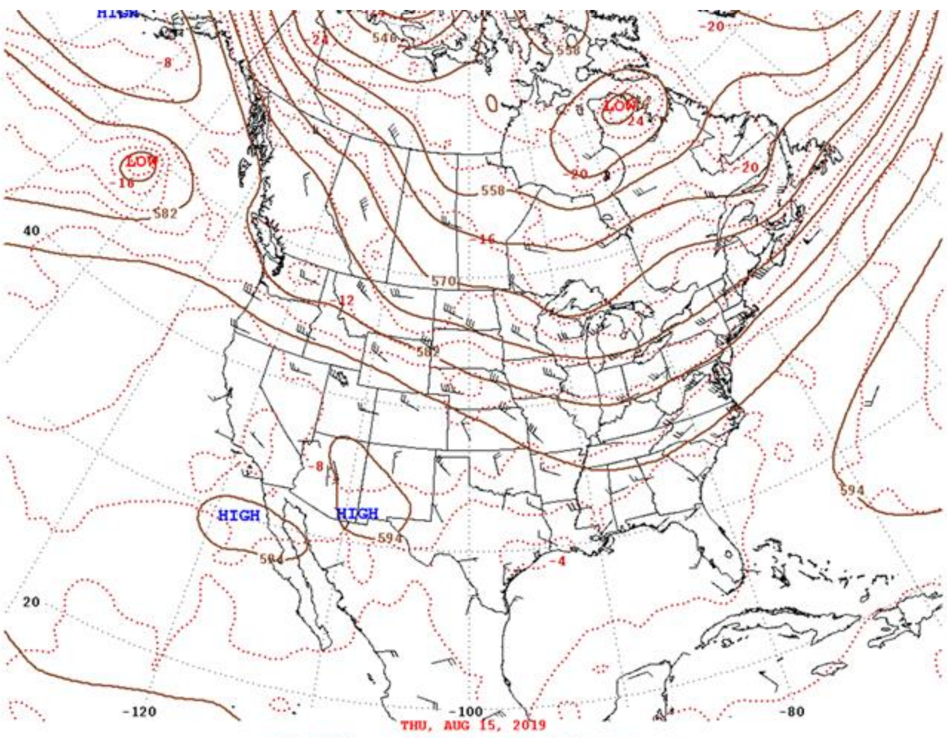

Figure 3-42: 500-Millibar Weather Chart for August 15, 2019

3.9 GENERALIZED ADDITIVE MODEL ANALYSIS

The EPA guidance (U.S. EPA, 2016a) identifies the use of statistical regression models as an example of a Tier 3 analysis to show that wildfire emissions caused an ozone exceedance: “Because regression equations are developed with several years of data, they represent the relationship between air quality and meteorology under typical emission patterns.” Therefore, days that the regression model cannot explain adequately can be thought of as exceptional days.

There are many ways to investigate the impacts of meteorology on ozone concentrations. Camalier *et al.* (2007) developed a model using Generalized Linear Models (GLM) to predict ozone from meteorological variables. Jaffe *et al.* (2004) used statistical models to quantify the amount of ozone due to wildfire. The Generalized Additive Model (GAM) is a statistical method used for modeling data as a function of many predictor variables (Woods 2017). Alvarado *et al.* (2015) used GAMs to see the relationship between ozone and meteorological variables using six Texas urban areas. Gong, *et al.* (2017) applied the GAM method to estimate the wildfire contributions to maximum daily eight-hour ozone averages in eight different cities in the western United States from 2008 to 2015. The Louisiana Department of Environmental Quality (2018) also used GAM modeling to show the 2017 Northwest wildfire contribution to ozone. The TCEQ submitted GAM modeling as supplemental material (Jaffe, 2017) in its 2016 exceptional event demonstration for El Paso, Texas (TCEQ, 2016).

An example equation for a GAM for this report can be written as:

$$\boldsymbol{g(Y_I) = f_1(X1_i) + f_2(X2_i) + f_3(X3_i) + \cdots + residual_i}$$

Where f_1, f_2, f_3, etc. are link functions obtained from spline fits to the observations, X1, X2, etc. are the predictor variables and the “*i*” refers to each daily observation. The “R” (2021) software program with an add-on package “mgcv” (Woods 2021) was used for GAMs modeling in this analysis. Model training started with 19 predictor variables and the final model contains 16 variables.

The daily meteorological variables used in this preliminary study are wind speed, wind direction, temperature, pressure, dew point, relative humidity, and solar radiation. Some variables were derived from meteorological parameters for modeling purposes. Table 3-7: *Meteorological Parameters Used for Grapevine Fairway GAMs* Model shows the meteorological variables used in the final model. Grapevine Fairway monitoring data were obtained from pre-generated reports at the EPA’s AirData website for the months of April through October and years 2011 through 2019. Similar data for 2020 was obtained from the TCEQ’s Leading Environmental Analysis and Display System (LEADS).

Table 3-7: Meteorological Parameters Used for Grapevine Fairway GAMs Model

Atmospheric Variables	Details
Daily average E/W-component of wind speed/direction (mph)	Derived from hourly resultant wind speed (61103) and wind direction (61104)

Atmospheric Variables	Details
Daily average N/S-component of wind speed/direction (mph)	Derived from hourly resultant wind speed (61103) and wind direction (61104)
Average morning E/W-component of wind speed/direction (mph)	Derived using 8 to 11 hours of resultant wind speed and wind direction
Average morning N/S-component of wind speed/direction (mph)	Derived using 8 to 11 hours of hourly resultant wind speed and wind direction
Average afternoon N/S-component of wind speed (mph)	Derived using 14 to 17 hours of hourly resultant wind speed and wind direction
Daily average temperature (˚F)	24-hour average (62101)
Average morning temperature (˚F)	Derived using 8 to 11 hours of hourly outdoor temperature
Average afternoon temperature (˚F)	Derived using 14 to 17 hours of hourly outdoor temperature
Maximum temperature (˚F)	Maximum hourly value for the day
Diurnal temperature (˚F)	Difference between maximum and minimum hourly value of temperature for the day
Daily average dew point (˚F)	Derived from hourly dew point (62103)
Daily average relative humidity (%)	Derived from hourly relative humidity (62201)
Maximum relative humidity (%)	Maximum hourly value for the day
Daily average solar radiation (Langley/minute)	Derived from hourly solar radiation (63301)
Maximum solar radiation (Langley/minute)	Maximum hourly value for the day
Daily average atmospheric (millibars)	Derived from hourly pressure (64101)

Maximum daily ozone averages at the Grapevine Fairway monitor were obtained from the EPA’s AirData website and can be provided upon request. Data from 2011 through 2019 were used for model development and training and data from 2020 was used as the predictive case.

As the EPA guidance suggests, the TCEQ used a train and test approach for its statistical model. Table 3-8: *Grapevine Fairway Ozone Generalized Additive Model Performance Characteristics* describes this model. The ability of the model to predict maximum daily ozone averages is shown graphically in

Figure 3-43: *Training Model Results Compared to Observed* **Ozone** and Figure 3-44: *2020 Model Predictions Compared to Observed Ozone* A more direct comparison of performance by the training model and 2020 model is shown in Figure 3-45: *A Comparison of 2020 Predictions with Results from Training Model.*

Figure 3-46: *Training and 2020 Residuals for Training and Predictive Models* shows the overlapped plot of training residuals and the 2020 validation dataset. Both sets of residuals do not show any clear pattern or bias of the residuals. This unbiased relation throughout the range of predicted ozone values shows the quality of the GAM used to predict maximum ozone averages.

Table 3-8: Grapevine Fairway Ozone Generalized Additive Model Performance Characteristics

Statistic	2011-2019 Model	2020 Predictions/Validation
N	1774	212
R2	0.71	0.63
Residual Mean	-0.01	-2.11

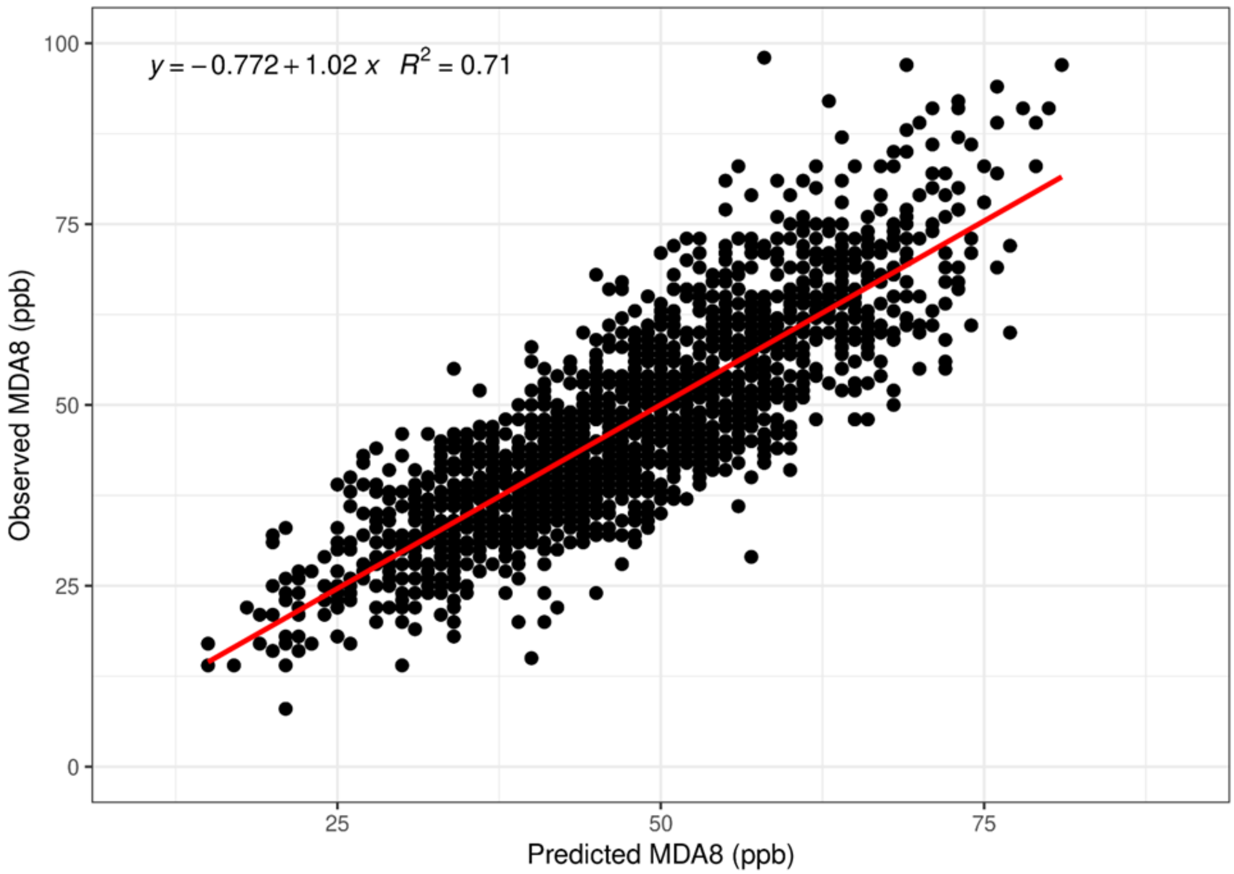

Figure 3-43: Training Model Results Compared to Observed Ozone

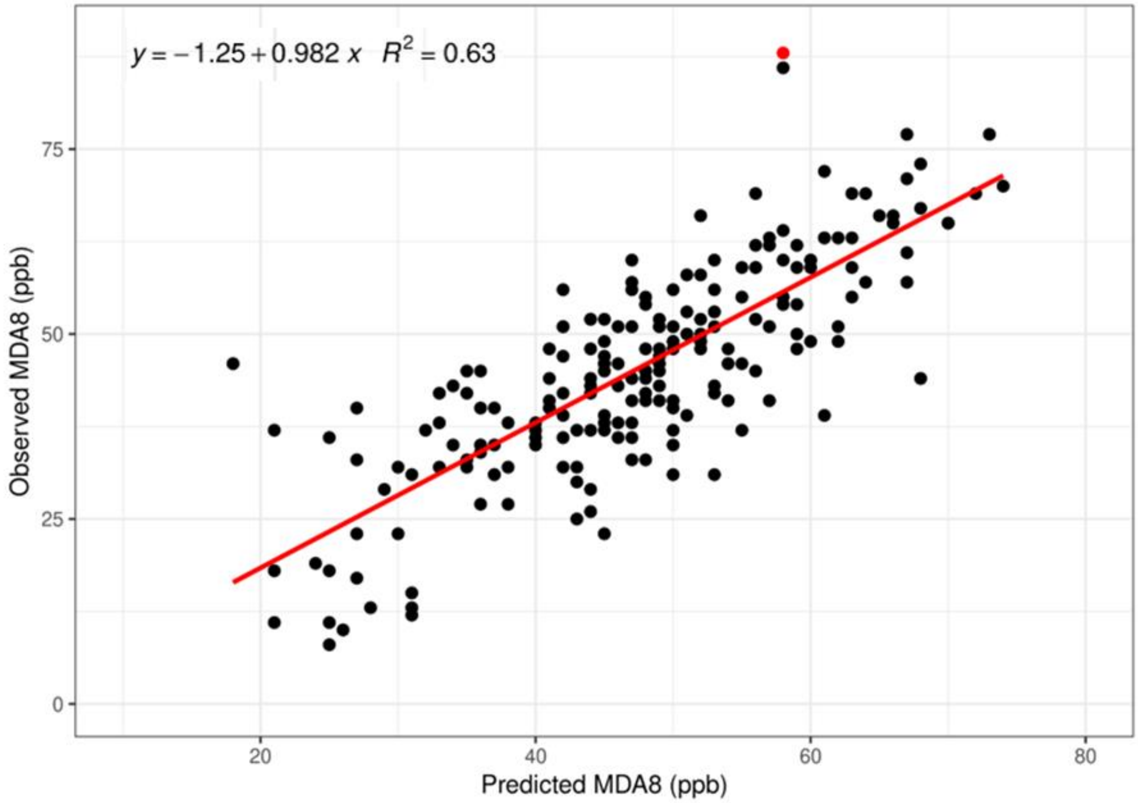

Figure 3-44: 2020 Model Predictions Compared to Observed Ozone

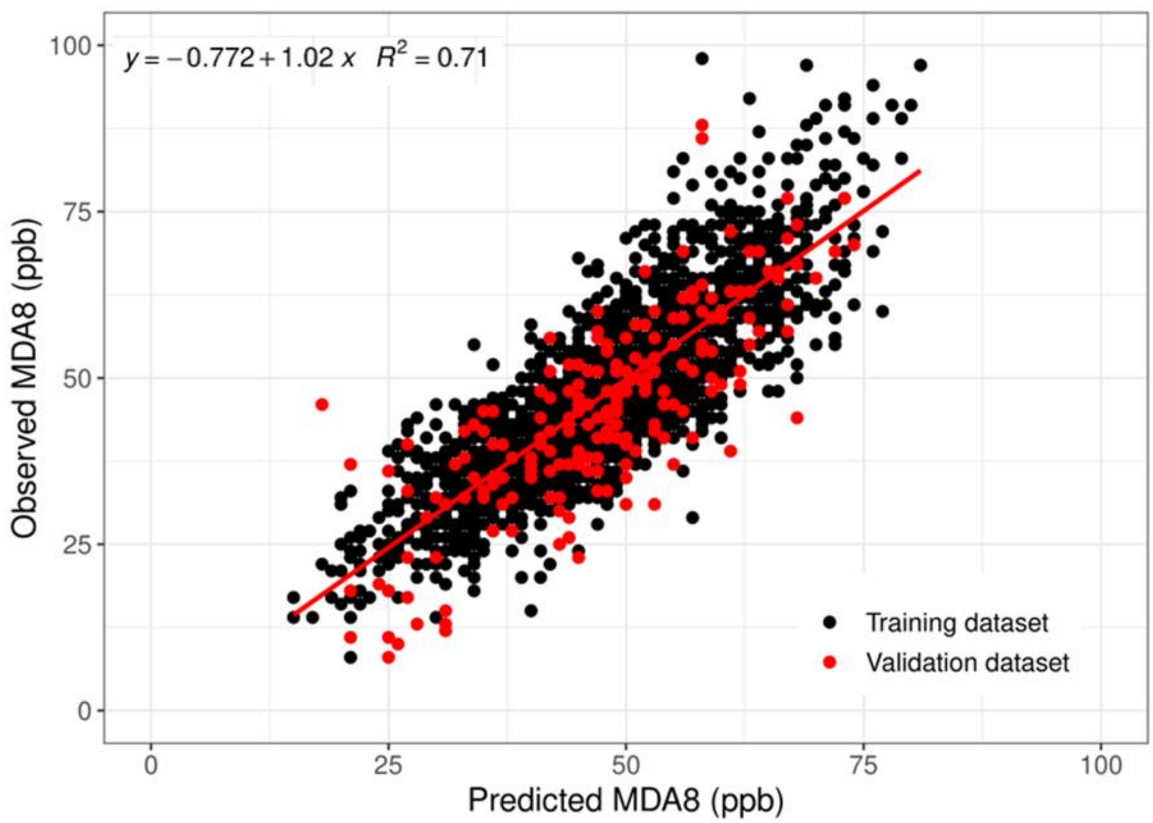

Figure 3-45: A Comparison of 2020 Predictions with Results from Training Model

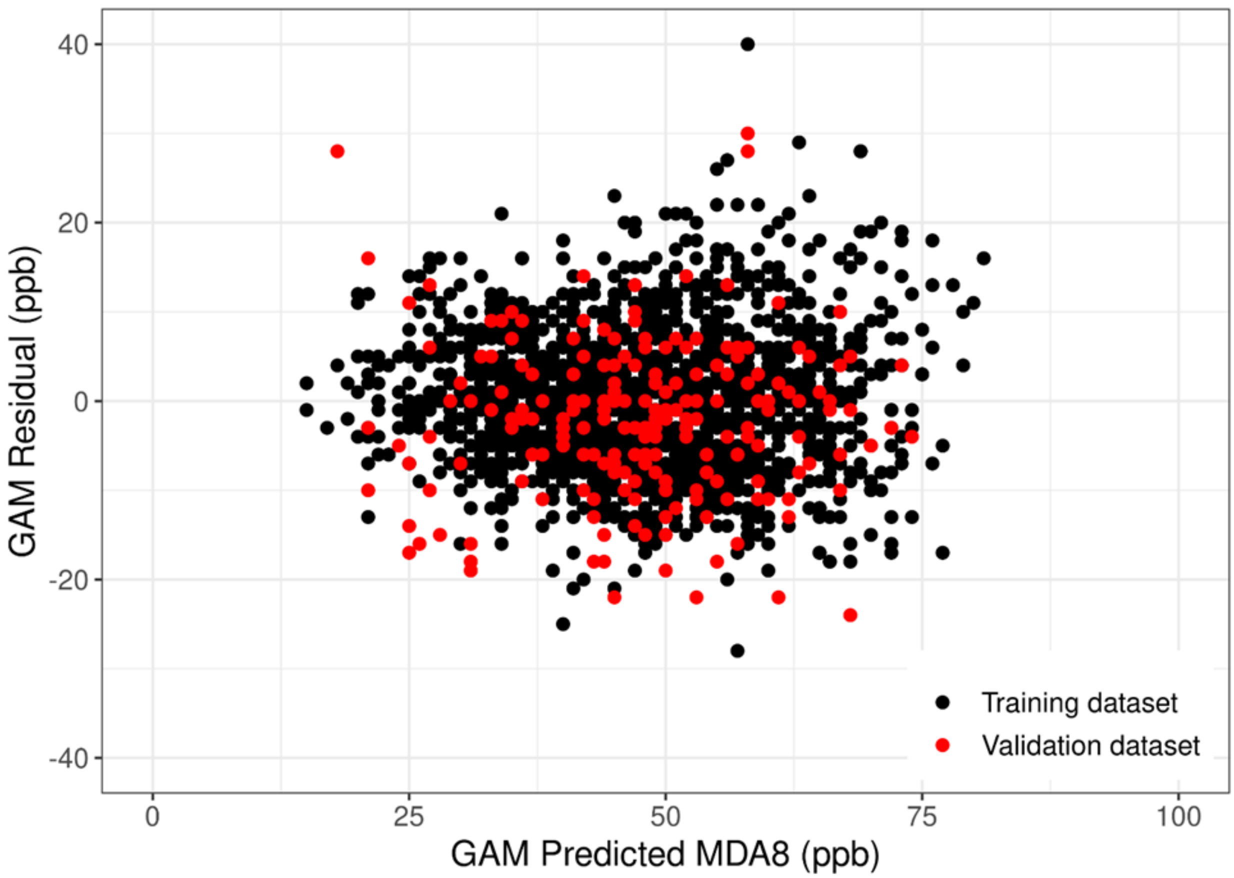

Figure 3-46: Training and 2020 Residuals for Training and Predictive Models

As shown in

Figure 3-47*: Time Series of Observed and Predicted Maximum Daily Ozone for August* **2020**, the model does a good job following the day-to-day changes in the observed ozone. Taken as a whole, the model has performed satisfactorily and can be used to support clear causal analysis.

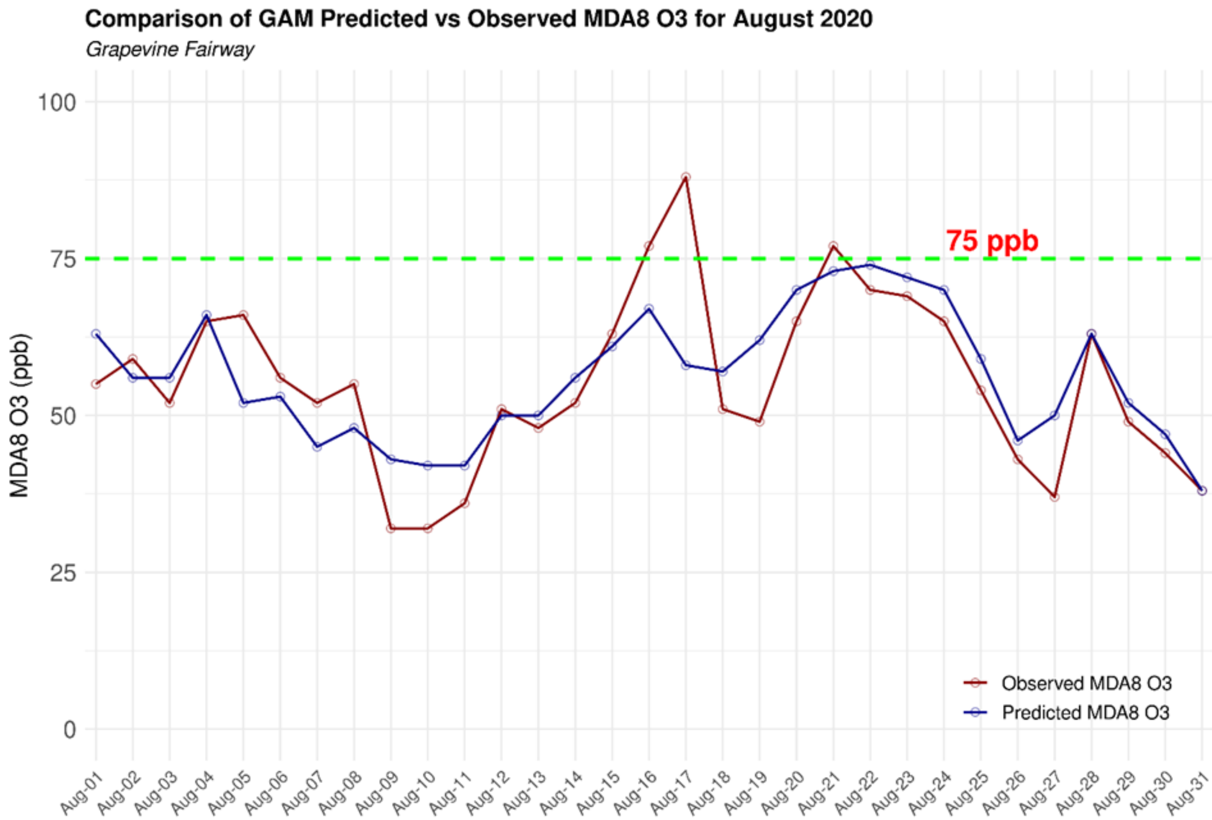

Figure 3-47: Time Series of Observed and Predicted Maximum Daily Ozone for August 2020

When evaluating model results for August 17, 2020, the TCEQ used EPA guidance (U.S. EPA, 2016a, p. 28) in assigning wildfire contributions to maximum ozone that day. This guidance provides that a state may use the difference between a particular day's residual and the 95th percentile of positive predicted residuals as the wildfire contribution to maximum ozone on that day. Table 3-9: *Determination of Wildfire Contribution to Ozone on August 17, 2020* shows the details of this approach. This approach is shown graphically in Figure 3-48: *Predicted and Observed Ozone with 95th Percentile of Positive Residuals*. Using this approach, the TCEQ concludes that the estimated wildfire contribution to the Grapevine Fairway monitor's maximum daily eight-hour ozone average on August 17, 2020 is 16 ppb.

Table 3-9: Determination of Wildfire Contribution to Ozone on August 17, 2020

GAM Results	August 17th 2020
Observed MDA8 (ppb)	88
GAM Prediction (ppb)	58
GAM residual 95th percentile (positive difference only)	14
GAM Prediction + 95th percentile	72
Estimated Wildfire Contribution	16

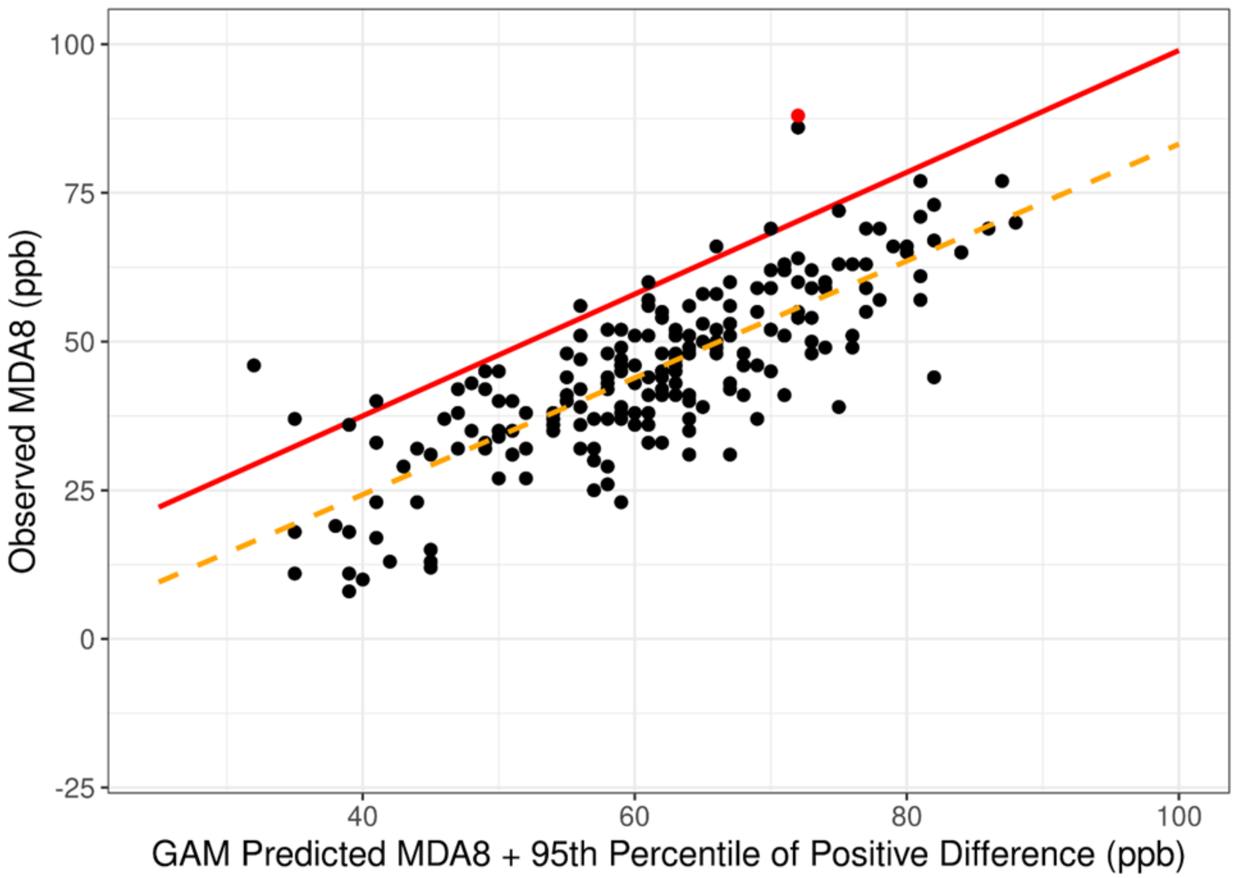

Figure 3-48: Predicted and Observed Ozone with 95th Percentile of Positive Residuals

3.10 CAUSAL RELATIONSHIP CONCLUSION

The analyses provided in this chapter demonstrate that on August 16, 17, and 21, 2020 air quality in the DFW area was affected by wildfires in Colorado (affecting August 16 through 17, 2020) and California (affecting August 21, 2020). These wildfires generated ozone and/or its precursors that resulted in elevated ozone concentrations at the Grapevine Fairway monitor. The monitored maximum daily eight-hour ozone average concentration of 88 ppb exceeded the 99th percentile for maximum daily eight-hour ozone averages over 2016 through 2020 on an annual basis. Meteorological conditions transported ozone and its precursors from these large wildfires in Colorado and California to the Grapevine Fairway monitor indicating that a clear causal relationship exists between the specific wildfire events and the monitored exceedances on August 16, 17, and 21, 2020.

CHAPTER 4: PUBLIC COMMENT

In following the requirements listed in Title 40 of the Code of Federal Regulations (CFR) §50.14(c)(3), the Texas Commission on Environmental Quality (TCEQ) posted this Exceptional Events Demonstration Package on its website for public comment from April 14 through May 14, 2021. In accordance with 40 CFR §50.14(c)(3), the TCEQ is documenting the public comments received in this section. All comments received during the comment period are included in Appendix B: *Public Comments*.

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APPENDIX A: DETAILED INFORMATION ON COLORADO AND NORTHERN CALIFORNIA WILDFIRES

A.1 WILDFIRE EMISSIONS ESTIMATES

The information in this appendix provides additional details on wildfires that caused ozone exceedances at the Grapevine Fairway monitor on August 16, 17, and 21, 2020. This information was obtained from the National Center for Atmospheric Research (NCAR) Fire INventory from NCAR (FINN) (Wiedinmyer and Yokelson, 2011). The FINN model provides high resolution, global emission estimates from open burning. FINN uses satellite observations of active fires and land cover, together with emission factors and estimated fuel loadings to provide daily, highly resolved (1 km) open burning emissions estimates for use in regional and global chemical transport models. Because these emissions are based on satellite detections, they are not linked to wildfire names used by federal or state firefighting agencies.

The additional information for each detected fire included in the tables are:

- date of satellite detection/emissions estimate;
- latitude and longitude of the detected fire;
- size in acres of the detected fire;
- nitrogen oxides (NO_x) emissions in daily tons;
- Non-Methane Organic Compound (NMOC) emissions in daily tons;
- Q the sum of daily NO_x and NMOC emissions in daily tons; and
- distance from the satellite detected fire to the Grapevine Fairway monitor in kilometers.

The emissions dates reported below are the days deemed relevant to wildfire influences on the Grapevine Fairway monitor on August 16, 17, and 21, 2020. Below each table are estimates for aggregated daily wildfire emissions (Q), distance (averaged and weighted by individual wildfire Q), and daily Q divided by distance (Q/D).

A.2 EMISSIONS DIVIDED BY DISTANCE CALCULATIONS

In order to help states and the United States Environmental Protection Agency (EPA) decide whether a state needed to provide Tier 3 evidence in their exceptional event demonstration, the EPA relies on a metric introduced in its 2016 "Guidance on the Preparation of Exceptional Events Demonstrations for Wildfire Events That May Influence Ozone Concentrations" (U.S. EPA, 2016a).

This metric uses emissions divided by distance (Q/D) as an indicator of source influence on a downwind monitor. Emissions are estimated as the sum of daily NO_x and NMOC emissions in tons per day (tpd) on days with emissions likely to influence a particular downwind monitor, Distance is the distance in kilometers (km) from the causal fire(s) to the downwind monitor influenced by the exceptional event. The EPA recommends that a state be able to show a Q/D value of at least 100 tpd/km in to use a Tier 2 demonstration.

If multiple fires potentially influence a monitor on the same day the EPA (U.S. EPA, 2016a, p. 17-21) provides a method to compute an averaged distance weighted by emissions. The equations for emissions and distance under this circumstance is shown in Figure 49: *Equations for Q/D That Involve Multiple Fires* below:

$$Q = \sum_{i=1}^{n} q_i$$

$$D_{weighted} = \frac{1}{n \times Q} \sum_{i=1}^{n} (q_i \times d_i)$$

Figure 49: Equations for Q/D That Involve Multiple Fires

Where

q_i = the sum of daily NO_X and VOC emissions from the individual wildfire *i;*

n = the number of wildfires on a given day;

Q = the total of all daily NO_X and VOC emissions from all wildfires;

d_i = the distance from wildfire *i* to the downwind monitor; and

$D_{weighted}$ = D_w = the average distance for all wildfires (*i* = 1 through n) weighted by each wildfire's emissions (q_i).

Q and D_w are calculated and shown below each table for each area's daily NOX and VOC emissions for days where the wildfires are likely to have influenced the Grapevine Fairway monitor.

Table A-10: Estimations of Colorado Wildfire Emissions on August 13, 2020, Based on NCAR's FINN Inventory

Date	Latitude	Longitude	Size (acres)	NO_x Emissions (tons)	NMOC Emissions (tons)	Q (tons)	Distance (km)
8/13/2020	39.494	-108.451	239.62	2.883	4.759	7.641	1,251.16
8/13/2020	39.491	-108.400	232.13	2.705	4.466	7.171	1,247.26
8/13/2020	39.467	-108.382	141.83	1.874	4.307	6.181	1,244.54
8/13/2020	39.492	-108.488	229.46	4.159	25.455	29.614	1,253.75
8/13/2020	39.460	-108.494	179.77	3.010	6.919	9.929	1,252.33
8/13/2020	39.594	-107.286	183.44	3.672	8.440	12.112	1,173.88
8/13/2020	39.573	-107.223	227.14	4.076	24.943	29.019	1,168.12
8/13/2020	39.580	-107.189	242.16	11.545	70.657	82.202	1,166.20
8/13/2020	39.591	-107.179	234.63	4.349	26.615	30.964	1,166.21
8/13/2020	39.494	-108.496	231.98	10.852	66.414	77.266	1,254.46
8/13/2020	39.498	-108.479	242.06	12.152	74.369	86.520	1,253.44
8/13/2020	39.501	-108.463	172.09	2.758	6.341	9.099	1,252.45
8/13/2020	39.595	-107.281	183.48	3.691	8.485	12.177	1,173.59
8/13/2020	39.598	-107.265	175.87	3.331	7.657	10.988	1,172.67
8/13/2020	39.601	-107.247	244.58	12.647	77.400	90.047	1,171.60
8/13/2020	39.597	-107.215	181.59	3.071	7.060	10.131	1,169.11
8/13/2020	39.543	-107.213	247.11	9.242	33.122	42.364	1,165.48
8/13/2020	39.566	-107.206	247.11	9.302	33.337	42.639	1,166.48
8/13/2020	39.579	-107.196	168.48	3.061	7.036	10.097	1,166.62
8/13/2020	39.612	-107.188	181.55	3.070	7.057	10.127	1,168.21
8/13/2020	39.562	-107.171	185.33	3.733	8.581	12.314	1,163.77
8/13/2020	39.630	-107.137	138.53	1.787	4.109	5.896	1,165.84
8/13/2020	40.605	-105.864	247.11	15.769	96.504	112.273	1,152.93

Q = 746.770 tons $Distance_{weighted}$ = 1192.48 km Q/D_w = 0.63

Table A-11: Estimations of Colorado Wildfire Emissions on August 13, 2020, Based on NCAR's FINN Inventory

Date	Latitude	Longitude	Size (acres)	NO_x Emissions (tons)	NMOC Emissions (tons)	Q (tons)	Distance (km)
8/14/2020	39.466	-108.383	141.83	1.874	4.307	6.181	1,244.55
8/14/2020	39.613	-107.247	239.62	2.883	4.759	7.641	1,172.38
8/14/2020	39.624	-107.244	168.48	2.644	6.078	8.722	1,172.89
8/14/2020	39.562	-107.224	247.11	14.092	86.245	100.337	1,167.48
8/14/2020	39.602	-107.191	172.22	2.763	6.351	9.114	1,167.76
8/14/2020	39.609	-107.166	164.74	2.528	5.811	8.338	1,166.48
8/14/2020	39.573	-107.163	179.66	3.006	6.911	9.917	1,163.93
8/14/2020	39.618	-107.157	144.14	1.935	4.449	6.384	1,166.44
8/14/2020	39.630	-107.155	147.51	2.027	4.659	6.685	1,167.09
8/14/2020	39.847	-106.072	239.69	13.220	80.910	94.130	1,109.13
8/14/2020	39.851	-106.056	247.11	15.013	91.878	106.891	1,108.38
8/14/2020	40.600	-105.894	181.59	3.635	8.356	11.991	1,154.36
8/14/2020	40.624	-105.887	131.04	1.599	3.677	5.276	1,155.79
8/14/2020	40.635	-105.880	242.11	14.150	86.601	100.751	1,156.23
8/14/2020	40.595	-105.870	247.11	15.975	97.766	113.741	1,152.51
8/14/2020	40.639	-105.870	242.06	13.574	83.074	96.648	1,155.93
8/14/2020	40.641	-105.850	244.58	14.441	88.377	102.818	1,154.88
8/14/2020	40.613	-105.837	247.11	14.371	87.953	102.324	1,151.92
8/14/2020	40.620	-105.811	242.11	12.393	75.846	88.240	1,150.90
8/14/2020	40.628	-105.787	247.11	15.542	95.116	110.658	1,150.08
8/14/2020	39.585	-107.225	181.59	3.071	7.060	10.131	1,169.03
8/14/2020	39.627	-107.193	173.98	2.819	6.481	9.300	1,169.53
8/14/2020	39.578	-107.149	214.66	3.640	22.277	25.917	1,163.28
8/14/2020	40.617	-105.892	136.66	1.739	3.999	5.738	1,155.55
8/14/2020	39.499	-108.482	242.11	11.924	72.973	84.897	1,253.72

Date	Latitude	Longitude	Size (acres)	NO_x Emissions (tons)	NMOC Emissions (tons)	Q (tons)	Distance (km)
8/14/2020	39.603	-107.173	157.25	2.303	5.294	7.597	1,166.58

Q = 1240.368 tons $Distance_{weighted}$ = 1155.73 km Q/D_w = 1.07

Table A-12: Estimations of Northern California Wildfire Emissions on August 15, 2020, Based on NCAR's FINN Inventory

Date	Latitude	Longitude	Size (acres)	NO_x Emissions (tons)	NMOC Emissions (tons)	Q (tons)	Distance (km)
8/15/2020	39.688	-120.129	224.64	2.534	4.182	6.716	2,192.75
8/15/2020	39.698	-120.127	224.64	2.534	4.182	6.716	2,192.83
8/15/2020	39.723	-120.157	224.64	3.987	24.398	28.384	2,195.94
8/15/2020	40.841	-119.630	93.60	0.816	1.876	2.692	2,183.59
8/15/2020	41.144	-123.495	227.14	11.501	70.386	81.887	2,506.89
8/15/2020	41.156	-123.435	237.02	4.438	27.161	31.599	2,502.27
8/15/2020	41.170	-123.422	244.61	15.134	92.622	107.756	2,501.55
8/15/2020	41.174	-123.403	237.12	11.430	69.950	81.380	2,500.09
8/15/2020	41.176	-123.450	247.11	16.494	100.945	117.440	2,503.99
8/15/2020	41.192	-123.433	247.11	16.616	101.691	118.307	2,502.99
8/15/2020	41.199	-123.426	247.11	15.542	95.116	110.658	2,502.59
8/15/2020	41.210	-123.403	247.11	16.135	98.747	114.882	2,500.98

Q = 808.417 tons $Distance_{weighted}$ = 2485.68 km Q/D_w = 0.33

Table A-13: Estimations of Northern California Wildfire Emissions on August 16, 2020, Based on NCAR's FINN Inventory

Date	Latitude	Longitude	Size (acres)	NOX Emissions (tons)	NMOC Emissions (tons)	Q (tons)	Distance (km)
8/16/2020	37.505	-121.429	164.74	2.528	5.811	8.338	2,266.73
8/16/2020	37.826	-121.783	247.11	3.066	5.061	8.127	2,301.37
8/16/2020	37.841	-121.785	247.11	3.066	5.061	8.127	2,301.72
8/16/2020	39.498	-122.270	170.20	4.293	38.014	42.308	2,369.04
8/16/2020	39.508	-122.230	179.66	4.784	42.356	47.139	2,365.84
8/16/2020	39.655	-120.129	214.33	2.306	3.807	6.114	2,191.95
8/16/2020	39.661	-120.029	156.96	2.295	5.275	7.570	2,183.72
8/16/2020	39.662	-120.102	224.64	2.534	4.182	6.716	2,189.86
8/16/2020	39.663	-120.057	110.45	1.136	2.612	3.748	2,186.12
8/16/2020	39.664	-120.085	147.89	2.037	4.683	6.720	2,188.49
8/16/2020	39.666	-120.116	222.39	2.483	4.099	6.582	2,191.13
8/16/2020	39.668	-120.147	134.78	1.692	3.890	5.582	2,193.77
8/16/2020	39.677	-122.792	247.11	4.824	29.521	34.345	2,416.62
8/16/2020	39.686	-122.757	247.11	11.310	69.219	80.529	2,413.83
8/16/2020	39.696	-120.142	146.02	1.986	4.565	6.551	2,194.03
8/16/2020	39.700	-120.154	157.25	2.303	5.294	7.597	2,195.13
8/16/2020	39.731	-120.209	125.42	1.465	3.368	4.833	2,200.49
8/16/2020	39.731	-120.169	214.33	2.306	3.807	6.114	2,197.14
8/16/2020	39.739	-120.177	117.94	1.296	2.978	4.274	2,198.01
8/16/2020	39.745	-120.169	119.81	1.337	3.073	4.410	2,197.48
8/16/2020	39.768	-122.703	247.11	4.824	29.521	34.345	2,410.85
8/16/2020	39.771	-122.663	247.11	4.824	29.521	34.345	2,407.53
8/16/2020	41.152	-123.492	244.61	13.993	85.636	99.628	2,506.84
8/16/2020	41.161	-123.493	247.11	15.224	93.173	108.398	2,507.14
8/16/2020	41.169	-123.434	247.11	16.135	98.747	114.882	2,502.50

Date	Latitude	Longitude	Size (acres)	NOX Emissions (tons)	NMOC Emissions (tons)	Q (tons)	Distance (km)
8/16/2020	41.170	-123.422	244.61	15.134	92.622	107.756	2,501.55
8/16/2020	41.172	-123.410	244.58	13.605	83.264	96.869	2,500.61
8/16/2020	41.181	-123.412	242.11	13.993	85.639	99.633	2,501.00
8/16/2020	41.189	-123.555	247.11	16.135	98.747	114.882	2,512.90
8/16/2020	41.191	-123.543	247.11	14.371	87.953	102.324	2,511.96
8/16/2020	41.196	-123.433	247.11	16.295	99.729	116.024	2,503.09
8/16/2020	41.198	-123.422	247.11	15.859	97.059	112.919	2,502.24
8/16/2020	41.200	-123.544	247.11	15.542	95.116	110.658	2,512.27
8/16/2020	41.208	-123.412	247.11	16.295	99.729	116.024	2,501.67
8/16/2020	41.217	-123.413	247.11	16.135	98.747	114.882	2,501.97

Q = 1789.293 tons Distance$_{weighted}$ = 2472.32 km Q/D$_w$ = 0.72

Table A-14: Estimations of Northern California Wildfire Emissions on August 17, 2020, Based on NCAR's FINN Inventory

Date	Latitude	Longitude	Size (acres)	NO_x Emissions (tons)	NMOC Emissions (tons)	Q (tons)	Distance (km)
8/17/2020	37.509	-121.853	247.11	3.066	5.061	8.127	2,304.10
8/17/2020	37.510	-121.431	164.74	2.528	5.811	8.338	2,266.96
8/17/2020	37.519	-121.429	160.74	2.407	5.532	7.939	2,266.88
8/17/2020	37.538	-120.602	179.71	4.787	42.383	47.169	2,194.38
8/17/2020	37.816	-119.640	138.53	1.787	4.109	5.896	2,113.93
8/17/2020	37.836	-121.083	185.33	5.090	45.073	50.163	2,240.24
8/17/2020	37.884	-119.646	244.61	13.360	81.765	95.126	2,115.50
8/17/2020	38.031	-121.211	247.11	3.066	5.061	8.127	2,253.99
8/17/2020	39.510	-122.258	174.10	4.492	39.775	44.267	2,368.25
8/17/2020	39.512	-122.209	157.25	3.665	32.449	36.114	2,364.14
8/17/2020	39.562	-121.497	242.06	2.942	4.856	7.798	2,304.93
8/17/2020	39.627	-120.039	149.40	2.079	4.779	6.858	2,183.74
8/17/2020	39.648	-120.052	145.62	1.975	4.540	6.515	2,185.33
8/17/2020	39.686	-120.176	111.20	1.152	2.647	3.799	2,196.64
8/17/2020	39.698	-120.197	125.42	1.465	3.368	4.833	2,198.68
8/17/2020	40.276	-120.764	247.11	4.824	29.521	34.345	2,260.31
8/17/2020	40.285	-120.762	247.11	4.824	29.521	34.345	2,260.38
8/17/2020	41.204	-123.414	247.11	16.135	98.747	114.882	2,501.73

Q = 524.642 tons $Distance_{weighted}$ = 2292.17 km Q/D_w = 0.23

Table A-15: Estimations of Southern California Wildfire Emissions on August 15, 2020 Based on NCAR's FINN Inventory

Date	Latitude	Longitude	Size (acres)	NO_X Emissions (tons)	NMOC Emissions (tons)	Q (tons)	Distance (km)
8/15/2020	34.635	-118.587	209.67	2.207	3.643	5.851	1,997.43
8/15/2020	34.659	-118.564	244.61	3.004	4.959	7.963	1,995.29
8/15/2020	34.673	-118.540	239.54	5.095	8.410	13.505	1,993.07

Q = 27.318 tons $Distance_{weighted}$ = 1994.65 km Q/D_w = 0.01

Table A-16: Estimations of Southern California Wildfire Emissions on August 16, 2020 Based on NCAR's FINN Inventory

Date	Latitude	Longitude	Size (acres)	NO_x Emissions (tons)	NMOC Emissions (tons)	Q (tons)	Distance (km)
8/16/2020	34.195	-117.919	247.11	3.066	5.061	8.127	1,937.20
8/16/2020	34.196	-117.903	242.11	6.021	9.940	15.962	1,935.72
8/16/2020	34.209	-117.915	247.11	3.066	5.061	8.127	1,936.78
8/16/2020	34.216	-117.906	242.11	2.943	4.858	7.802	1,935.93
8/16/2020	34.219	-117.894	229.63	2.647	4.370	7.018	1,934.81
8/16/2020	34.673	-118.588	219.65	2.422	3.999	6.421	1,997.47
8/16/2020	34.679	-118.568	234.63	2.764	4.563	7.326	1,995.63
8/16/2020	34.681	-118.554	244.63	5.492	9.066	14.558	1,994.34
8/16/2020	34.684	-118.555	244.63	5.492	9.066	14.558	1,994.43
8/16/2020	34.686	-118.584	247.11	5.658	9.341	14.999	1,997.08
8/16/2020	34.686	-118.541	247.11	4.824	29.521	34.345	1,993.14
8/16/2020	34.687	-118.526	247.11	3.066	5.061	8.127	1,991.77
8/16/2020	34.698	-118.527	242.11	2.943	4.858	7.802	1,991.85
8/16/2020	35.249	-115.627	69.19	0.240	0.397	0.637	1,728.33
8/16/2020	35.250	-115.641	77.38	0.301	0.496	0.797	1,729.61
8/16/2020	35.255	-115.597	69.89	0.245	0.405	0.650	1,725.64
8/16/2020	35.259	-115.625	69.89	0.245	0.405	0.650	1,728.21
8/16/2020	35.264	-115.581	82.37	0.341	0.562	0.903	1,724.24
8/16/2020	35.265	-115.595	71.66	0.258	0.426	0.683	1,725.52
8/16/2020	35.272	-115.652	69.19	0.240	0.397	0.637	1,730.74
8/16/2020	35.280	-115.556	89.86	0.405	0.669	1.075	1,722.07
8/16/2020	35.280	-115.497	91.43	0.420	0.693	1.113	1,716.71
8/16/2020	35.284	-115.664	59.90	0.180	0.297	0.478	1,731.90

Date	Latitude	Longitude	Size (acres)	NO_x Emissions (tons)	NMOC Emissions (tons)	Q (tons)	Distance (km)
8/16/2020	35.284	-115.586	97.34	0.476	0.785	1.261	1,724.82
8/16/2020	35.286	-115.563	99.84	0.500	0.826	1.327	1,722.74
8/16/2020	35.292	-115.648	74.13	0.276	0.455	0.731	1,730.50
8/16/2020	35.300	-115.632	79.87	0.320	0.529	0.849	1,729.10
8/16/2020	35.302	-115.647	64.90	0.211	0.349	0.561	1,730.47
8/16/2020	35.307	-115.610	92.35	0.428	0.707	1.135	1,727.14
8/16/2020	35.356	-115.586	69.89	0.245	0.405	0.650	1,725.28
8/16/2020	35.360	-115.566	59.90	0.180	0.297	0.478	1,723.49
8/16/2020	36.547	-121.608	185.33	3.199	7.354	10.553	2,275.02
8/16/2020	36.556	-121.667	239.62	2.883	4.759	7.641	2,280.35
8/16/2020	36.582	-121.635	227.34	2.595	4.283	6.878	2,277.63
8/16/2020	37.466	-121.763	177.92	2.948	6.777	9.726	2,295.75

Q = 204.582 tons $Distance_{weighted}$ = 2010.73 km Q/D_w = 0.10

Table A-17: Estimations of Southern California Wildfire Emissions on August 17, 2020 Based on NCAR's FINN Inventory

Date	Latitude	Longitude	Size (acres)	NO_x Emissions (tons)	NMOC Emissions (tons)	Q (tons)	Distance (km)
8/17/2020	34.684	-118.530	247.11	3.066	5.061	8.127	1,992.14
8/17/2020	34.694	-118.526	247.11	3.066	5.061	8.127	1,991.76
8/17/2020	34.699	-118.555	247.11	4.824	29.521	34.345	1,994.41
8/17/2020	35.261	-115.555	82.37	0.341	0.562	0.903	1,721.86
8/17/2020	35.291	-115.492	74.88	0.282	0.465	0.746	1,716.33
8/17/2020	35.678	-119.293	155.38	3.578	31.681	35.259	2,062.83
8/17/2020	36.191	-119.148	175.97	4.589	40.635	45.224	2,052.43
8/17/2020	36.840	-120.411	174.10	4.492	39.775	44.267	2,170.30
8/17/2020	37.443	-121.418	147.89	2.037	4.683	6.720	2,265.12
8/17/2020	37.447	-121.441	148.26	2.047	4.707	6.754	2,267.19
8/17/2020	37.451	-121.774	247.11	3.066	5.061	8.127	2,296.57
8/17/2020	37.452	-121.410	151.29	2.132	4.901	7.032	2,264.51
8/17/2020	37.455	-121.432	166.61	2.585	5.943	8.529	2,266.48
8/17/2020	37.458	-121.455	166.42	2.580	5.930	8.509	2,268.53
8/17/2020	37.462	-121.784	247.11	3.066	5.061	8.127	2,297.56
8/17/2020	37.467	-121.453	157.25	2.303	5.294	7.597	2,268.45
8/17/2020	37.472	-121.793	242.11	2.943	4.858	7.801	2,298.45
8/17/2020	37.476	-121.451	159.12	2.358	5.421	7.779	2,268.37
8/17/2020	37.481	-121.791	239.62	2.883	4.759	7.641	2,298.37
8/17/2020	37.481	-121.428	170.20	2.698	6.202	8.900	2,266.39
8/17/2020	37.488	-121.471	174.21	3.247	7.463	10.709	2,270.25
8/17/2020	37.498	-121.844	247.11	5.493	9.068	14.562	2,303.20
8/17/2020	37.499	-121.480	159.38	2.366	5.439	7.805	2,271.16

Q = 303.592 tons $Distance_{weighted}$ = 2153.84 km Q/D_w = 0.14

APPENDIX B: PUBLIC COMMENTS

Note to reviewers:

All public comments received will be placed here for submission to the Environmental Protection Agency.