APPENDIX F:

2016–2024 Ozone Technical Supporting Documents and Atypical Event Demonstrations

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1. 2016 Ozone Technical Supporting Documents

This document includes technical analyses conducted by the Clark County Department of Environmental Sustainability (DES), Division of Air Quality, assessing the likelihood that emissions from several large California wildfires impacted air quality within the Las Vegas Valley (LVV) on specific days during the summer of 2016. This report supports the selection of fire-influenced "exceptional event-like days" during 2016 that are referenced in the Weight of Evidence portion of the Clark County Moderate Ozone Nonattainment Area State Implementation Plan (SIP).

1.1 Clark County and Nonattainment Area Description

Clark County covers 20,956 km^2 at the southern tip of Nevada and has a population of over 2.2 million. More than 95% of the county's residents live in the LVV, which is part of the Mojave Desert and constitutes Hydrographic Area (HA) 212. The valley encompasses about 1,600 km^2 and is surrounded by mountains extending 2,000 to 10,000 feet above its floor (**Figure 1**). The valley slopes downward from west to east (approximately 900 to 500 m above mean sea level). The terrain within and surrounding the LVV affects the local climatology by driving variations in wind, temperature, and precipitation.

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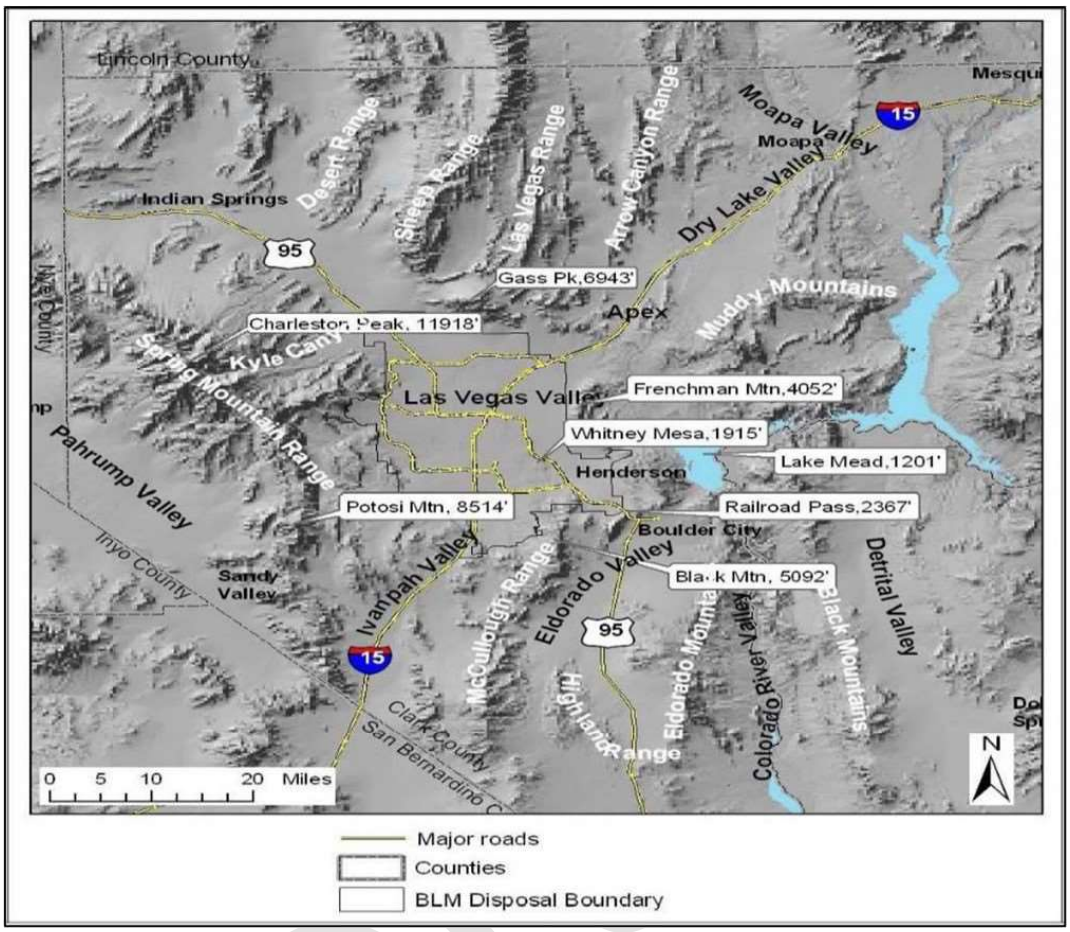

Figure 1. Mountain ranges and hydrographic areas surrounding the Las Vegas Valley.

Valley weather is characterized by low rainfall, hot summers, and mild winters. On average, June is the driest month, whereas monsoons from the Gulf of California increase humidity and cloud cover during July and August. The Interstate 15 (I-15) corridor from Cajon Pass in California through the Mojave Desert links Las Vegas with the eastern Los Angeles Basin, about 275 km to the southwest. This corridor is a potential pathway for the export of pollution from Los Angeles to the Mojave Desert and the LVV.

Figure 2 shows the locations of Clark County ozone monitors. Most of the stations, including Paul Meyer (PM), Walter Johnson (WJ), Palo Verde (PV), Joe Neal (JO), Jerome Mack (JM), and Green Valley (GV), are within the populated areas of the LVV, but there are other outlying stations at Apex (AP), Mesquite (MQ), Boulder City (BC), Jean (JN), and Indian Springs (IS). An additional station at the Spring Mountain Youth Camp (SM, approximately 2.58 km above sea level) was operated as a special purpose monitoring site.

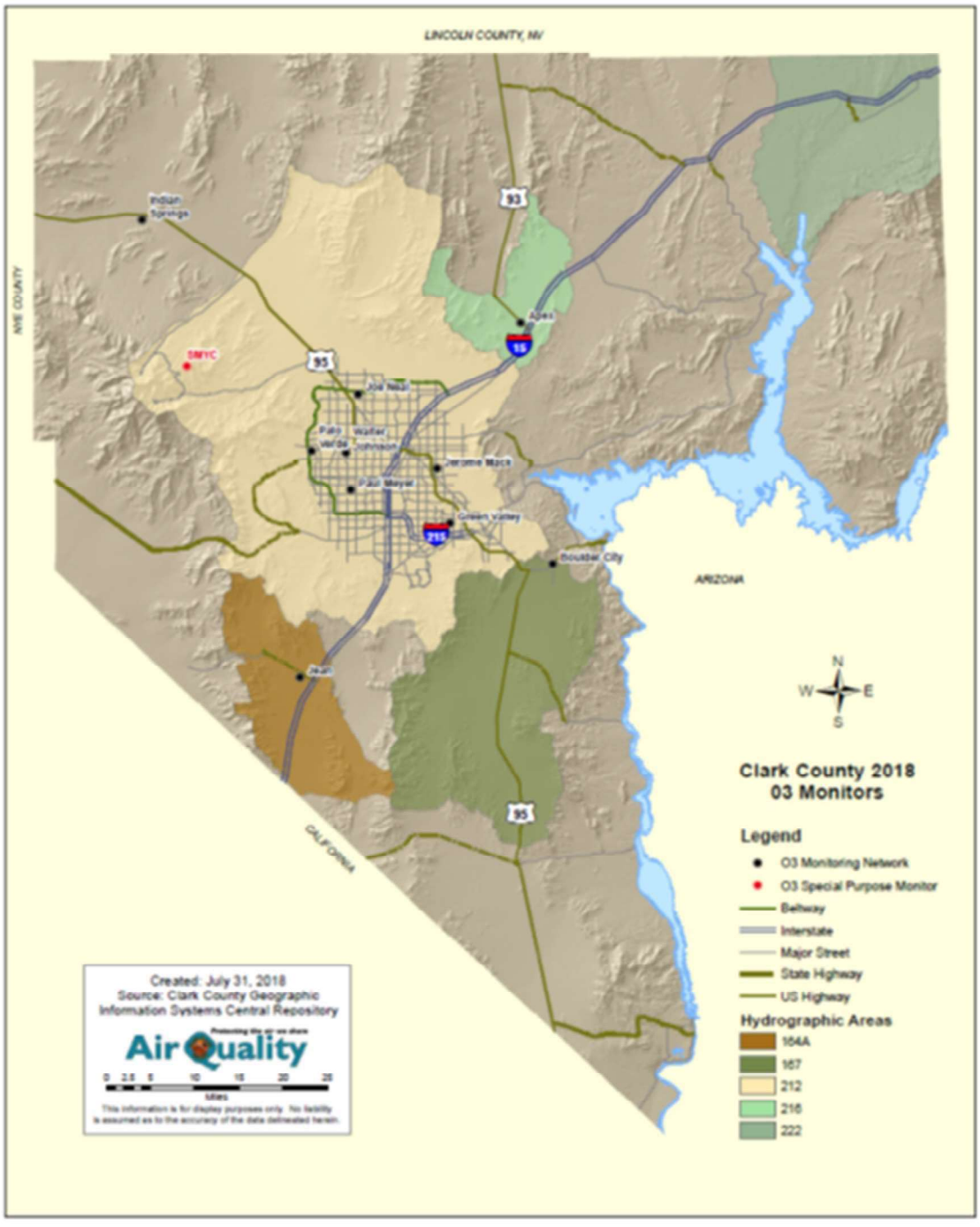

Figure 2. Map of Clark County showing the 2018 ozone monitoring network, hydrographic areas, and major roadways.

Figure 3 and Figure 4 show the locations of Clark County's Federal Equivalent Method (FEM) and Federal Reference Method (FRM) $PM_{2.5}$ monitors, respectively. Most of the stations are within the populated areas of the LVV, with one outlying station in Jean, Nevada. Jean is considered a regional background site because (1) it is located far enough from the valley to avoid impacts from local

emissions, and (2) it is upwind of the LVV during the summer season and senses pollution entering the LVV from southern California.

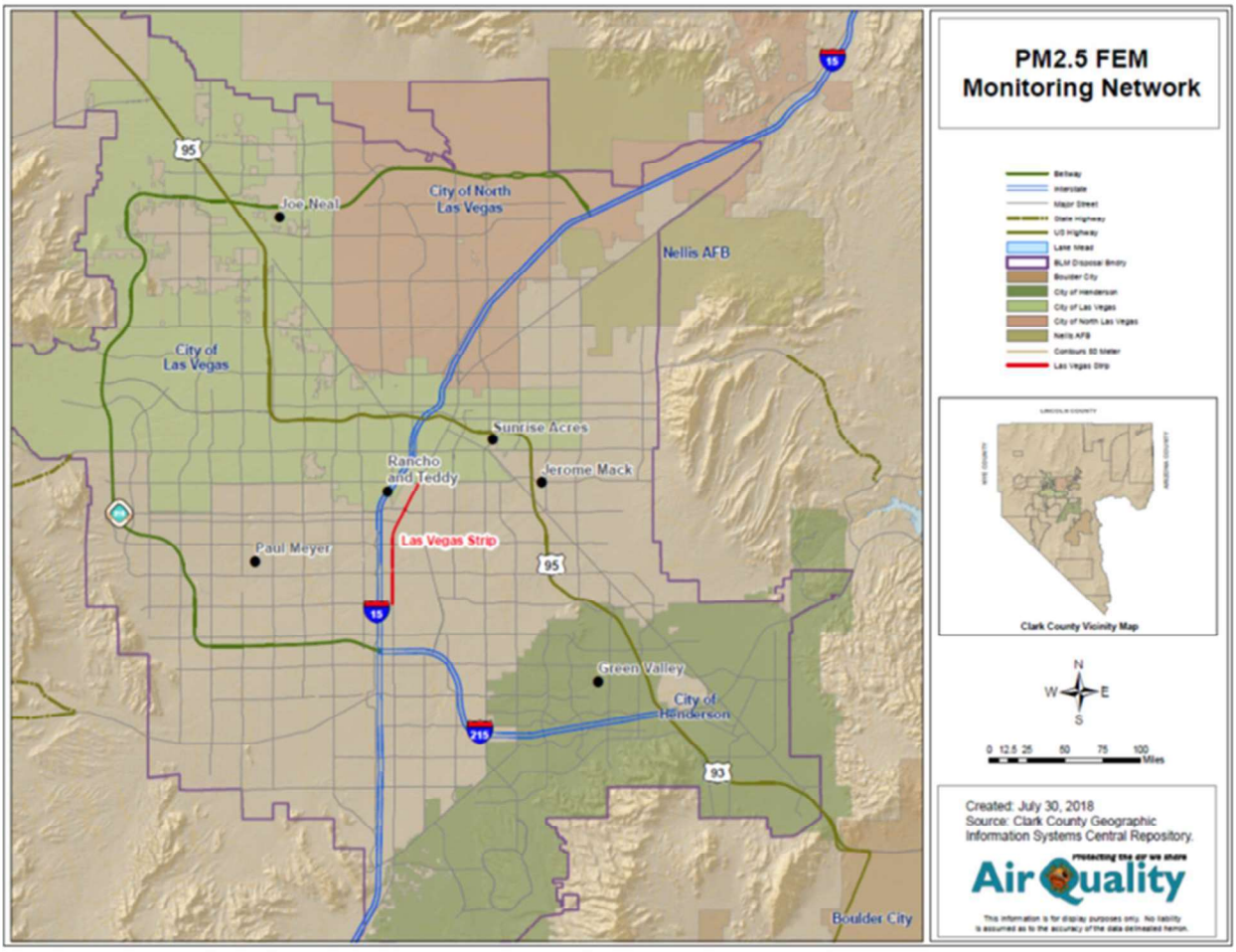

Figure 3. Locations of FEM $PM_{2.5}$ monitors within the LVV in 2018. The Jean FEM monitor (not shown) is located well south of the valley along I-15 (see Figure 2).

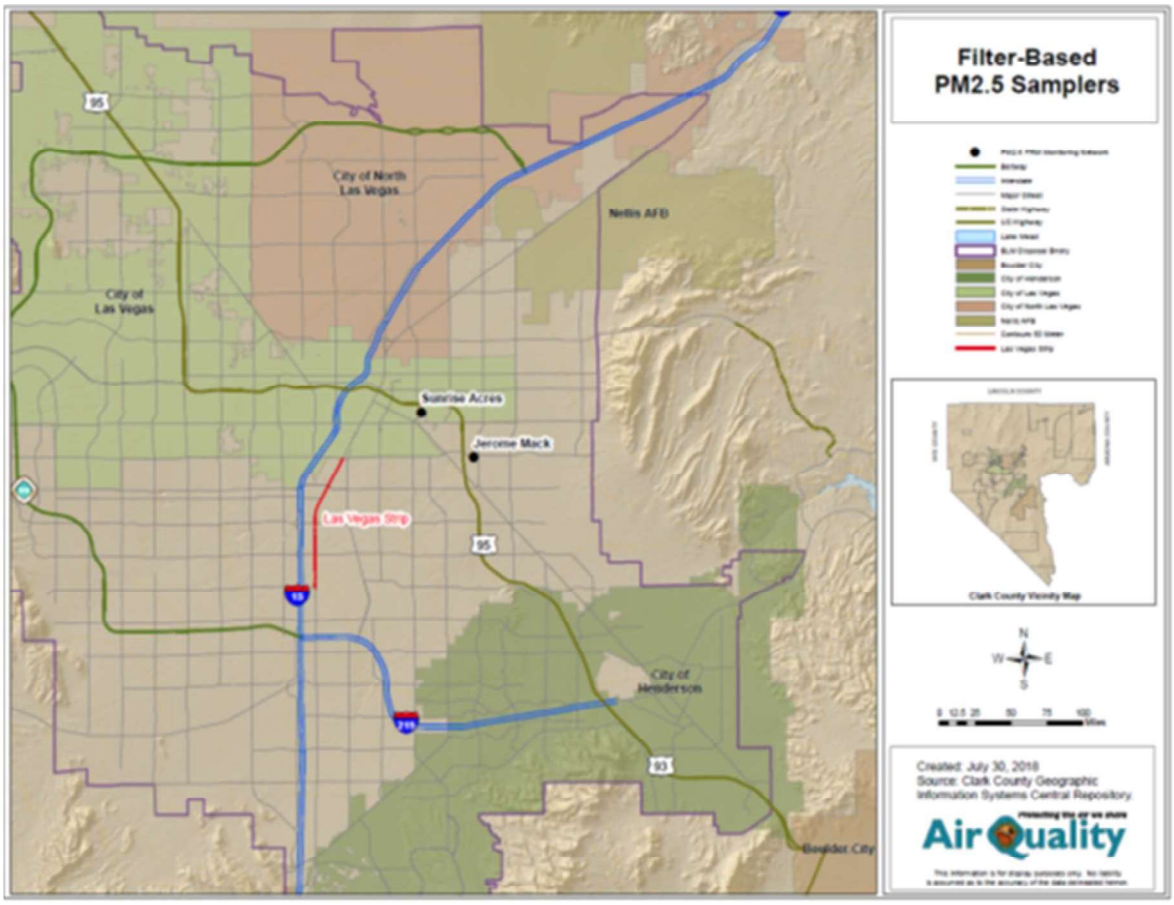

Figure 4. Locations of FRM $PM_{2.5}$ monitors within the LVV in 2018.

1.2 Prevailing Meteorological Conditions

During the summer season, the weather across the Mojave Desert is dictated by a semi-permanent surface thermal low-pressure system. Thermal lows are caused by intense surface heating and strong capping subsidence aloft associated with broad upper-level high pressure ridging. Therefore, thermal lows are relatively shallow, extending from 850 hPa (approximately 1,500 m) to 700 hPa (approximately 3,000 m) within the lower troposphere. Based on a study of synoptic climatology of thermal lows over southwestern North America (Rowson et al., 1992[1]), this system is most prevalent from mid-June through mid-September and reaches its maximum vertical extent near 700 hPa in July and early August. The low normally extends across the Mojave, Yuma, and Sonora Deserts and the plateau highlands of the Sierra Madre Occidental. Resulting surface winds in southern Nevada are most frequently northwesterly from central/northern California and southerly from Mexico and southern California. As a result, there is a strong link between the ozone concentration in the LVV

[1] Rowson, D. and Colucci S., 1992. Synoptic Climatology of Thermal Low-Pressure Systems over South-Western North America. *International Journal of Climatology*, vol. 12: 529-545.

and the smoke from wildfires in California and Mexico. Moreover, the meteorological conditions associated with thermal lows enhance vertical mixing of smoke-generated ozone plumes within the lowest 3,000 m and downward subsidence of plumes above that altitude. All of these factors help to elevate episodic ozone concentration in the LVV.

1.3 2016 California Wildfire Events

1.3.1 Summary of 2016 Wildfire Frequency

Western U.S. wildfire frequencies and intensities are increasing every year. They are bigger, hotter, and more deadly and destructive. In 2016, a total of 6,954 fires had burned 669,534 acres in California, according to the California Department of Forestry and Fire Protection (CAL FIRE). The number of fires and burned area increased greatly in June, July, and August, as shown in Figure 5 from the 2016 Wildfire Activity Statistics report published by CAL FIRE. Table 1 lists all fires that exceeded 1,000 acres from May through September of 2016. Starting in June, significant wildfires broke out, such as Erskine fire. Later, a series of large wildfires erupted across California, mostly in the southern part of the state, including the destructive Sand and Soberanes fires in July and the Chimney, Blue Cut, Cedar, Rey, and Gap fires in August. As shown in Figure 6, more frequent LVV ozone exceedances after mid-June coincided with these California wildfire events. Table 2 shows the maximum daily 8-hr average (MDA8) ozone recorded at LVV monitoring site on days impacted by 2016 wildfires. Details for each event are presented below.

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Table 1. List of fires exceeding 1,000 acres during the 2016 California wildfire season.

Name	County	Acres	Start Date	Containment Date	Notes
Roberts	San Luis Obispo	3,712	18-May-16	20-May-16	
Metz	Monterey	3,876	22-May-16	25-May-16	
Coleman	Monterey	2.520	4-Jun-16	17-Jun-16	
Pony	Siskiyou	2,860	7-Jun-16	30-Jun-16	
Sherpa	Santa Barbara	7,474	15-Jun-16	12-Jul-16	
Border	San Diego	7,609	19-Jun-16	30-Jun-16	2 fatalities, 5 hoes and 11 outbuildings destroyed
Pine	Ventura	2,304	19-Jun-16	17-Jul-16	
San Gabriel Complex	Los Angeles	5,399	20-Jun-16	23-Jul-16	Reservoir Fire burned 1,146 acres; Fish Fire burned 4,253 acres
Erskine	Kern	48,019	23-Jun-16	12-Jul-16	2 fatalities, 285 homes destroyed, 12 damaged
Trailhead	Placer	5,646	28-Jun-16	18-Jul-16	
Deer	Kern	1,785	1-Jul-16	11-Jul-16	
Curry	Fresno	2,944	1-Jul-16	5-Jul-16	

Name	County	Acres	Start Date	Containment Date	Notes
Sage	Los Angeles	1,109	9-Jul-16	16-Jul-16	
Roblar	San Diego	1,245	21-Jul-16	30-Jul-16	
Sand	Los Angeles	41,432	22-Jul-16	3-Aug-16	2 fatalities, 18 homes destroyed, 4 damaged
Soberanes	Monterey	132,100	22-Jul-16	12-Oct-16	1 fatality, 3 injuries, 57 homes and 11 outbuildings destroyed
Goose	Fresno	2,241	30-Jul-16	9-Aug-16	4 homes, 5 outbuildings destroyed
Cold	Yolo	5,731	2-Aug-16	12-Aug-16	2 outbuildings destroyed
Pinot	San Bernardino	8,110	7-Aug-16	16-Aug-16	
Mineral	Fresno	7,050	9-Aug-16	18-Aug-16	2 structures destroyed
Chimney	San Luis Obispo	46,344	13-Aug-16	6-Sep-16	48 structures destroyed
Clayton	Lake	3,929	13-Aug-16	26-Aug-16	300 buildings destroyed
Blue Cut	San Bernardino	36,274	16-Aug-16	23-Aug-16	105 homes, 213 outbuildings destroyed
Cedar	Kern	29,322	16-Aug-16	30-Sep-16	
Rey	Santa Barbara	32,606	18-Aug-16	16-Sep-16	
Gap	Siskiyou	33,867	27-Aug-16	17-Sep-16	
Bogart	Riverside	1,470	30-Aug-16	2-Sep-16	1 outbuilding destroyed
Willard	Lassen	2,575	11-Sep-16	22-Sep-16	5 structures destroyed
Owens River	Mono	5,443	17-Sep-16	15-Oct-16	
Canyon	Santa Barbara	12,518	17-Sep-16	24-Sep-16	1 firefighter killed in crash
Sawmill	Sonoma	1,547	25-Sep-16	29-Sep-16	
Marshes	Tuolumne	1,080	26-Sep-16	4-Oct-16	
Loma	Santa Clara	4,474	26-Sep-16	12-Oct-16	28 structures destroyed

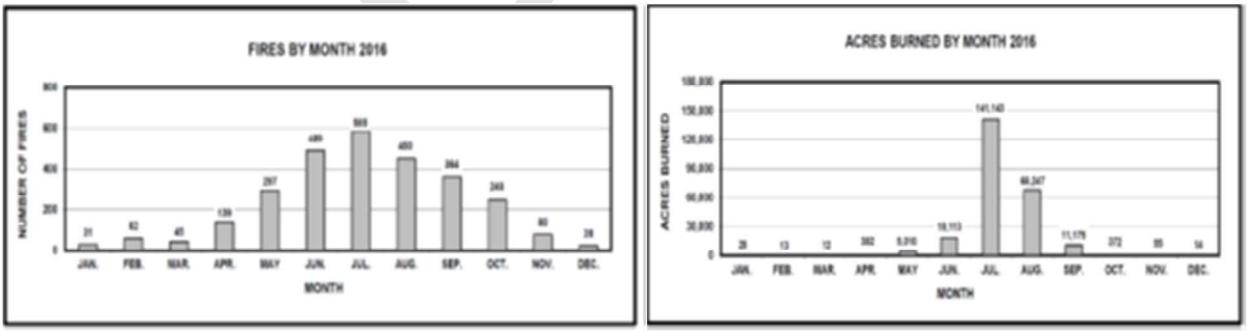

Figure 5. Number of fires and acres burned by month in 2016 (CAL FIRE, reference).

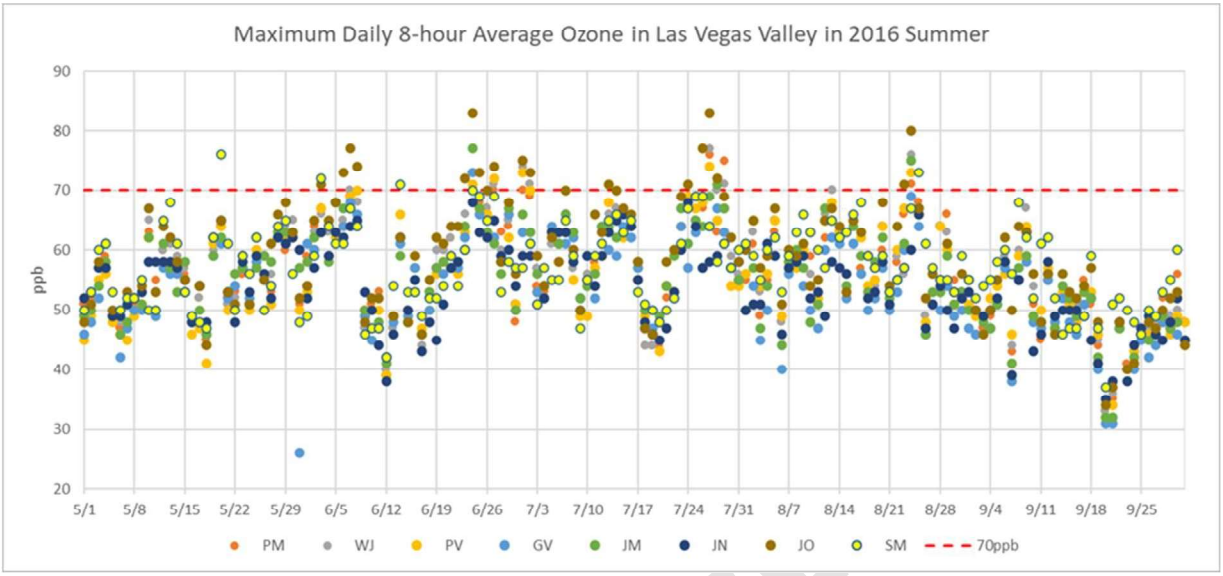

Figure 6. MDA8 ozone (ppb) at LVV monitors during the 2016 ozone season.

Table 2. MDA8 ozone (ppb) during days influenced by wildfires during the 2016 ozone season. "EE-like" days (red) are identified as impacted by wildfire smoke.

Date	PM	WJ	PV	GV	JM	JO	AP	JN	EE-like
6/24/2016	73	73	71	73	77	83	84	68	Y
6/25/2016	68	69	67	66	67	73	64	63	Y
6/26/2016	67	67	66	65	63	70	66	62	N
6/27/2016	70	71	72	62	61	74	57	65	Y
7/24/2016		69	69	57	61	71	48	68	Y
7/25/2016		65	67	63	65	69	65	64	N
7/26/2016	67	69	68	57	64	77	63	57	Y
7/27/2016	76	77	74	64	69	83	62	58	Y
7/28/2016	63	70	65	67	71	72	67	59	Y
7/29/2016	75	71	67	63	67	69	64	61	Y
8/23/2016	66	56	67	60	61	71	57	57	N
8/24/2016	71	76	73	69	75	80	68	60	Y

1.3.2 June 24-27, 2016

The Erskine Fire in Kern County, California was the second-largest wildfire of 2016 (Figure 7). It started on the afternoon of June 23, and by the evening of June 24, the fire had grown to over 30,000 acres with 5% containment. On July 11 the fire was 100% contained and the total burned area was ~47,864 acres.

Figure 7. Location and size of the Erskine Fire.

Figure 8 presents the upper-air synoptic weather patterns at 500 hPa (approximately 5,500 m) over June 22-27. A large trough of low pressure moved into the Pacific Northwest on June 22-23 and pushed across the intermountain western U.S. through June 25. An upper-level high pressure ridge was subsequently reestablished over the western U.S. As the high pressure strengthened over the region, winds lessened and conditions over southern Nevada became dry and very hot. Airflow over the region was mainly southwesterly on June 24 and shifted to northwesterly on June 25. During June 26-27, weak airflow shifted back from southwesterly to southeasterly. Consequently, elevated smoke from Erskine Fire was likely transported across the Mohave Desert and over the LVV, where a combination of strong subsidence and vertical mixing brought ozone and precursors to the surface.

At the surface, a weak stationary front passed through central Nevada (Figure 9) while a persistent thermal low system existed over southern Nevada. As a result, winds were light but ranged from westerly to southwesterly, bringing smoky air from the Erskine fire into the LVV. This weather pattern produced abundant sunshine, high temperatures, and low wind speeds, contributing to strong ozone generation with suppressed dilution. Therefore, this elevated ozone period was likely enhanced by the Erskine fire to exceed the ozone NAAQS, except perhaps during June 26 when ozone was likely diluted by a relatively deep mixing layer.

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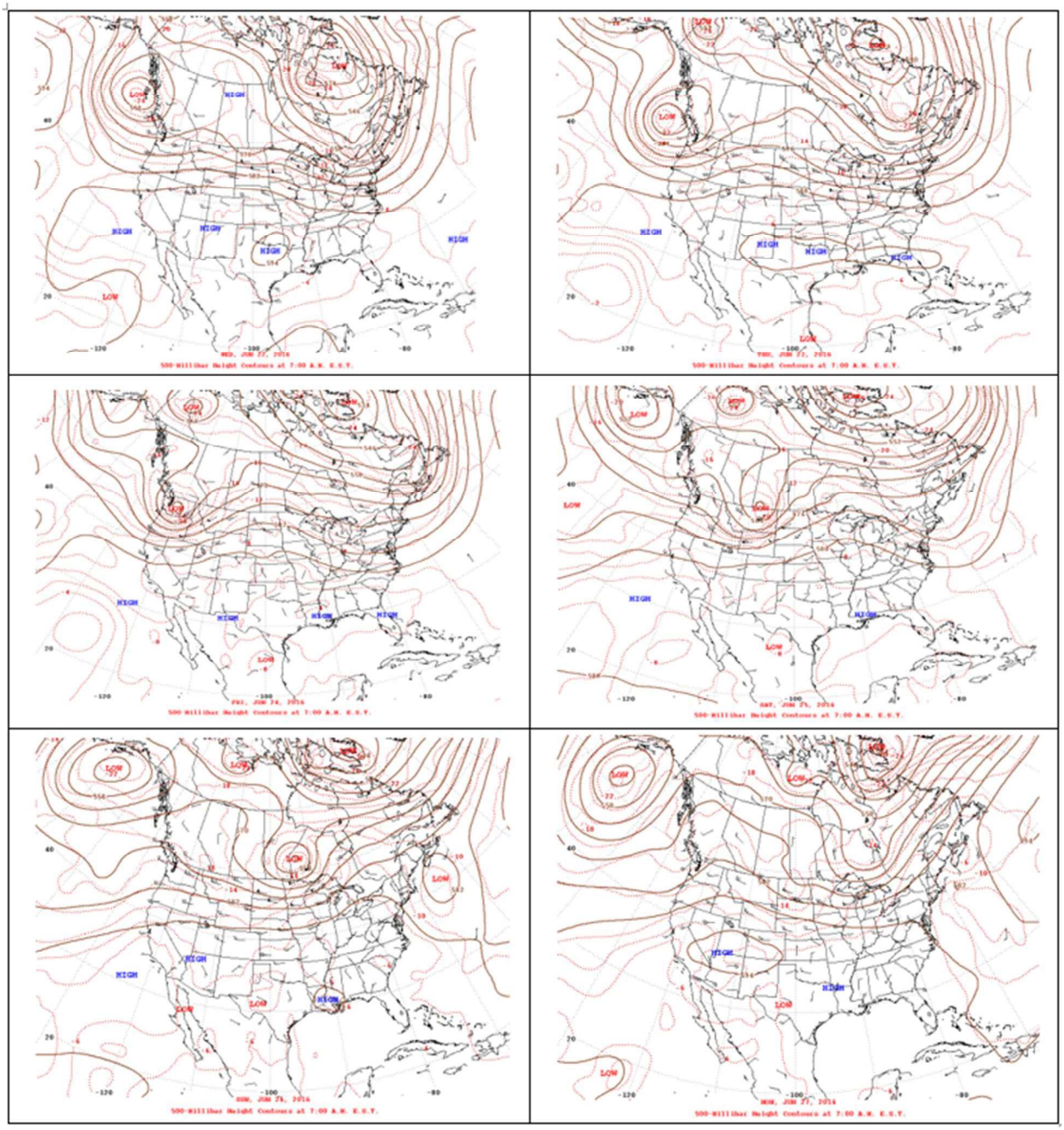

Figure 8. 500 hPa (approximately 5,500 m) weather patterns at 07:00 EST (04:00 PST) from June 22 to 27, 2016.

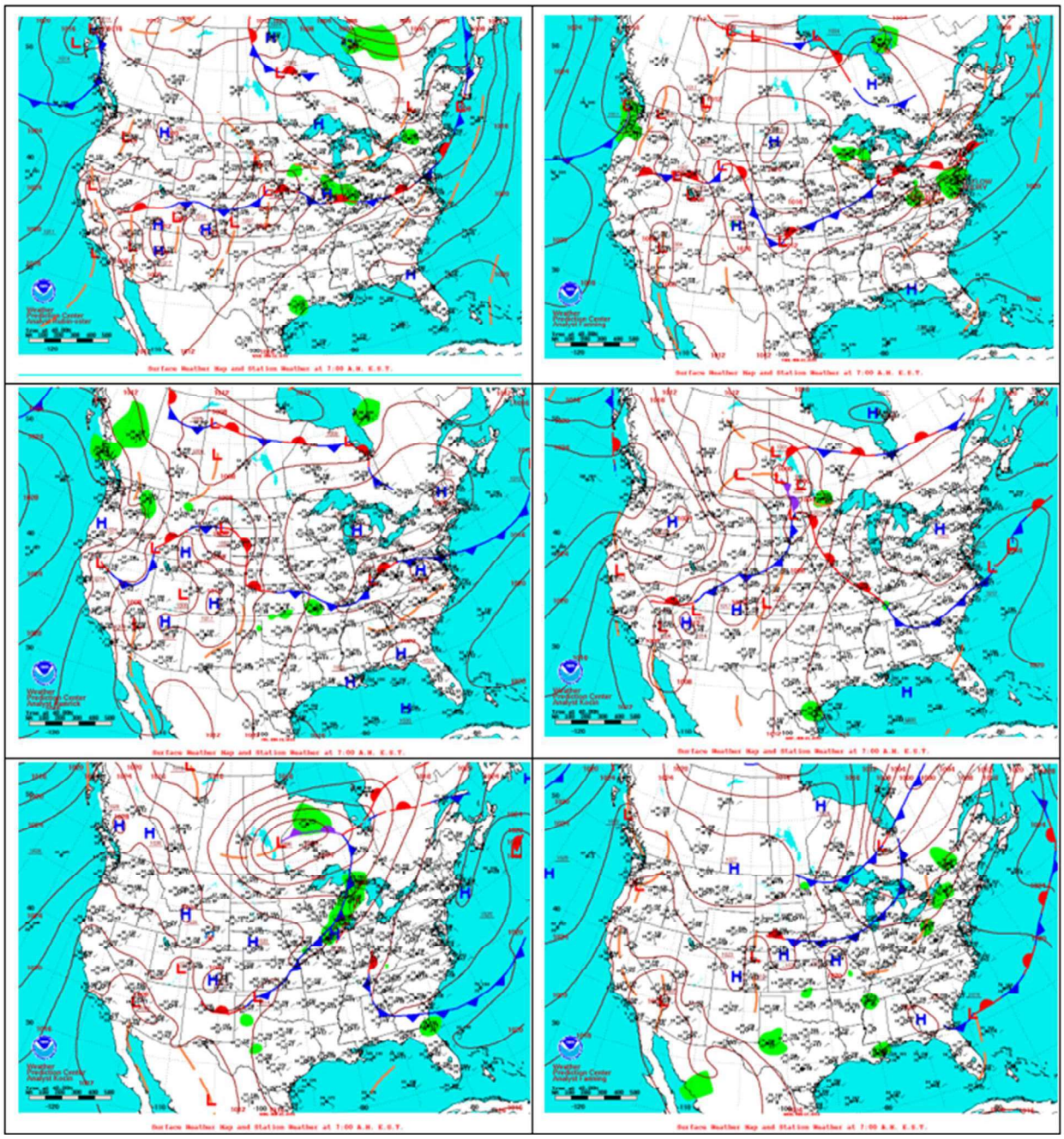

Figure 9. Surface weather patterns at 07:00 EST (04:00 PST) from June 22 to 27, 2016.

Figure 10 presents a visible satellite image showing smoke from the Erskine fire extending over Clark County on June 24. Figure 11 shows 24-hr backward trajectories of airflow arriving in Las Vegas at 13:00 PST during June 24-27 at altitudes of 20, 200 and 2,000 m, along with National Oceanic and Atmospheric Administration (NOAA) Hazard Mapping System (HMS) smoke maps overlaid. Large areas of regional smoke, including from the Erskine fire, existed over or near the LVV on all days. The shorter backward trajectories starting on June 25 corroborate the low windspeeds associated with

the dominant high-pressure conditions over the region, as described above. Figure 12 and Figure 13 show very high ozone and $PM_{2.5}$ concentrations associated with the smoke arriving in Las Vegas on June 24, resulting in most stations exceeding the NAAQS. Ozone at the elevated Spring Mountain site also provides evidence of an elevated layer of ozone arriving on this date and maintaining very high concentrations above 60 ppb throughout June 24-27. Figure 14 and Figure 15 show the hourly seasonal percentiles for ozone and $PM_{2.5}$ from 2014-2019 (May-August) compared to measured hourly ozone and $PM_{2.5}$ on June 24-27, 2016, at LVV sites and Jean (outlying site). Figure 14 shows the most excessive ozone on June 24, 2016, at the monitors in the valley and Jean. Figure 15 shows the most excessive $PM_{2.5}$ on June 24-25, 2016. All figures support the conclusion that wildfire smoke had been transported to the LVV.

Table 3 compares MDA8 ozone during June 24-27 against historical 95th percentile MDA8 ozone from 2014 to 2018 at monitoring sites with sufficient data. On June 24, MDA8 ozone exceeded the 95th percentile at all monitoring sites. Taken together, there is strong evidence that MDA8 ozone in the LVV was enhanced by emissions from the Erskine fire during this event.

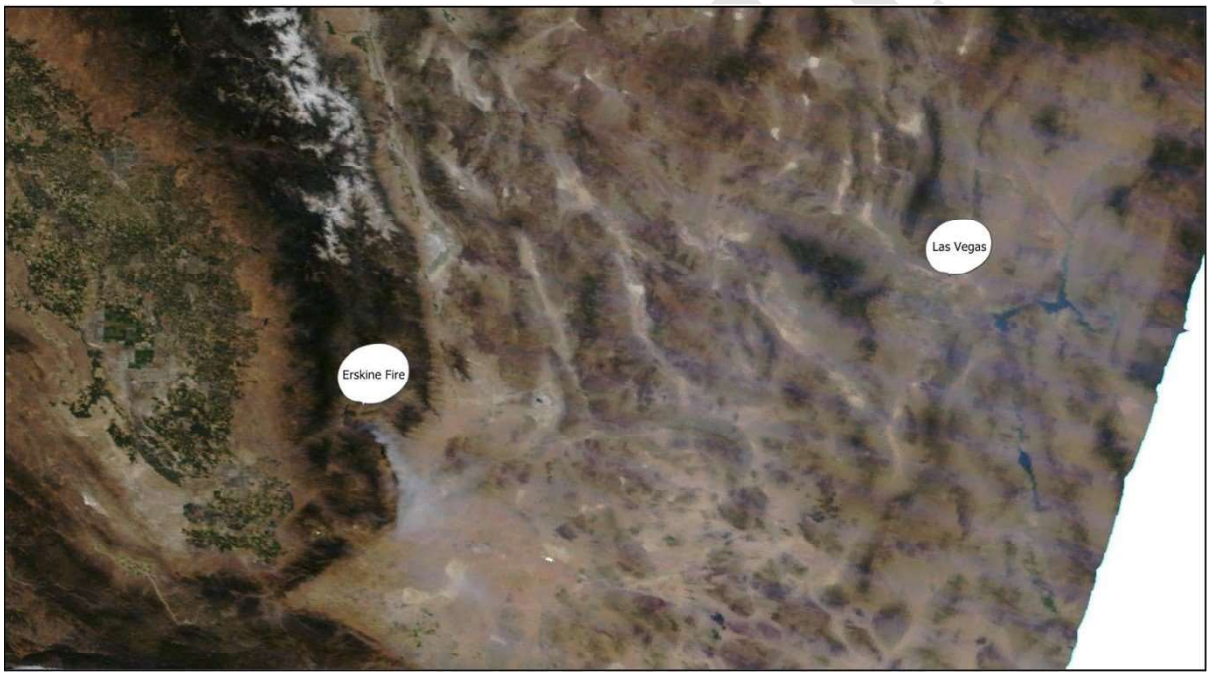

Figure 10. Visible satellite imagery of southern California and Nevada on June 24, 2016.

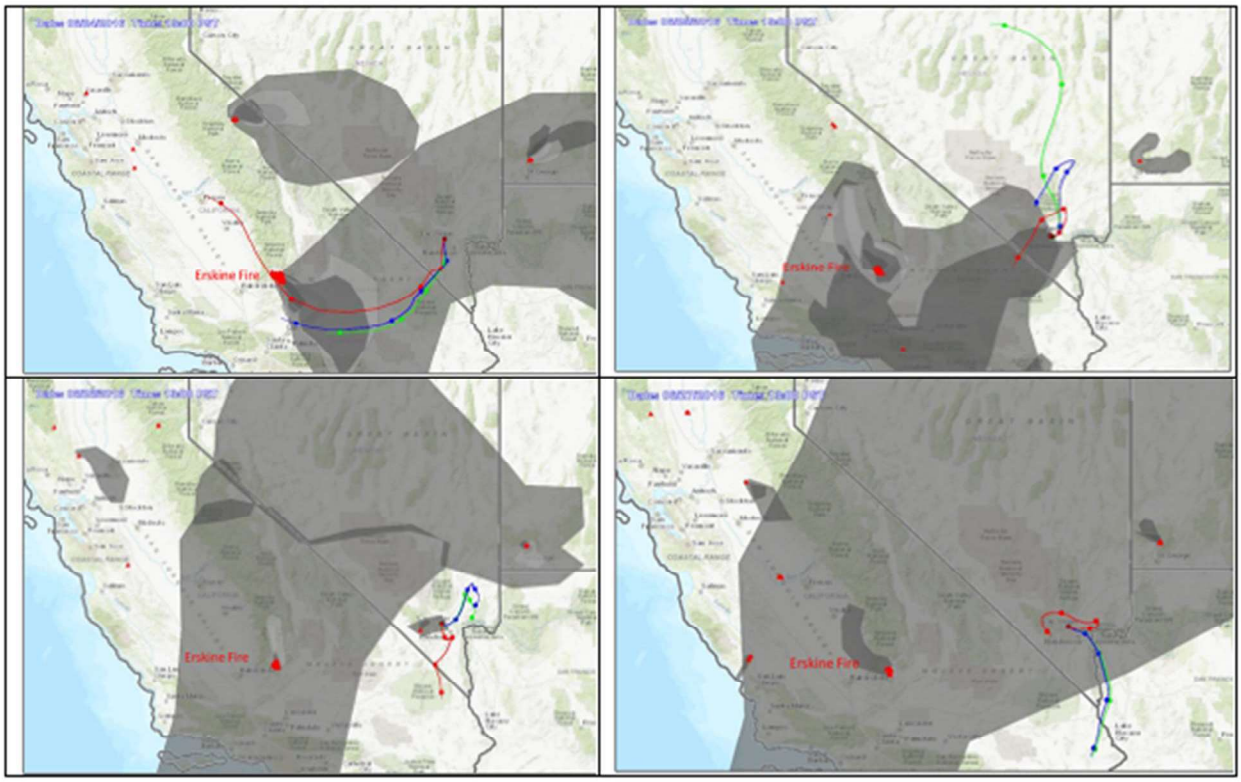

Figure 11. 24-hr backward trajectories arriving in Las Vegas at 13:00 PST on June 24-27, 2016, at altitudes of 20 m (green), 200 m (blue), and 2,000 m (red).

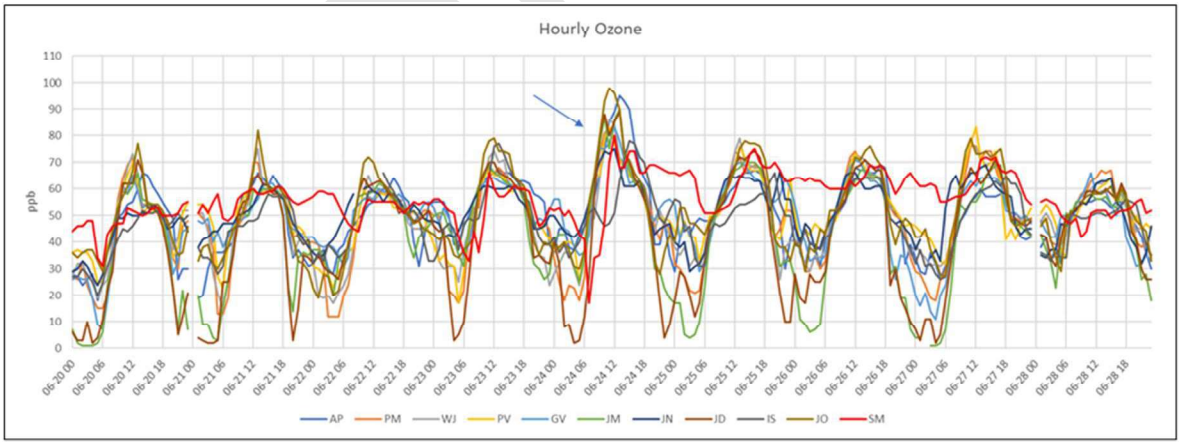

Figure 12. Time series of 1-hr ozone (ppb) at all LVV monitors during June 20-28, 2016.

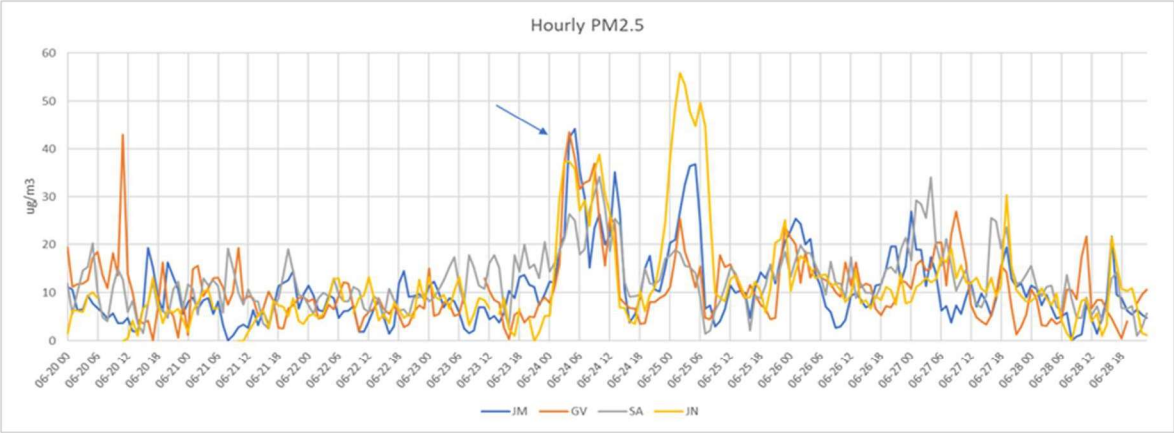

Figure 13. Time series of 1-hr $PM_{2.5}$ concentration (µg/m^3) at LVV FEM monitors during June 20-28, 2016.

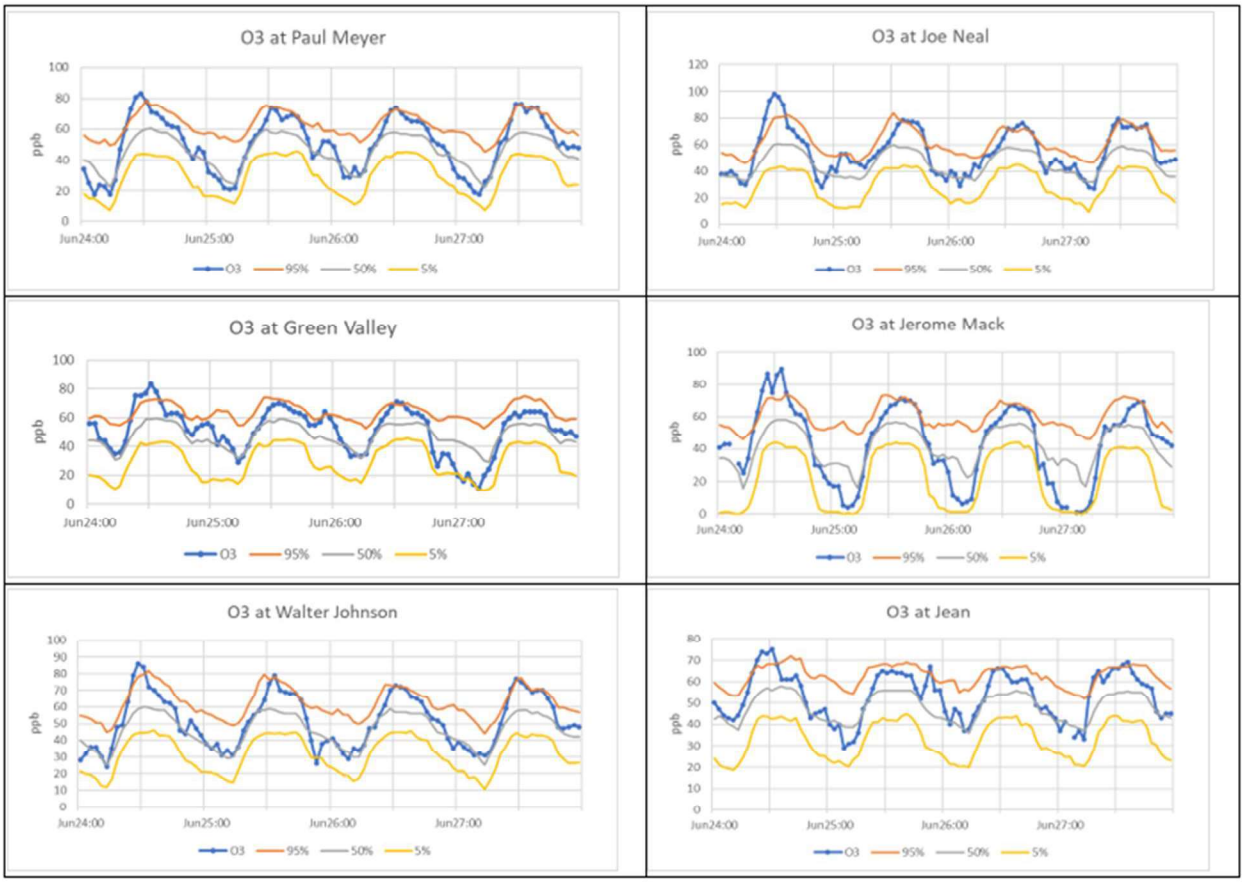

Figure 14. 6-yr hourly seasonal 95th, 50th, and 5th percentiles for ozone concentrations at the Paul Meyer, Joe Neal, Green Valley, Jerome Mack, Walter Johnson, and Jean monitoring sites during June 24-27, 2016.

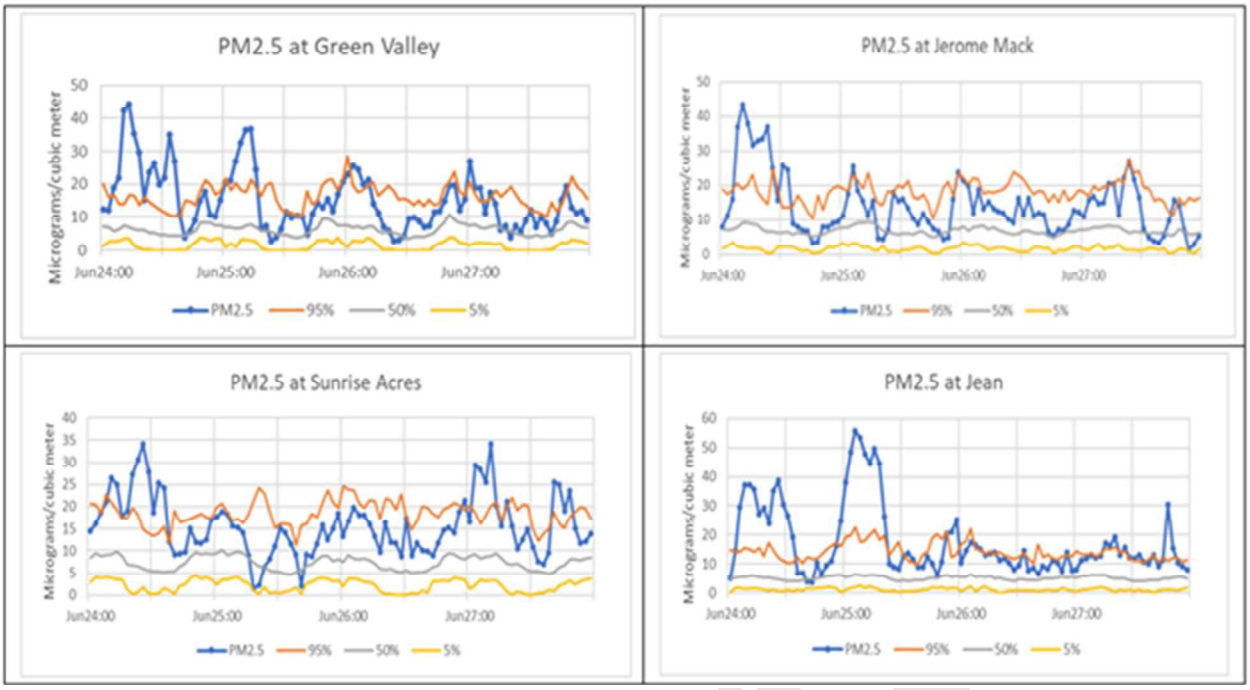

Figure 15. 6-yr hourly seasonal 95th, 50th, and 5th percentiles for $PM_{2.5}$ concentrations ($\mu g/m^3$) at LVV FEM monitors during June 24-27, 2016.

Table 3. Comparison of MDA8 ozone (ppb) during June 24-27 against 2014-2018 95th percentile MDA8 ozone concentrations.

2014-2018 (ppb)	PM	WJ	PV	GV	JM	JO	AP	JN
6/24	73	73	71	73	77	83	84	68
6/25	68	69	67	66	67	73	64	63
6/26	67	67	66	65	63	70	66	62
6/27	70	71	72	62	61	74	57	65
95th percentile	71	72	70	71	70	73	70	68

1.3.3 July 24-29, 2016

The Sand fire started during the afternoon of July 22 within the Angeles National Forest east of Santa Clarita, California (Figure 16). By the evening of July 23, the fire had grown to 20,000 acres with 10% containment, while on the morning of July 25 the fire was reported to reach 33,000 acres with 10% containment. On July 28, the fire reached an estimated 38,346 acres and was 65% contained.

The upper-air synoptic weather patterns at 500 hPa during July 24-29 (Figure 17) show that a weak short-wave trough initially propagated across the western U.S., then was replaced by an eastern Pacific ridge that broadened across the western U.S. The ridge was a persistent feature that

dominated weather over the region for the remaining period. It was associated with light winds and deep subsidence from the upper troposphere that maintained clear skies and warm temperatures.

The surface analyses (Figure 18) show a weak trough associated with the upper-level trough propagated across Nevada on July 24, splitting the surface eastern Pacific high pressure. After the trough's passage on subsequent days, the thermal low system centered over Southern Nevada intensified with hot and dry conditions in the LVV throughout the period. On July 27, a transition to a widespread return of monsoonal moisture produced excessive heat resulting in extreme temperatures and low daytime wind speeds through July 29. During this event, airflow in the region varied from westerly to southerly and transported the smoke toward southern Nevada.

Figure 16. Location and size of the Sand fire.

Satellite imagery on July 23 (Figure 19) shows smoke from the Sand fire extending toward Clark County. Figure 20 shows 24-hr backward trajectories arriving at Las Vegas at 13:00 PST on July 24-29 at 100, 1,000 and 2,000 m with HMS smoke maps overlaid. Smoke remained over the LVV during July 24-26 while trajectories extended back toward the fire. On July 27 winds weakened substantially as shown by the shorter trajectory paths, leading to less ventilation that retained pollution within the LVV and promoted ozone production. Time series of ozone and $PM_{2.5}$ during July 22-30 (Figure 21 and Figure 22) show that smoke arrived in the LVV on July 23, after which ozone remained near or above 60 ppb at the high elevation Spring Mountain site (red). Figure 23 and Figure 24 show the hourly seasonal percentiles for ozone and $PM_{2.5}$ from 2014-2019 (May-August) compared to measured hourly ozone and $PM_{2.5}$ on July 24-27, 2016, at LVV sites and Jean. Figure 23 shows the diurnal ozone patterns are near or exceed 95th percentile on July 24-29, 2016, at the monitors in the valley and outlying site, Jean. Figure 24 shows the greatly elevated $PM_{2.5}$ on July 24-25, 2016. All figures support the conclusion that wildfire smoke had been transported to the LVV.

Table 4 compares MDA8 ozone against historical 95th percentile values from 2014 to 2018 at monitoring sites with sufficient data. During this event, the Sand fire burned during the entire period with an airflow pattern that consistently brought smoke toward the Las Vegas area. Strong and persistent high pressure dominated the region, resulting in continuous smoke and poor air quality in the Las Vegas Valley. On July 24, MDA8 ozone exceeded the 95th percentile at Jean (the upwind transport site). On July 26, MDA8 ozone exceeded the 95th percentile at Joe Neal; on July 27, MDA8 ozone exceeded the 95th percentile at Paul Meyer, Walter Johnson, Palo Verde and Joe Neal; on July 28, MDA8 ozone exceeded the 95th percentile at Jerome Mack; and on July 29, MDA8 ozone exceeded the 95th percentile at Paul Meyer. Although ozone reached extreme levels at just a single site on several days during this event, the western valley sites experienced relatively elevated high ozone too. Thus, these analyses provide evidence that ozone in the Las Vegas Valley was significantly impacted by the Sand Fire during this event.

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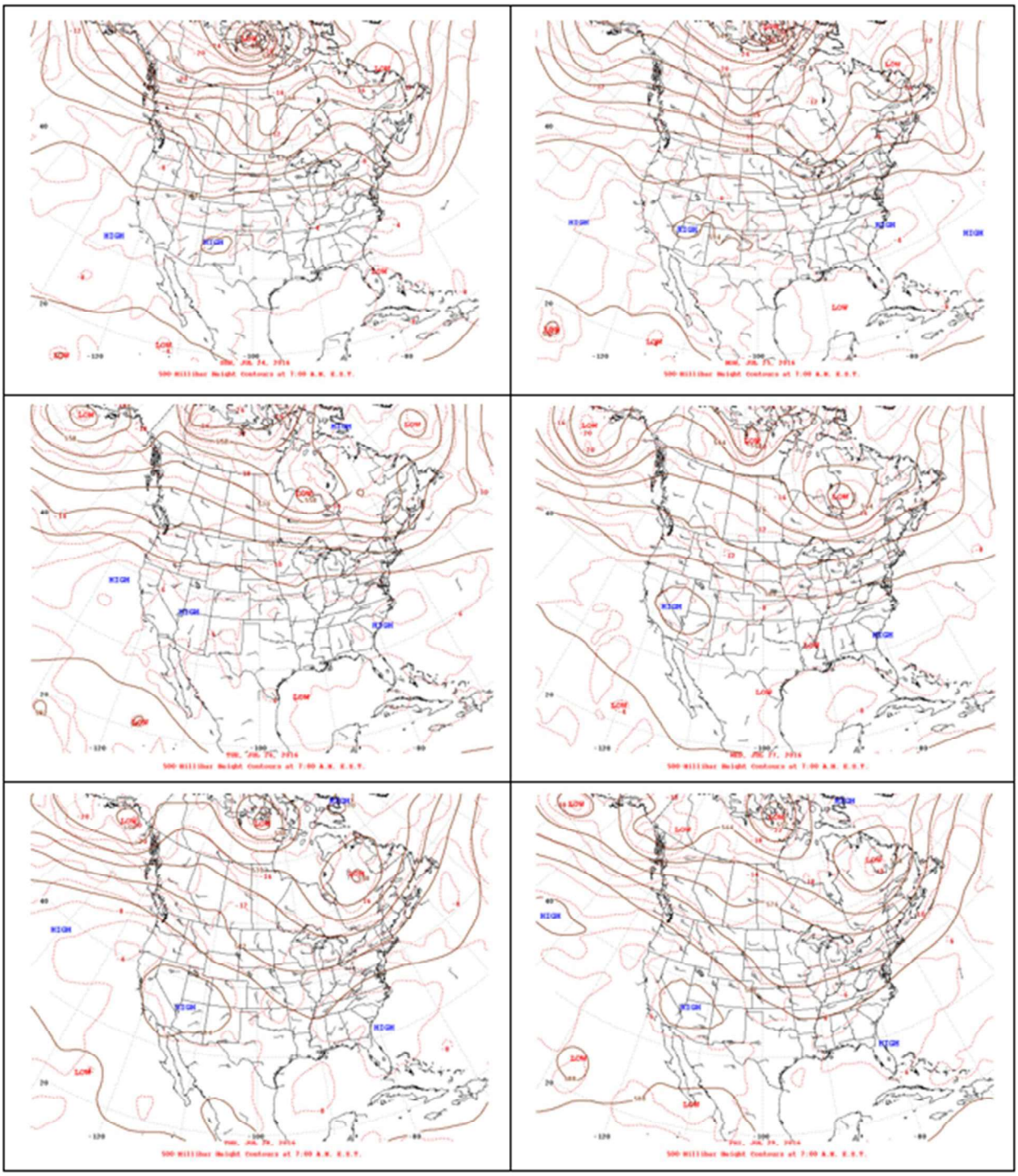

Figure 17. 500 hPa (approximately 5,500 m) weather patterns at 07:00 EST (04:00 PST) from July 24 to 29, 2016.

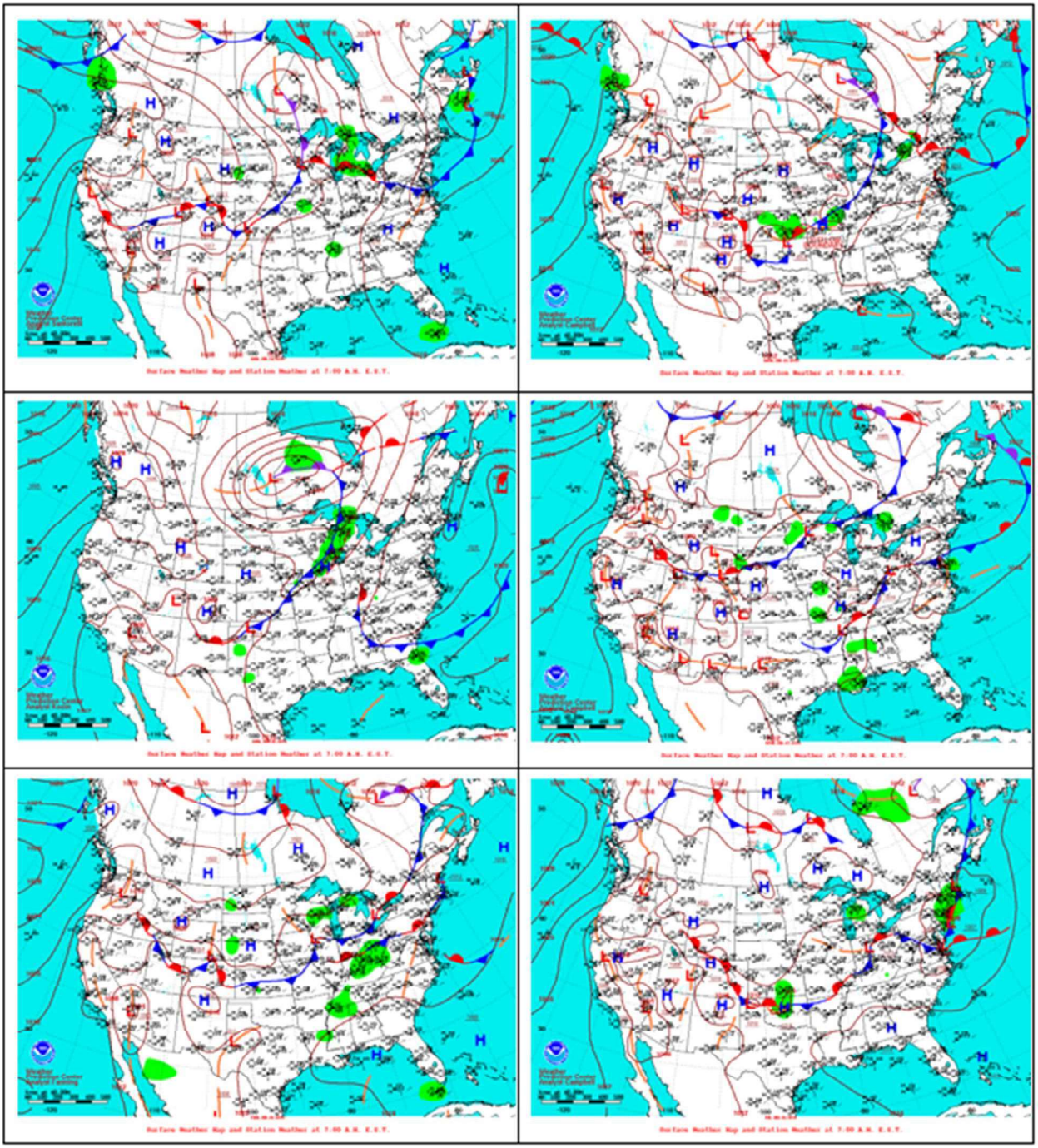

Figure 18. Surface weather patterns at 07:00 EST (04:00 PST) from July 24 to 29, 2016.

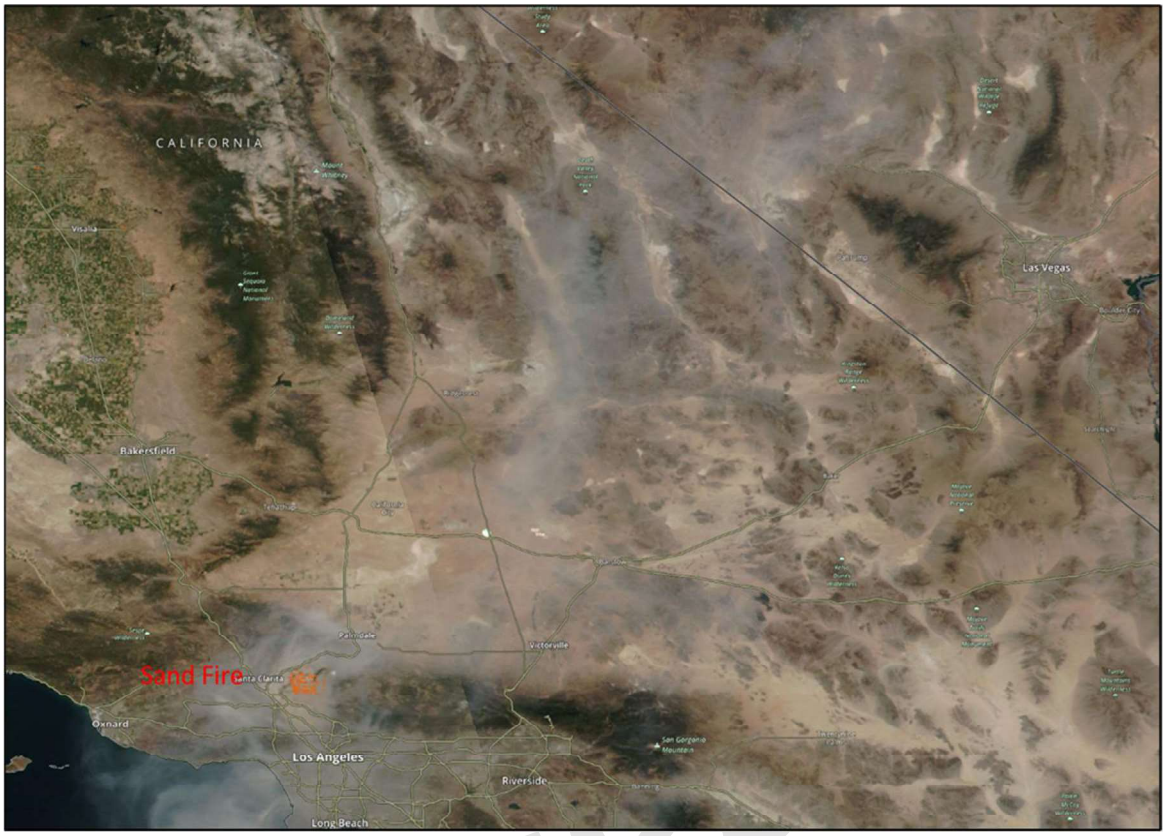

Figure 19. Visible satellite imagery of southern California and Nevada on July 23, 2016.

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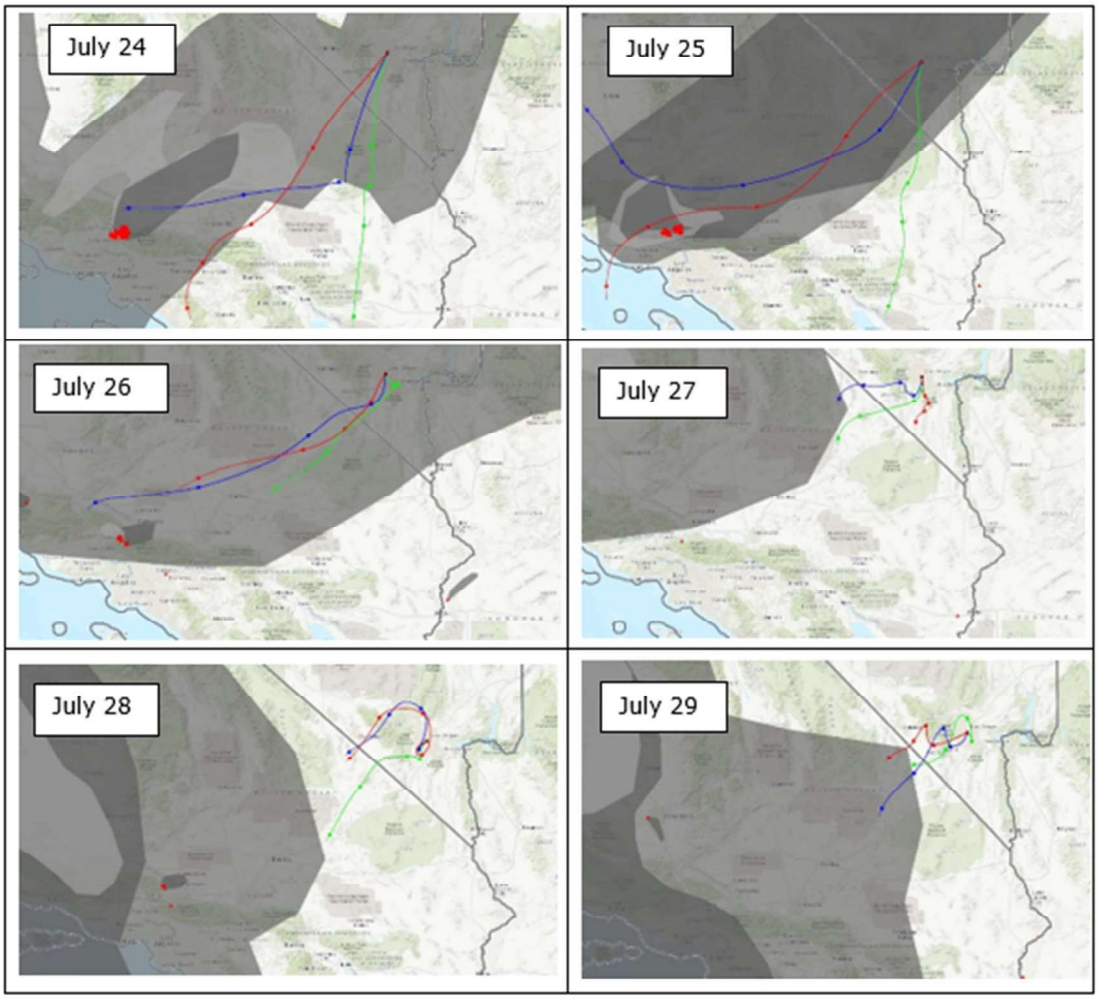

Figure 20. 24-hr backward trajectories arriving in Las Vegas at 13:00 PST on July 24-29, 2016, at altitudes of 100 m (green), 1,000 m (blue), and 2,000 m (red).

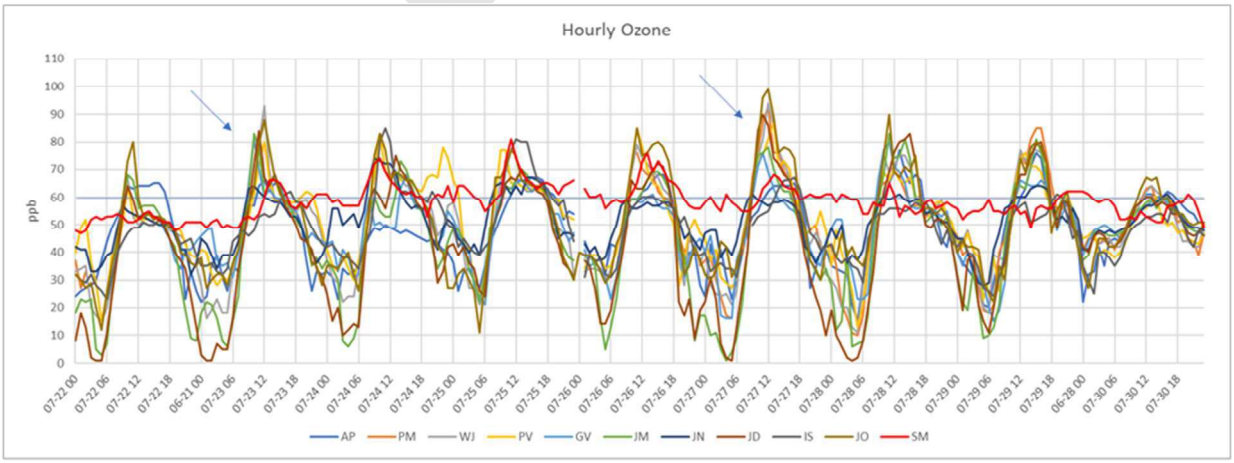

Figure 21. Time series of 1-hr ozone (ppb) at all Las Vegas Valley monitors during July 22-30, 2016.

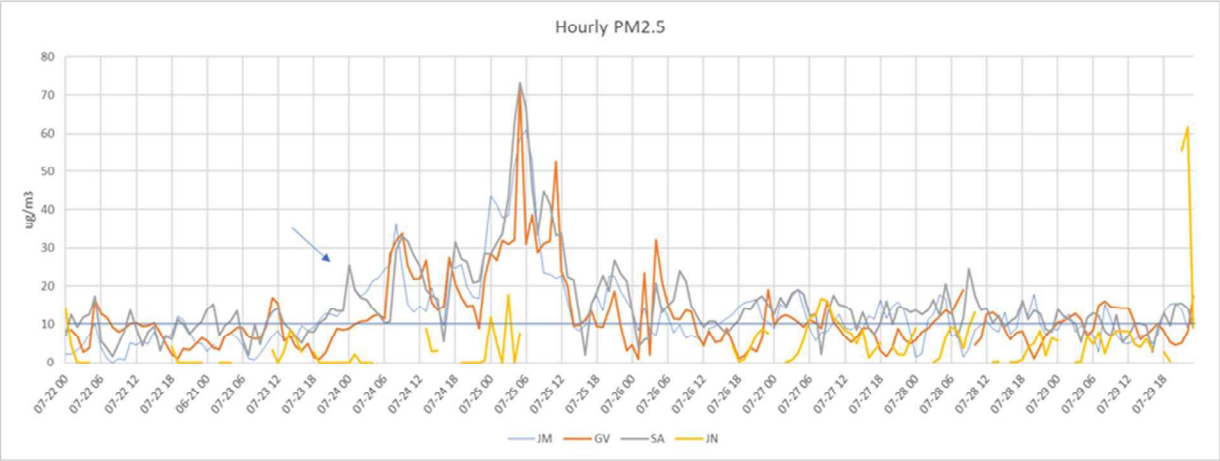

Figure 22. Time series of 1-hr $PM_{2.5}$ concentration (µg/m^3) at LVV FEM monitors during July 22-29, 2016.

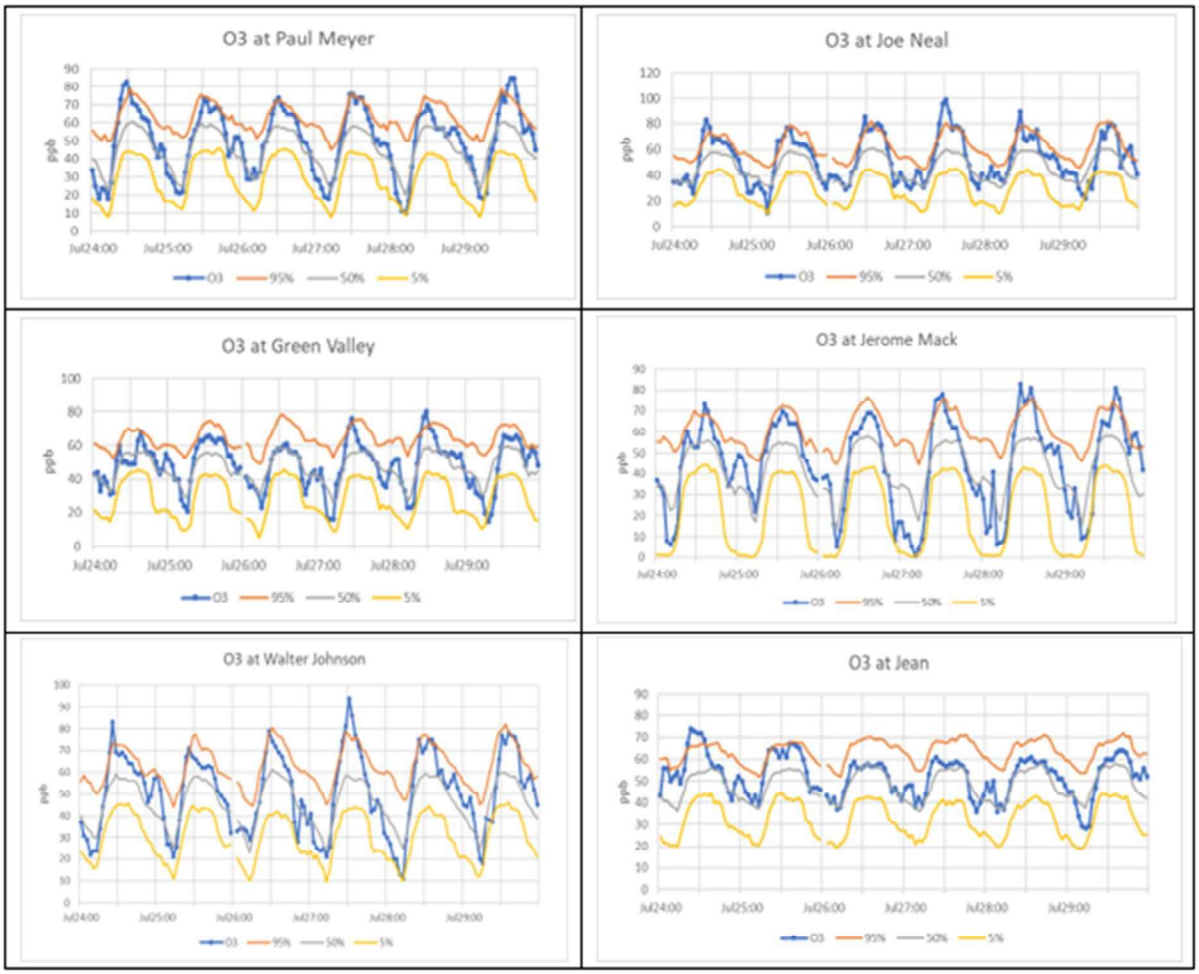

Figure 23. 6-yr hourly seasonal 95th, 50th, and 5th percentiles for ozone concentrations at the Paul Meyer, Joe Neal, Green Valley, Jerome Mack, Walter Johnson, and Jean monitoring sites during July 24-29, 2016.

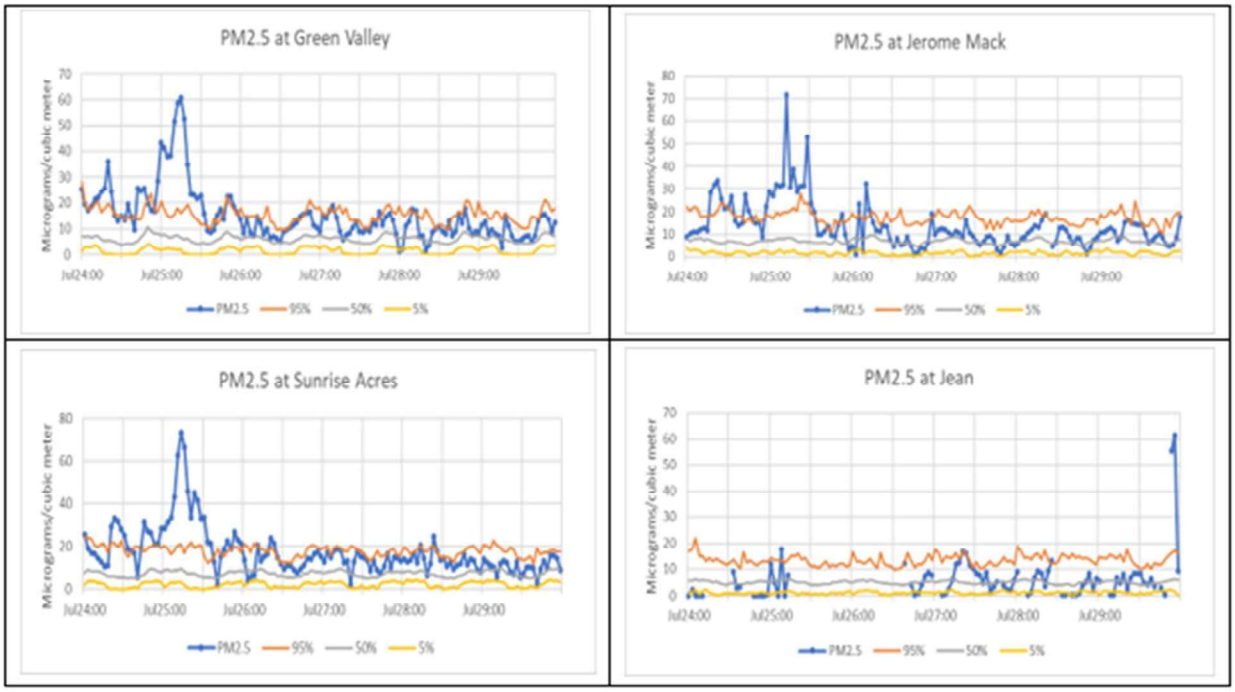

Figure 24. 6-yr hourly seasonal 95th, 50th, and 5th percentiles for $PM_{2.5}$ concentrations ($\mu g/m^3$) at LVV FEM monitors during July 24-29, 2016.

Table 4. Comparison of MDA8 ozone (ppb) during July 24-29 against 2014-2018 95th percentile MDA8 ozone.

2014-2018	PM	WJ	PV	GV	JM	JO	AP	JN
7/24		69	69	57	61	71	48	68
7/25		65	67	63	65	69	65	64
7/26	67	69	68	57	64	77	63	57
7/27	76	77	74	64	69	83	62	58
7/28	63	70	65	67	71	72	67	59
7/29	75	71	67	63	67	69	64	61
95th percentile	71	72	70	71	70	73	70	68

1.3.4 August 22-24, 2016

Clark County was impacted by smoke from multiple wildfires burning in central and southern California through much of August 2016 (Figure 25). The Soberanes fire started on July 22 as the result of an illegal campfire in Garrapata State Park, California and burned approximately 88,600 acres by August 24 with 60% containment. Ultimately, the fire burned an area of 132,127 acres when 100% containment was achieved on October 12. The Chimney fire started on the afternoon of

August 13 in the Santa Lucia Range of San Luis Obispo County, California. On August 26, the fire had grown to 45,008 acres with 47% containment. The Cedar fire started on August 16 in Kern County near Lake Isabella, California. On August 23, the fire had grown to ~21,000 acres with 5% containment. The fire burned a total of 29,322 acres by September 30 when 100% containment was achieved. The Rey fire started on August 18 in the area southeast of Lake Cachuma in Santa Barbara County, California. On August 22, the fire had grown to 23,546 acres with 20% containment. The fire burned a total of 32,606 acres by September 16 when 100% containment was achieved.

Figure 25. Locations and sizes of the Soberanes, Chimney, Cedar, and Rey Fires.

According to upper air synoptic weather patterns at 500 hPa over August 22-24 (Figure 26), a strong low-pressure trough propagated across the western U.S., followed by the buildup of a ridge over the west coast on August 24. During this period, the airflow over the LVV transitioned from northeasterly to northwesterly and had weakened by August 24.

The surface analyses for August 22-24 (Figure 27) depict a weakening cold front moved into central Nevada and stalled as a stationary front and later as a weak trough. Toward the end of the period, the thermal low reestablished over southern Nevada and central California, with hot and dry conditions in the LVV. The local daytime airflow remained light and varied from easterly through southeasterly (Figure 28).

Satellite imagery on August 22 (Figure 29) shows smoke from the Sobernanes, Chimney, Rey, and Cedar fires proceeding toward Clark County. Figure 30 shows 24-hr backward trajectories arriving in Las Vegas at 13:00 on August 22-24 at 100, 1,000 and 2,000 m, with HMS smoke maps overlaid. Smoke from multiple fires transported to the LVV during the event, especially indicated by the 2,000 m trajectories. At lower altitudes, the shorter backward trajectories reveal very low wind speeds late in the period. Figure 31 and Figure 32 show time series of 1-hr ozone and $PM_{2.5}$ during August 21-25. The $PM_{2.5}$ plot clearly shows that wildfire smoke arrived in Las Vegas on the night of August 22

and the morning of August 24. Ozone impacts are not as obvious, but ozone steadily built up over the period when additional smoke and the thermal low favoring ozone production helped to raise ozone levels. Figure 33 and Figure 34 show the hourly seasonal percentiles for ozone and $PM_{2.5}$ from 2014-2019 (May-August) compared to measured hourly ozone and $PM_{2.5}$ on August 23-24, 2016, at LVV sites and outlying site, Jean. Figure 33 shows the diurnal ozone pattern exceed 95th percentile on August 24, 2016, at the monitors in the valley and near 95th percentile at Jean. Figure 34 shows the elevated $PM_{2.5}$ exceeds 95th percentile during the evening on August 23, 2016, at Jean and few hours later right before the mid-night $PM_{2.5}$ also increased at Green Valley and Sunrise Acres. Moreover, the level of $PM_{2.5}$ had gradually increased at all sites in the LVV and Jean, especially with far beyond 95th percentile. All figures support the conclusion that wildfire smoke had been transported to the LVV.

The LVV was often impacted by smoke from multiple wildfires burning in central and southern California through much of August 2016. When the weather pattern evolved to suppress ventilation and dilution later in the period, ozone increased to extreme values. Table 5 compares MDA8 ozone with historical summer 95th percentile MDA8 ozone from 2014 to 2018 at monitoring sites with sufficient data. On August 24, MDA8 ozone exceeded the 95th percentile at the Paul Meyer, Walter Johnson, Palo Verde, Jerome Mack, and Joe Neal monitoring sites.

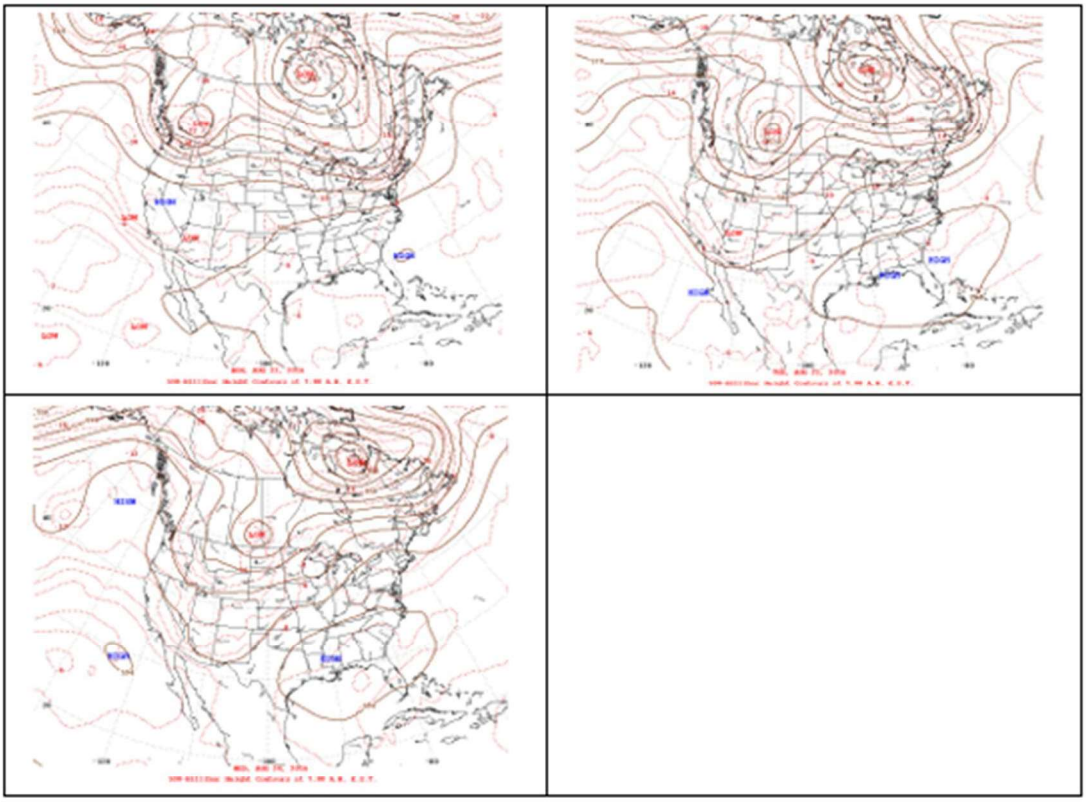

Figure 26. 500 hPa (approximately 5,500 m) weather patterns at 07:00 EST (04:00 PST) from August 22 to 24, 2016.

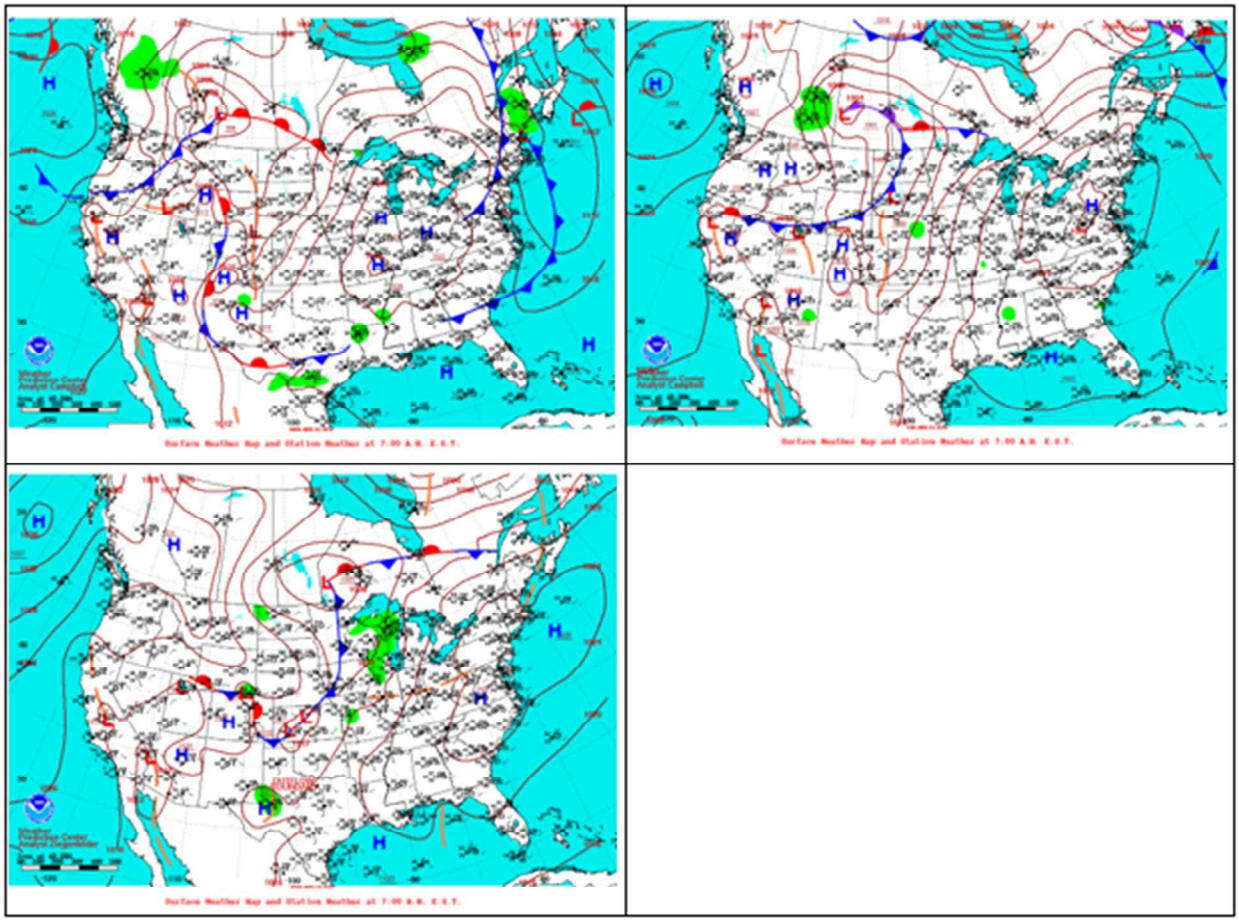

Figure 27. Surface weather patterns at 07:00 EST (04:00 PST) from August 22 to 24, 2016.

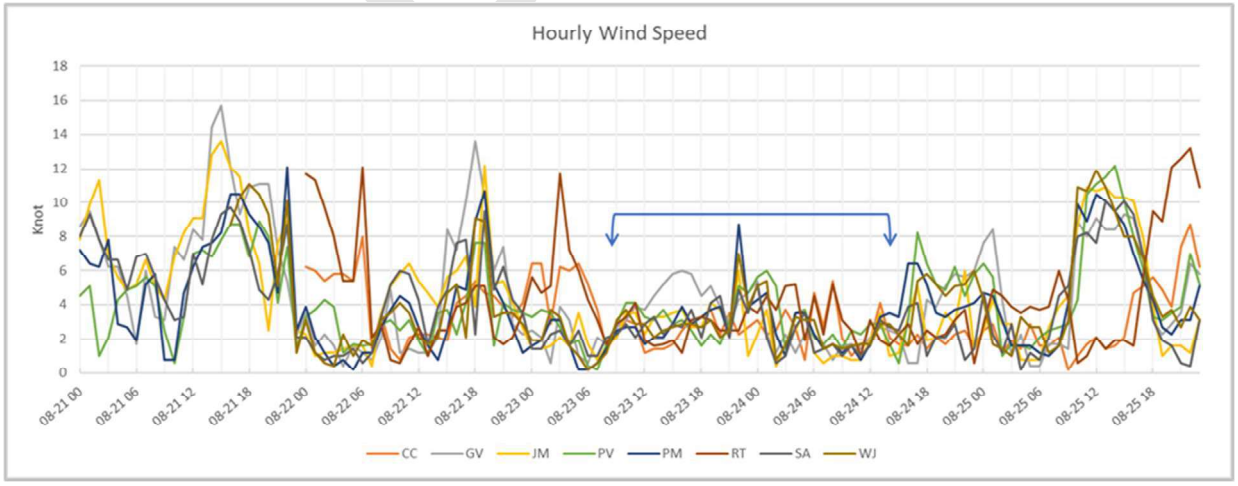

Figure 28. Time series of 1-hr wind speed (knots) at all monitors in the LVV from August 21 to 25, 2016.

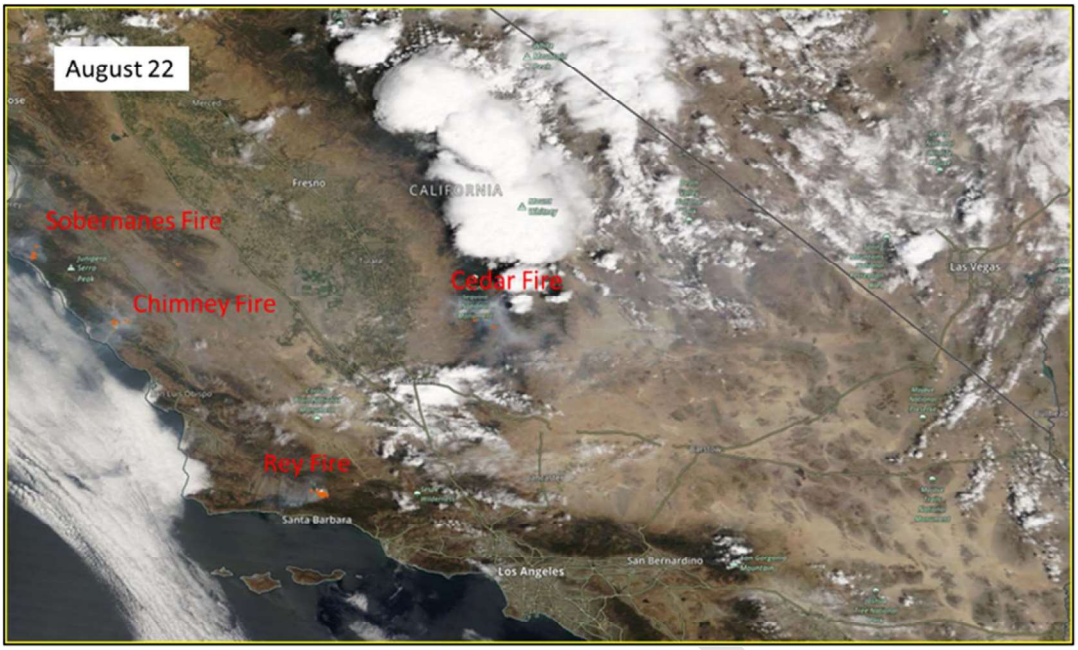

Figure 29. Visible satellite imagery of Central and Southern California and Nevada on August 22, 2016.

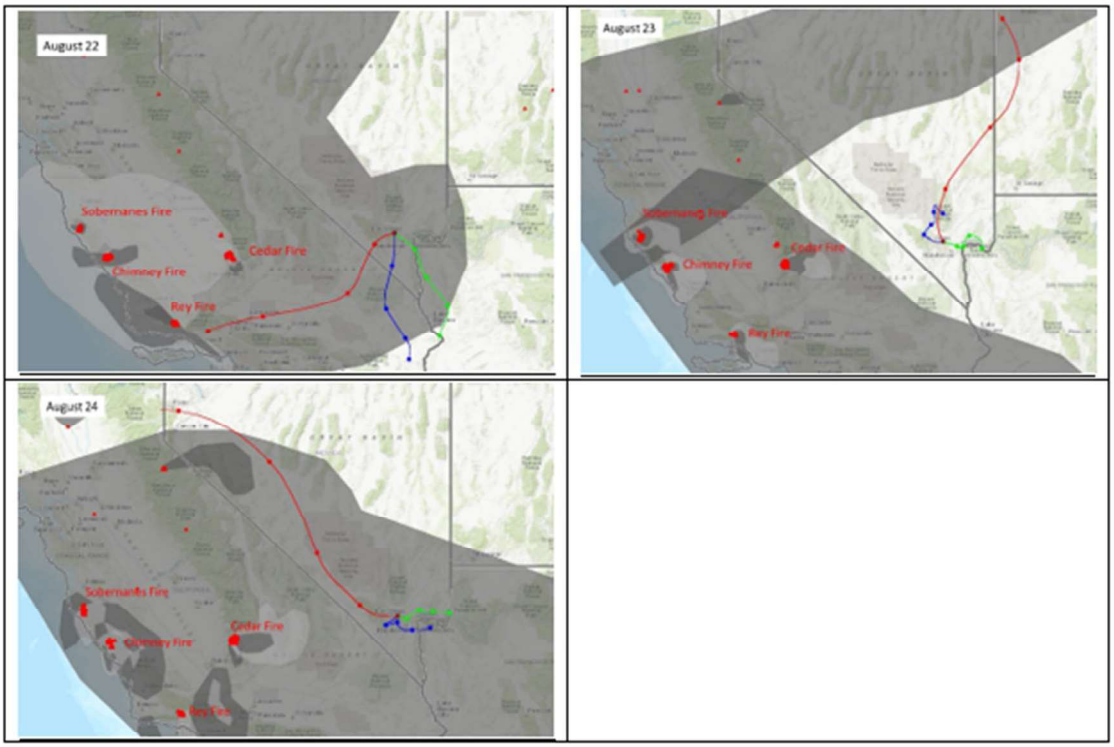

Figure 30. 24-hr backward trajectories arriving in Las Vegas at 13:00 PST on August 22-24, 2016, at altitudes of 100 m (green), 1,000 m (blue), and 2,000 m (red).

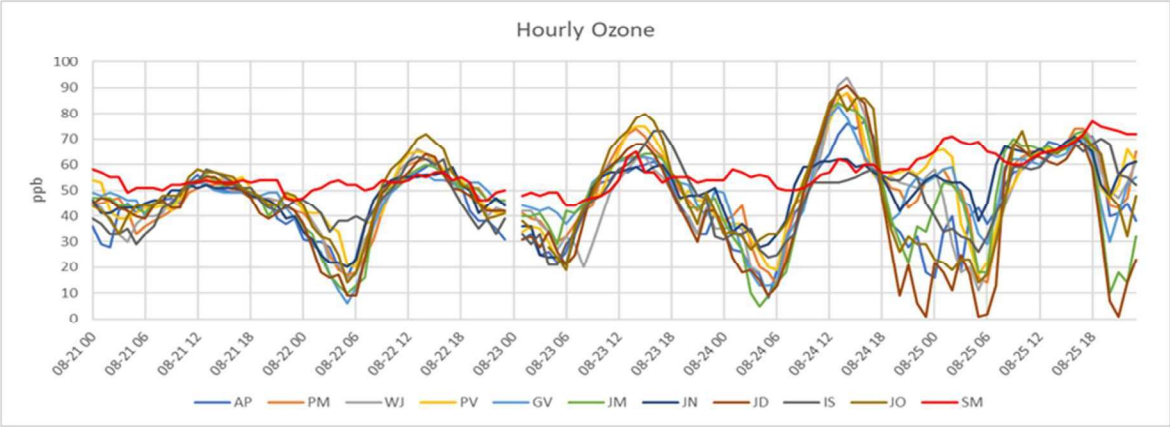

Figure 31. Time series of 1-hr ozone (ppb) at all LVV monitors during August 21-25, 2016.

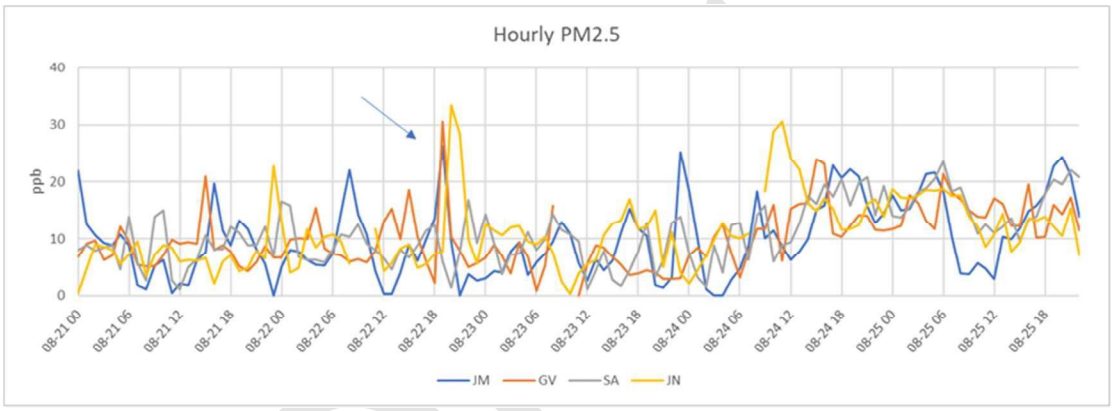

Figure 32. Time series of 1-hr $PM_{2.5}$ concentration ($\mu g/m^3$) at LVV FEM monitors during August 21-25, 2016.

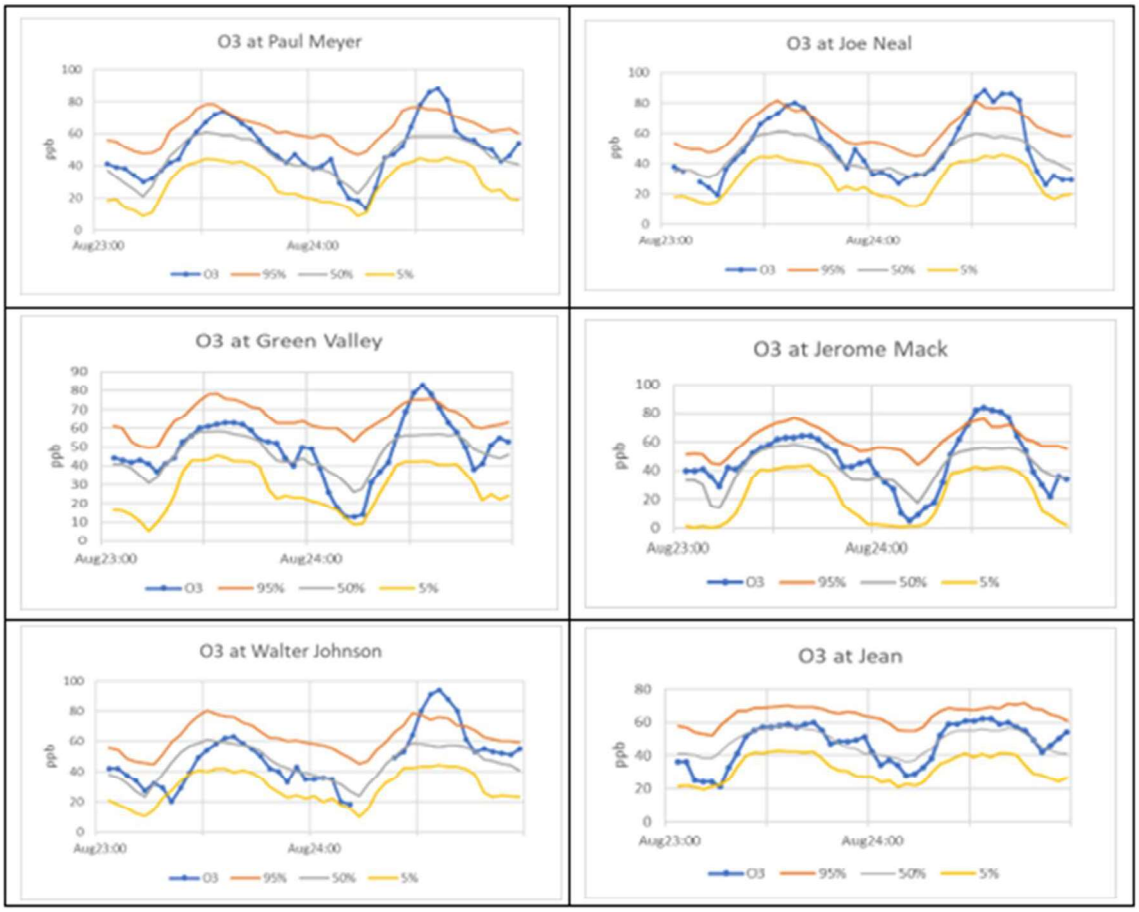

Figure 33. 6-yr hourly seasonal 95th, 50th, and 5th percentiles for ozone concentrations at the Paul Meyer, Joe Neal, Green Valley, Jerome Mack, Walter Johnson, and Jean monitoring sites during August 23-24, 2016.

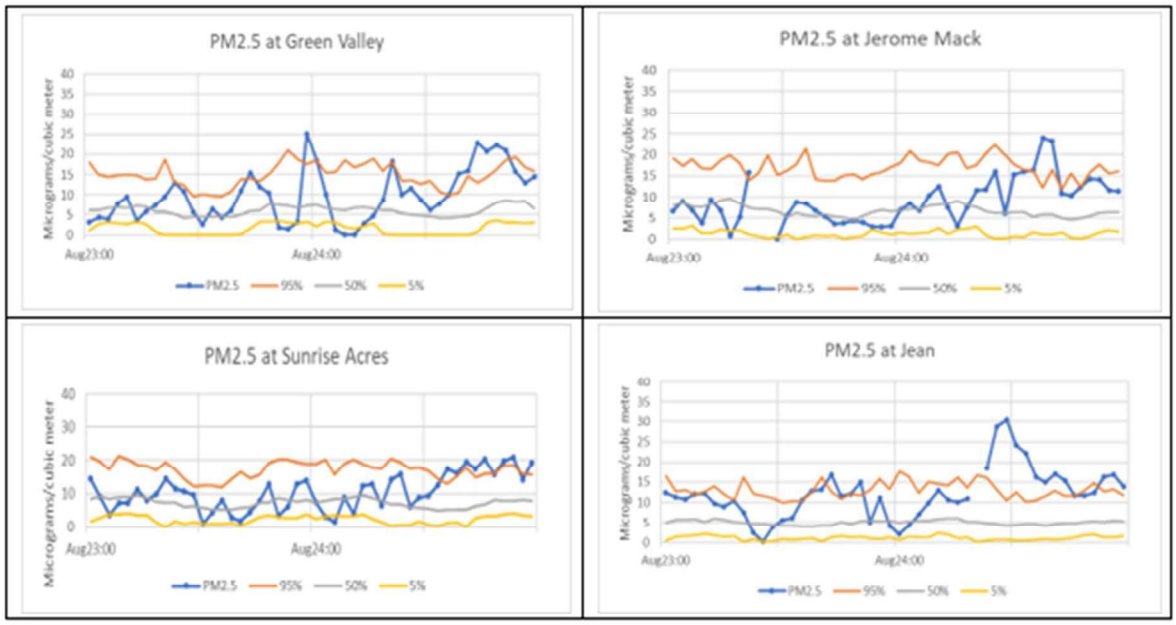

Figure 34. 6-yr hourly seasonal 95th, 50th, and 5th percentiles for $PM_{2.5}$ concentrations ($\mu g/m^3$) at LVV FEM monitors during August 23-24, 2016.

Table 5. Comparison of MDA8 ozone (ppb) during August 22-24, 2016, against 2014-2018 95th percentile MDA8 ozone.

2014-2018	PM	WJ	PV	GV	JM	JO	AP	JN
8/23	66	56	67	60	61	71	57	57
8/24	71	76	73	69	75	80	68	60
95th percentile	71	72	70	71	70	73	70	68

2. 2018 Ozone Exceptional Events

Thirteen dates in 2018 were found to be exceptional events, and demonstrations were prepared and submitted to EPA Region 9 in 2021 that all received a "Deferred Review" status on April 11, 2022. The Clark County Department of Environment & Sustainability (DES) is submitting a request to exclude data from these dates on this basis for the following case explicitly defined in the U.S. Environmental Protection Agency (EPA) memo "Clarification Memo on Additional Methods, Determinations, and Analyses to Modify Air Quality Data Beyond Exceptional Events": "Estimating base and future-year design values ozone SIP attainment demonstrations," as a part of DES' State Implementation Plan (SIP). As stated in the memo, the EPA or the appropriate reviewing authority will determine whether the air agency—in this case, Clark County DES—has appropriately documented and justified the data exclusion and/or adjustment when it acts on a SIP submission. Table 6 provides the links to all 2018 Exceptional Event demonstrations that provide evidence of wildfire smoke impacts on ozone concentrations during the period of June-August 2018 and meet the criteria as defined in the document and guidance. This evidence is included as part of Clark County's request to exclude these data from base and future-year design values as a part of their SIP.

The wildfire smoke events presented in the Exceptional Events demonstrations resulted in ozone measurements that were extreme and nonrepresentative of past and future days for Clark County, Nevada. The *Guideline on Air Quality Models* (40 CFR Part 51, Appendix W) states "control agencies have long expressed a need for consistency in the application of air quality models for regulatory purposes…the expanded requirements for models to cover even more complex problems have emphasized the need for period review and update of guidance on these techniques". Wildfire smoke events are one such complex problem, as wildfire season has extended and encompasses the summer months, which are also considered to be ozone production season. Wildfire occurrence is wildly considered to be a stochastic, natural phenomenon, and is therefore inconsistent year-to-year. Downstream smoke impacts, including ozone formation, are not typical nor representative of the ambient conditions of Clark County, NV. Based on the evidence provided, we formally request exclusion of the following dates in base and projected ozone design values.

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Table 6. Links to Exceptional Event demonstrations and associated appendices for all 2018 dates removed from base and future-year design values for ozone SIP attainment.

Event Date	Link to Exceptional Event Demonstrations
June 23, 2018	**Main Document:** https://www.clarkcountynv.gov/adobe/assets/urn:aaid:aem:6fa32585-208c-47b6-a25b-4da393b63338/original/as/20180623-clarkcounty-wildfire-ee.pdf **Appendices:** https://www.clarkcountynv.gov/adobe/assets/urn:aaid:aem:18fe6818-c7c9-468e-8927-062be4b9d134/original/as/20180623-clarkcounty-wildfire-ee-appendix.pdf
June 27, 2018	**Main Document:** https://www.clarkcountynv.gov/adobe/assets/urn:aaid:aem:43a47d7d-a0bd-4879-aa7f-7d74b55c7207/original/as/20180627-clarkcounty-wildfire-ee.pdf **Appendices:** https://www.clarkcountynv.gov/adobe/assets/urn:aaid:aem:e8fc3903-358a-484d-9a88-84dd75d18737/original/as/20180627-clarkcounty-wildfire-ee-appendix.pdf
July 14-17, 2018	**Main Document:** https://www.clarkcountynv.gov/adobe/assets/urn:aaid:aem:d72dd8da-85e4-47cd-bb5f-f34506699e46/original/as/20180714-17-clarkcounty-wildfire-ee.pdf **Appendices:** https://www.clarkcountynv.gov/adobe/assets/urn:aaid:aem:fcdf4393-86b9-4bac-80f4-f18ce2d5a734/original/as/20180714-17-clarkcounty-wildfire-ee-appendix.pdf
July 25-27, 2018	**Main Document:** https://www.clarkcountynv.gov/adobe/assets/urn:aaid:aem:992c0aa0-7f6b-41c4-ac03-b885146c11a3/original/as/20180725-27-clarkcounty-wildfire-ee.pdf **Appendices:** https://www.clarkcountynv.gov/adobe/assets/urn:aaid:aem:fbc1fc5c-ba0e-4571-acdc-9fbc51e285a0/original/as/20180725-27-clarkcounty-wildfire-ee-appendix.pdf
July 30-31, 2018	**Main Document:** https://www.clarkcountynv.gov/adobe/assets/urn:aaid:aem:6072108f-b38c-4f87-a7fa-bc5ac502e895/original/as/20180730-31-clarkcounty-wildfire-ee.pdf **Appendices:** https://www.clarkcountynv.gov/adobe/assets/urn:aaid:aem:f0756a75-3b25-4001-885f-8a1804defd33/original/as/20180730-31-clarkcounty-wildfire-ee-appendix.pdf

Event Date	Link to Exceptional Event Demonstrations
August 6-7, 2018	**Main Document:** https://www.clarkcountynv.gov/adobe/assets/urn:aaid:aem:6ca629a0-f85c-4af5-96cd-b4d1cb2f88c6/original/as/20180806-07-clarkcounty-wildfire-ee.pdf **Appendices:** https://www.clarkcountynv.gov/adobe/assets/urn:aaid:aem:e4190cbf-ff0e-4d33-9aa4-954df2743176/original/as/20180806-07-clarkcounty-wildfire-ee-appendix.pdf

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3. 2020 Ozone Exceptional Events

Eight dates in 2020 were found to be exceptional events, and demonstrations were prepared and submitted to EPA Region 9 in 2021 that received a "Deferred Review" status on April 11, 2022. The Clark County Department of Environment & Sustainability (DES) is submitting a request to exclude data from these dates on this basis for the following case explicitly defined in the U.S. Environmental Protection Agency (EPA) memo "Clarification Memo on Additional Methods, Determinations, and Analyses to Modify Air Quality Data Beyond Exceptional Events": "Estimating base and future-year design values ozone SIP attainment demonstrations," as a part of DES' State Implementation Plan (SIP). As stated in the memo, the EPA or the appropriate reviewing authority will determine whether the air agency—in this case, Clark County DES—has appropriately documented and justified the data exclusion and/or adjustment when it acts on a SIP submission. Table 7 provides the links to all 2020 Exceptional Event demonstrations that provide evidence of wildfire smoke impacts on ozone concentrations during the period of August-September 2020 and meet the criteria as defined in the document and guidance. This evidence is included as part of Clark County's request to exclude these data from base and future-year design values as a part of their SIP.

The wildfire smoke events presented in the Exceptional Events demonstrations resulted in ozone measurements that were extreme and nonrepresentative of past and future days for Clark County Nevada. The *Guideline on Air Quality Models* (40 CFR Part 51, Appendix W) states "control agencies have long expressed a need for consistency in the application of air quality models for regulatory purposes…the expanded requirements for models to cover even more complex problems have emphasized the need for period review and update of guidance on these techniques". Wildfire smoke events are one such complex problem, as wildfire season has extended and encompasses the summer months, which are also considered to be ozone production season. Wildfire occurrence is wildly considered to be a stochastic, natural phenomenon, and is therefore inconsistent year-to-year. Downstream smoke impacts, including ozone formation, are not typical nor representative of the ambient conditions of Clark County, Nevada. Based on the evidence provided, we formally request exclusion of the following dates in base and projected ozone design values.

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Table 7. Links to Exceptional Event demonstrations and associated appendices for all 2020 dates removed from base and future-year design values for ozone SIP attainment.

Event Date	Link to Exceptional Event Demonstrations
August 3, 2020	**Main Document:** https://www.clarkcountynv.gov/adobe/assets/urn:aaid:aem:0047a6da-3b45-4271-8064-d68df95f9e10/original/as/20200803-clarkcounty-wildfire-ee.pdf **Appendices:** https://www.clarkcountynv.gov/adobe/assets/urn:aaid:aem:d2abbe49-d0b1-4e4a-8b57-a650ab55a4c1/original/as/20200803-clarkcounty-wildfire-ee-appendix.pdf
August 7, 2020	**Main Document:** https://www.clarkcountynv.gov/adobe/assets/urn:aaid:aem:32c815b2-949f-47b7-9433-f23af5505810/original/as/20200807-clarkcounty-wildfire-ee.pdf **Appendices:** https://www.clarkcountynv.gov/adobe/assets/urn:aaid:aem:06ed8332-9b0a-4268-bbe7-a3998bdb570b/original/as/20200807-clarkcounty-wildfire-ee-appendix.pdf
August 18-21, 2020	**Main Document:** https://www.clarkcountynv.gov/adobe/assets/urn:aaid:aem:bb181869-9c3a-4046-893d-a376ba646814/original/as/20200818-21-clarkcounty-wildfire-ee.pdf **Appendices:** https://www.clarkcountynv.gov/adobe/assets/urn:aaid:aem:dbd12a5e-16dc-47df-9d05-ac24717a1dce/original/as/20200818-21-clarkcounty-wildfire-ee-appendix.pdf
September 2, 2020	**Main Document:** https://www.clarkcountynv.gov/adobe/assets/urn:aaid:aem:9717f3fd-b4d8-41c6-8cc4-306a812d4d14/original/as/20200902-clarkcounty-wildfire-ee.pdf **Appendices:** https://www.clarkcountynv.gov/adobe/assets/urn:aaid:aem:83307941-0e92-49b5-9eec-8bdbdd02d3f0/original/as/20200902-clarkcounty-wildfire-ee-appendix.pdf **Addendum:** https://www.clarkcountynv.gov/adobe/assets/urn:aaid:aem:50bcd36a-cafd-4e32-83b8-5b3d4b90ed69/original/as/20200902-clarkcounty-wildfire-ee-addendum.pdf
September 26, 2020	**Main Document:** https://www.clarkcountynv.gov/adobe/assets/urn:aaid:aem:1a33ee23-9e40-4ed3-885c-44224dbcb85f/original/as/20200926-clarkcounty-wildfire-ee.pdf **Appendices:** https://www.clarkcountynv.gov/adobe/assets/urn:aaid:aem:588e2ec0-d6a3-4e08-bf05-0cfd022b4596/original/as/20200926-clarkcounty-wildfire-ee-appendix.pdf

4. 2021 Ozone Technical Supporting Documents

The U.S. Environmental Protection Agency (EPA) published the memo *Clarification Memo on Additional Methods, Determinations, and Analyses to Modify Air Quality Data Beyond Exceptional Events*[2] (the memo), which illustrates cases where air quality data may be modified for certain regulatory determinations, actions, and analysis. The document defines cases where a request to exclude data can be made through the Exceptional Events Rule, such as when a National Ambient Air Quality Standard (NAAQS) design value is recalculated in EPA's Air Quality System (AQS) using modified data to determine attainment. The document also defines additional analyses that are not covered in the Exceptional Events Rule, where submitting modified data may be appropriate. These additional cases that are not covered in the Exceptional Event Rule are defined as conditions where ambient air quality data may have been "influenced by an atypical, extreme or unrepresentative event." The Clark County Department of Environment & Sustainability (DES) is submitting a request to exclude data on this basis for the following case explicitly defined in the document: "Estimating base and future-year design values ozone SIP attainment demonstrations" as a part of their State Implementation Plan (SIP).

The EPA document states that monitoring data could qualify for exclusion if "[A]mbient data are not representative to characterize background or base period concentrations in accordance with the *Guideline,*" in reference to *Guideline on Air Quality Models*, 40 CFR Part 51, Appendix W. Extreme wildfire events are increasingly prevalent in the western United States (U.S.), resulting in increased smoke impacts. Clark County, Nevada, was impacted by wildfire smoke from local and regional sources in the summer of 2021 (Table 8). Following an atypical smoke intrusion, high ozone concentrations were measured as a result of direct transport and secondary photochemical processes.

As stated in the memo, EPA or the appropriate reviewing authority will determine whether the air agency—in this case, Clark County DES—has appropriately documented and justified the data exclusion and/or adjustment when it acts on a SIP submission. The following documentation is provided to demonstrate that seven local and regional wildfire smoke events in the period of June-September 2021 meet the criteria as defined in the document and guidance. This evidence is included as part of Clark County's request to exclude these data from base and future-year design values for ozone SIP attainment demonstrations as a part of their SIP.

[2] https://www.epa.gov/sites/default/files/2019-04/documents/clarification_memo_on_data_modification_methods.pdf

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Table 8. Summary of events requested for exclusion from ozone SIP base and future-year design values.

Event Date	Event Ozone Concentration Percentile	Sites Exceeded During Event	Type of Event
June 11-12, 2021	93rd – 97th	6 sites: Green Valley, Joe Neal, Palo Verde, Paul Meyer, Walnut Community Center, and Walter Johnson	Local Smoke
June 16-17, 2021	>95th	5 sites: Palo Verde, Joe Neal, Paul Meyer, Walter Johnson, and Mountain's Edge	Regional Smoke
July 20, 2021	93rd – 98th	4 sites: Green Valley, Joe Neal, Walnut Community Center, and Walter Johnson	Regional Smoke
August 2-3, 2021	96th – 99.5th	8 sites: Green Valley, Jerome Mack-NCore, Joe Neal, Liberty High School, Mountain's Edge, Palo Verde, Paul Meyer, and Walter Johnson	Regional Smoke
August 7, 2021	99th – 100th	12 sites: Green Valley, Indian Springs, Jean, Jerome Mack-NCore, Noe Neal, Liberty High School, Mountain's Edge, Palo Verde, Paul Meyer, Virgin Valley High School, and Walter Johnson	Regional Smoke
August 19, 2021	97th – 99th	5 sites: Joe Neal, Palo Verde, Paul Verde, Walnut Community Center, and Walter Johnson	Regional Smoke
September 8, 2021	96th	2 sites: Palo Verde and Walter Johnson	Regional Smoke

4.1 June 11-12, 2021

4.1.1 Event Summary

The unrepresentative ozone event took place on June 11-12, 2021, and affected six sites in Clark County, Nevada: Green Valley, Joe Neal, Palo Verde, Paul Meyer, Walnut Community Center, and Walter Johnson. The MDA8 concentrations at the effected sites ranged from 71-73 ppb: 73 ppb at Joe Neal, 72 ppb at each of Paul Meyer, Walnut Community Center, and Walter Johnson, and 71 ppb at Green Valley on June 11, and 71 ppb at Palo Verde and Walter Johnson on June 12. Time series graphs showing hourly ozone concentrations that exceeded the seasonal means (calculated using May 1 – October 31, 2017-2021) and 10th-90th percentiles at each site are shown in **Figure 35**.

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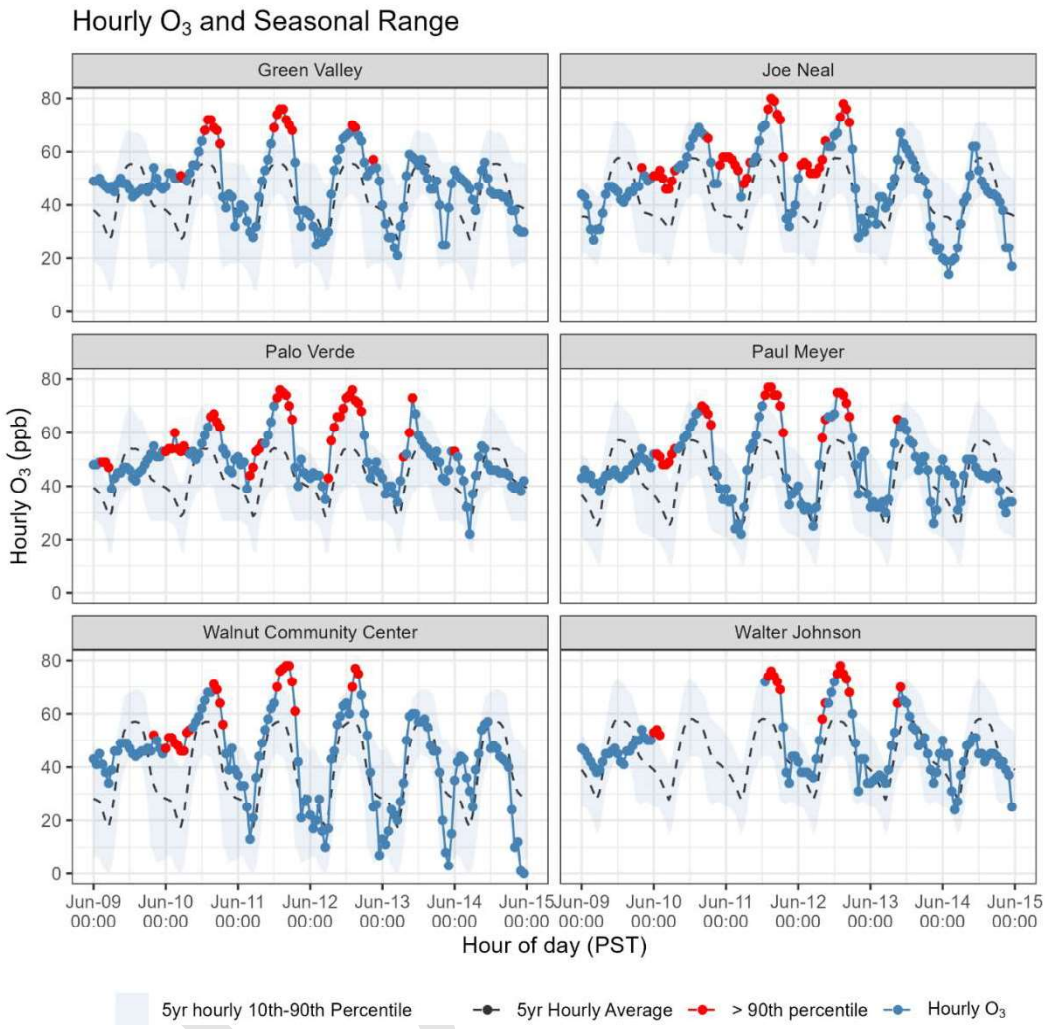

Figure 35. Hourly ozone concentrations (ppb) compared to 5-yr ozone season (May 1 – October 31) hourly means and 10-90th percentiles. Note: data from the Walnut Community Center site are only available for June 1 – October 31, 2021.

On June 11, hourly ozone measurements at many sites, such as Joe Neal, Palo Verde, and Walnut Community Center, were already greater than 10% above the mean seasonal values during the overnight hours. Measurements exceeded the 90th percentiles between 12:00 to 19:00 PST for most sites, and as early as 0:00 – 04:00 PST at the Joe Neal and Palo Verde sites, indicative of overnight transport of ozone and ozone precursors from a nearby wildfire. In general, measurements returned below the 90th percentile on June 12 at 17:00 PST.

The local Sandy Valley Fire southwest of Las Vegas was identified as a major contributor to this event. Evidence includes (1) HYSPLIT dispersion modeling and meteorological analysis showing accumulation of smoke in Clark County, (2) visible smoke in camera images and video news coverage; (3) elevated $PM_{2.5}$, CO, and NO_2 concentrations; and (4) a spike in the $PM_{2.5}$-to-PM_{10} ratio

observed immediately after the fire became active. This combination of evidence indicates that this is an unrepresentative event for base and future design value ozone assessments.

4.1.2 Identification of Wildfires

A local fire was active during June 11-12, the exclusion days. The Sandy Valley Fire was first reported at 13:34 PST on June 10[3] and grew to approximately 700 acres during the first day of burning. The fire expanded to its full size of 1,380 acres (originally estimated at 1,600 acres) by June 11, 2021.[4] Full containment of the fire was achieved on June 20, based on data from the Wildland Fire Interagency Geospatial Services (WFIGS) Current Interagency Fire Perimeters[5] (Figure 36). The fire was in close proximity to the Las Vegas metropolitan region, about 20 km to the west (Figure 37).

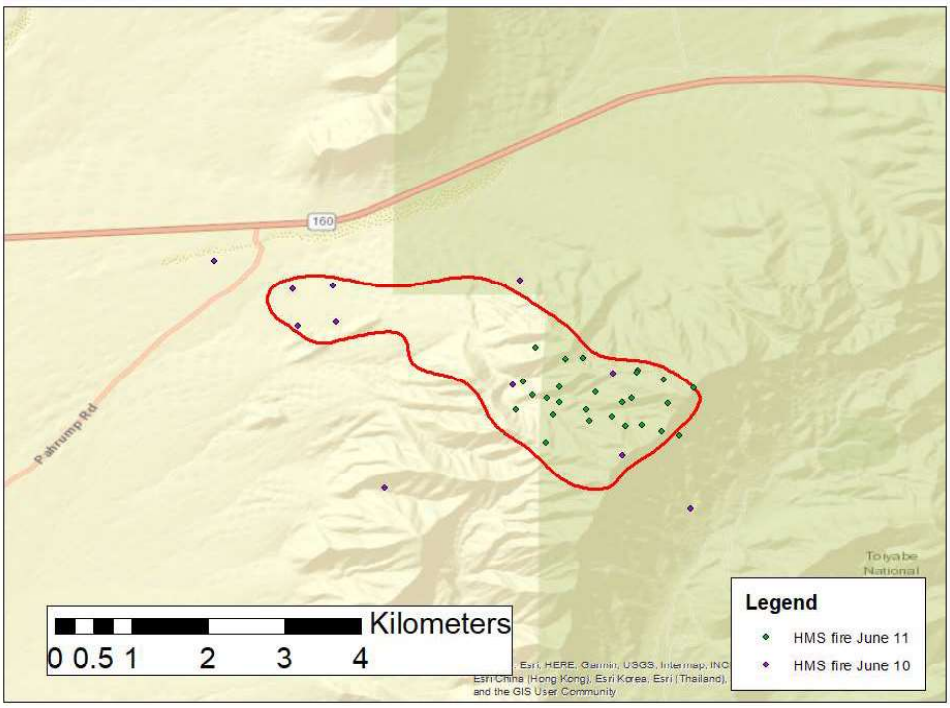

Figure 36. Sandy Valley Fire perimeter and active fire detections from June 10 and 11, 2021. From NOAA's Hazard Mapping System (HMS).

[3] https://data-nifc.opendata.arcgis.com/maps/wfigs-interagency-fire-perimeters (fire value 2021-NVSND-500708)

[4] https://www.ktnv.com/news/crews-respond-to-fire-southwest-of-las-vegas-near-sandy-valley-road-highway-160

[5] McClure et al. (2023) Consistent, high-accuracy mapping of daily and sub-daily wildfire growth with satellite observations. International Journal of Wildland Fire 32, 694-708. Available at https://www.publish.csiro.au/wf/ExportCitation/WF22048.

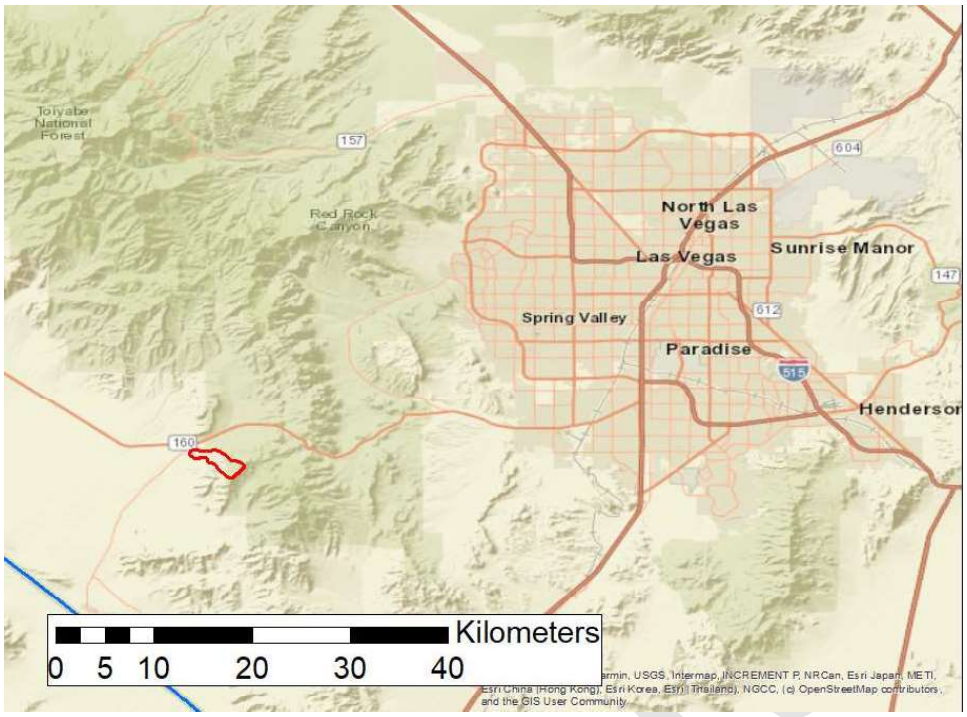

Figure 37. Sandy Valley Fire perimeter with HMS fire detections in proximity to Las Vegas, NV.

4.1.3 Dispersion Modeling and Regional Analysis

HYSPLIT dispersion modelling was performed and covered the period of June 10 through June 12, 2021. Dispersion was initiated from the location of the Sandy Valley Fire based on satellite hot spot retrievals at 14:00 PST on June 10 (to coincide with the ignition of the Sandy Valley Fire). High Resolution Rapid Refresh (HRRR) data at 3 km horizontal resolution was used for meteorological input. A high-resolution meteorological dataset was required for this event due to the proximity of the fire to Clark County. Output from the dispersion modeling at 0-100 m is shown in **Figure 38**. The first 12 hours of dispersion is shown in the left panel (June 10 at 14:00 through June 11 at 02:00 PST), indicating that most of the smoke from the fire initially entered the Las Vegas valley from the mountain pass between the Spring Mountains and McCullough Range. This smoke passed through the Jean monitoring station as it entered the valley. The middle panel shows the next 24 hours of dispersion (June 11 at 02:00 through June 12 at 02:00 PST), and the right panel shows the final 18 hours of dispersion (June 12 at 02:00 through June 12 at 20:00 PST). Both panels indicate that smoke from the Sandy Valley fire had entered the valley and was present in the lower mixed layer, impacting the surface conditions.

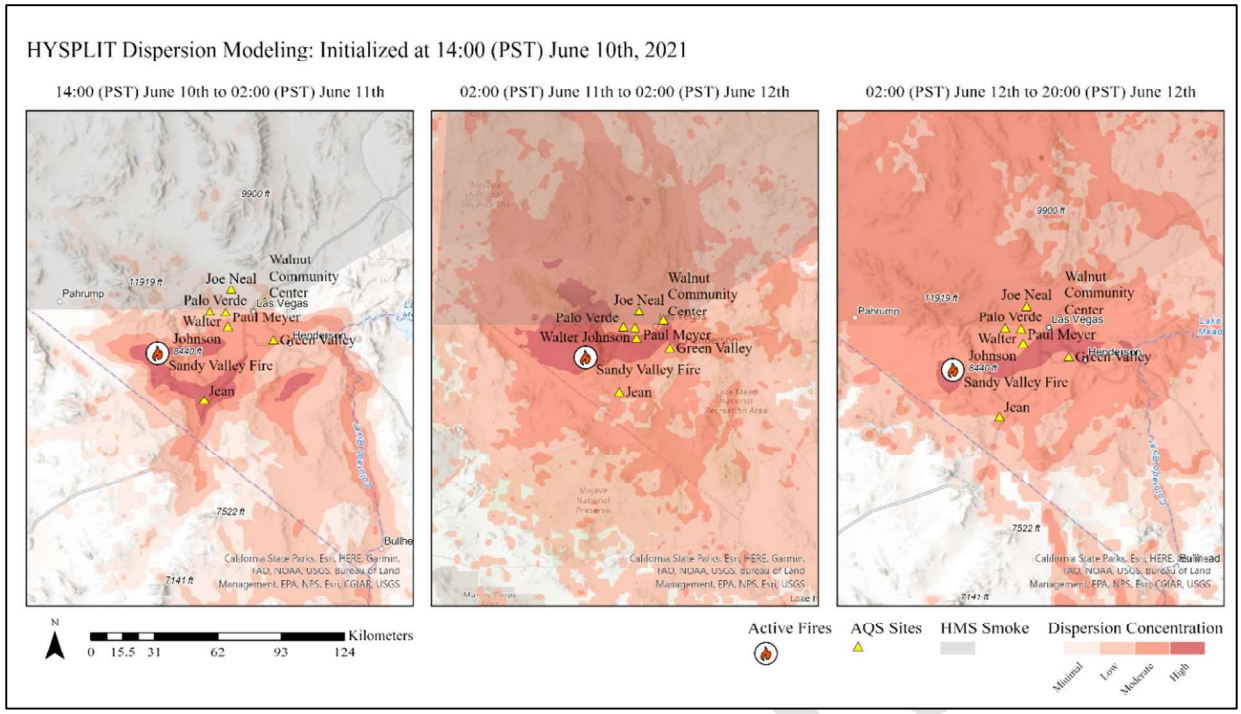

Figure 38. HYSPLIT dispersion modeling from the Sandy Valley Fire (labeled as "Active Fires"). HRRR 3 km meteorological data was used, and dispersion was initiated on June 10 at 14:00 PST to correspond with the ignition of the Sandy Valley Fire. The left panel shows the first 12 hours of dispersion after ignition, the middle panel shows the next 24 hours of dispersion, and the right panel shows the last 18 hours of dispersion. Clark County monitoring sites are labeled as yellow triangles. HMS smoke is shown as a grey polygon. In this case, the HMS smoke data satellite product did not capture the hyperlocal surface impacts of the Sandy Valley Fire.

Several meteorological factors were evaluated to determine the potential for smoke impacts on ozone concentrations in the Las Vegas region on June 11-12. These factors include boundary layer heights, upper-level winds, HYSPLIT back trajectories from the Las Vegas area, and surface winds.

Given the fire ignition time of 13:34 PST on June 10, boundary layer height data were assessed for the evening of June 10 to determine the extent of upper-level winds to be investigated for smoke transport into the Las Vegas area. Figure 39 shows mixing heights from the 00:00 UTC sounding on June 11 (16:00 PST on June 10) reached approximately 700 mb (3,139 m).

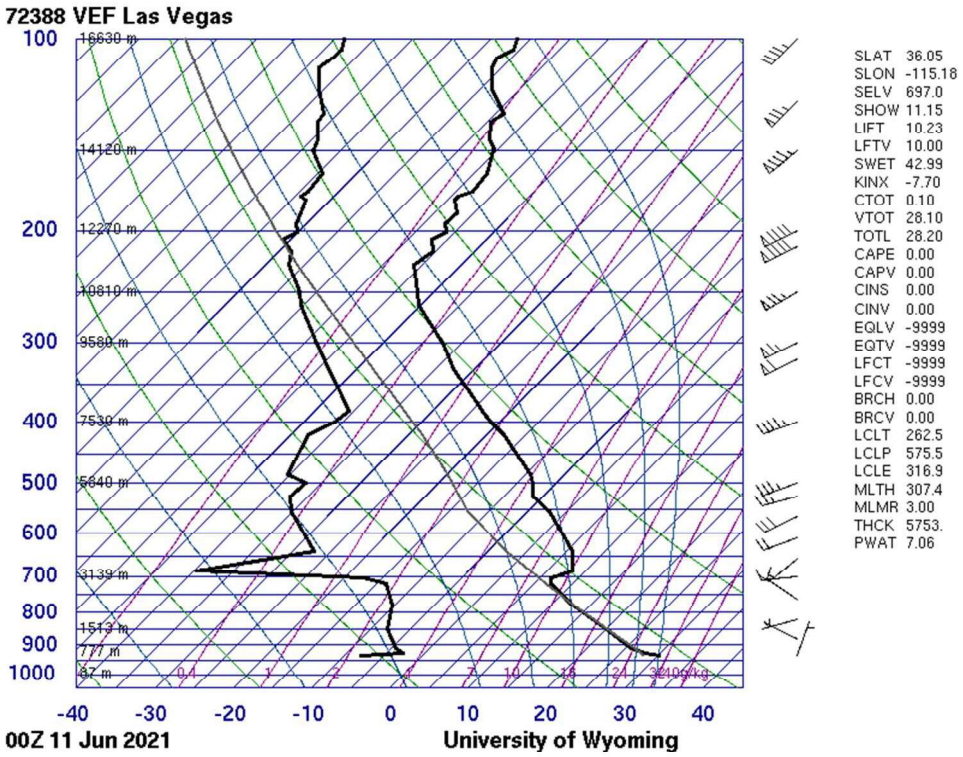

Figure 39. Sounding from Las Vegas, NV, at 00:00 UTC on June 11 (16:00 PST on June 10), 2021.

Based on these mixing heights, upper-level winds from 925 mb to 700 mb were examined for potential smoke transport. The 700 mb weather pattern featured an upper-level trough along the West Coast, and a weak ridge of high pressure over the Four Corners region, with westerly winds at 10 knots over the Las Vegas region at 00:00 UTC on June 11 (**Figure 40**). This pattern was conducive to smoke transport from the Sandy Valley Fire located to the west-southwest of Las Vegas.

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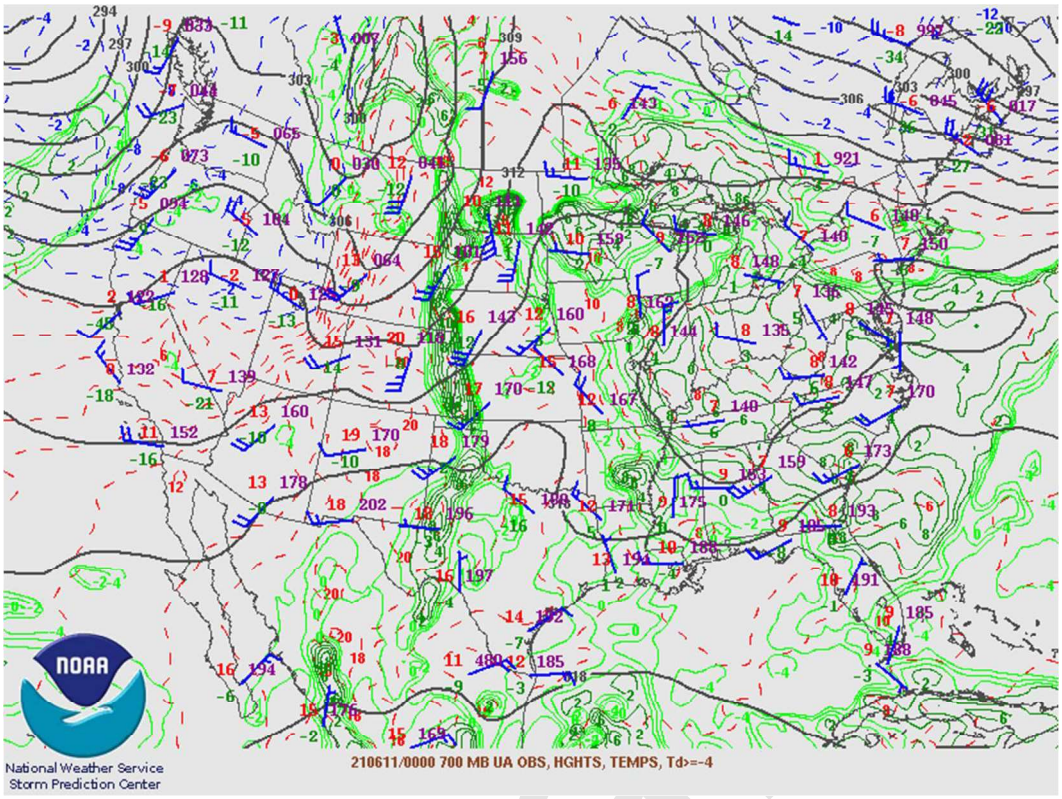

Figure 40. 700-mb map for 00:00 UTC on June 11, 2021 (16:00 PST on June 10, 2021).

As the Sandy Valley Fire ignited around 20:00 UTC (12:00 PST) on June 10, HYSPLIT back trajectories were computed from 00:00 UTC on June 11 (16:00 PST on June 10) back to 20:00 UTC (12:00 PST) on June 10 using HRRR meteorology in Las Vegas at heights of 10 meters, 1,500 meters, and 3,000 meters (Figure 41). The path of the 3,000-meter back trajectory goes directly across the location of the Sandy Valley Fire, implying smoke advection over Las Vegas near the top of the boundary layer on the evening of June 10. In addition, with low-level mixing reaching slightly above 3,000 meters, there was potential for the fumigation process to mix smoke down to the surface.

The upper-level weather pattern remained consistent through June 11, with westerly winds around 10 knots at 700 mb continuing to push smoke toward the Las Vegas region and lighter winds limiting advection near the surface at 00:00 UTC on June 12 (16:00 PST on June 11) (Figure 42).

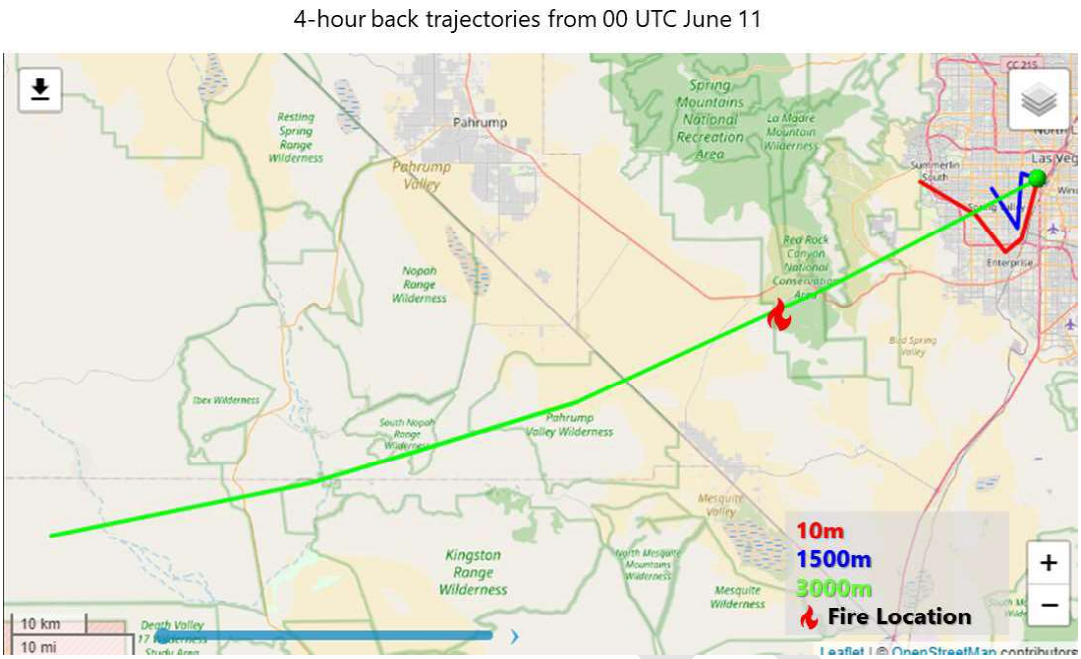

Figure 41. HYSPLIT back trajectories from 10, 1,500, and 3,000 meters using HRRR 3-km meteorological data and initiated at 00:00 UTC on June 11 back through 20:00 UTC on June 10 (16:00 PST on June 10 back through 12:00 PST on June 10).

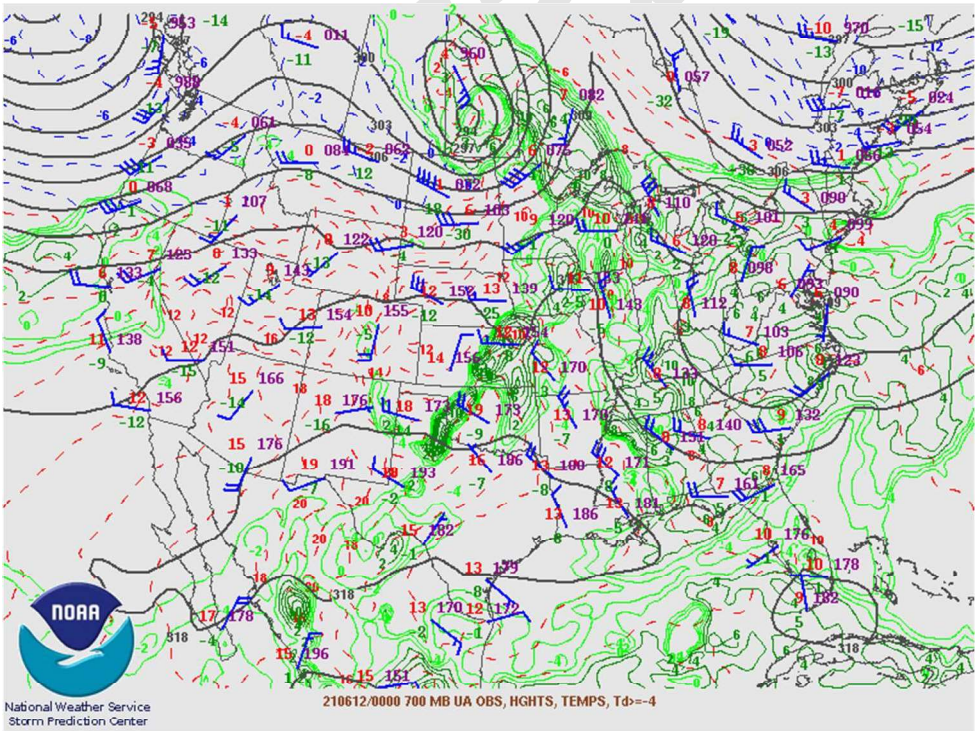

Figure 42. 700-mb map valid 00:00 UTC on June 12, 2021 (16:00 PST on June 11).

Mixing heights on the evening of June 11 were also consistent with the previous day, with a boundary layer height of 735 mb (2,743 meters) during the 00:00 UTC Las Vegas sounding on June 12 (16:00 PST on June 11) (Figure 43).

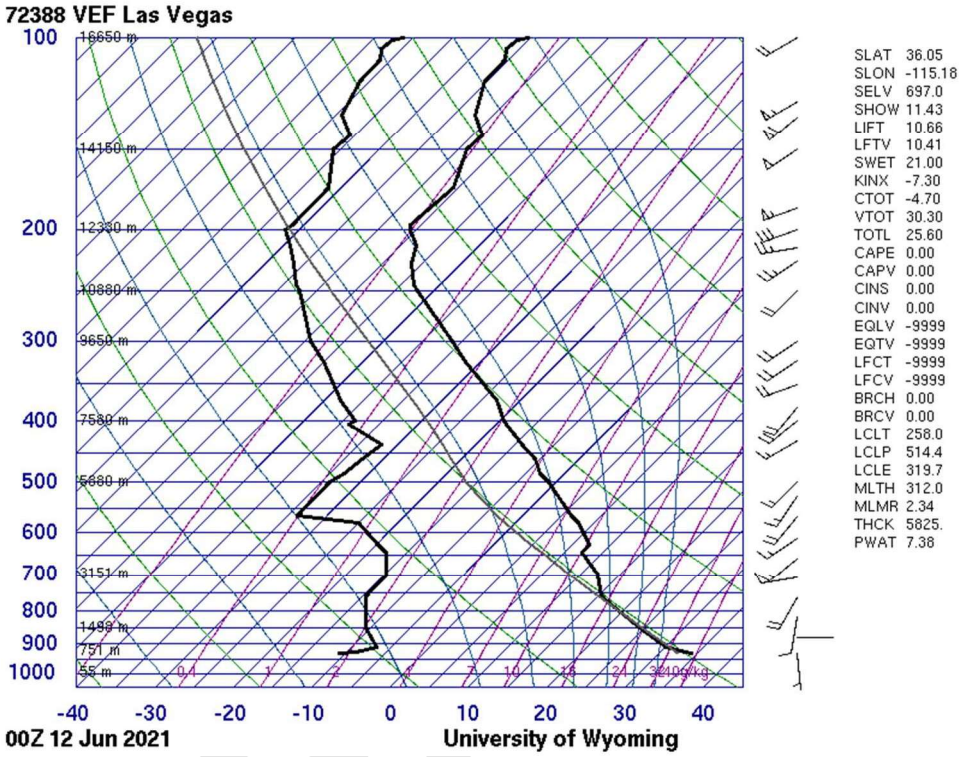

Figure 43. Sounding from Las Vegas, NV, at 00:00 UTC on June 12 (16:00 PST on June 11), 2021.

Again, HRRR back trajectories were computed at 00:00 UTC on June 12 (16:00 PST on June 11) over the previous six hours (Figure 44) to determine the potential for continued smoke transport across the Las Vegas region on the afternoon and evening of June 11. Trajectories at the top of the boundary layer continued to support smoke transport from the Sandy Valley Fire. In addition, the short trajectories within the Las Vegas Metro area were computed at 10 meters, indicating light winds and limited dispersion near the surface during the afternoon and early evening of June 11.

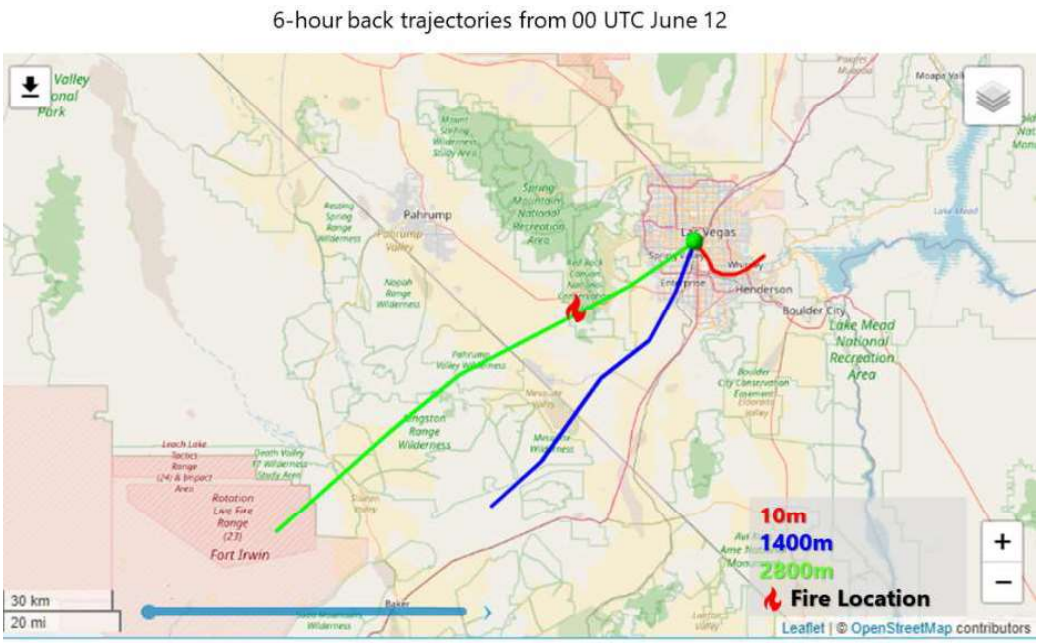

Figure 44. HYSPLIT back trajectories from 10, 1,400, and 2,800 meters using HRRR 3-km meteorological data and initiated at 00:00 UTC on June 12 back through 18:00 UTC on June 11 (16:00 PST on June 11 back through 10:00 PST on June 11).

The ridge of high pressure at 700 mb east of Las Vegas amplified on June 12, leading to a slight increase in the southerly wind component over Las Vegas. This pushed HRRR boundary layer back trajectories south of the Sandy Valley Fire. However, light winds continued to limit dispersion at the surface through June 12, allowing smoke to linger in the area. Table 9 summarizes the average surface wind speeds and directions at the meteorological stations across Las Vegas from June 10-12.

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Table 9. Wind speed and direction from meteorological sites across the Las Vegas Valley for the exclusion days.

Station Name (ID)	Day	Average Wind Speed (kts)	Average Wind Direction (deg)
Las Vegas – Harry Reid Intl. (LAS)	06-10-21	7.6	225
Henderson (HND)	06-10-21	9.7	215
NORTH LAS VEGAS (VGT)	06-10-21	10.9	279
Las Vegas – Harry Reid Intl. (LAS)	06-11-21	3.5	103
Henderson (HND)	06-11-21	5.4	166
NORTH LAS VEGAS (VGT)	06-11-21	5.3	348
Las Vegas – Harry Reid Intl. (LAS)	06-12-21	5.7	164
Henderson (HND)	06-12-21	4.6	15
NORTH LAS VEGAS (VGT)	06-12-21	3.8	143

As shown in Table 9, moderate westerly to southwesterly winds on June 10 subsided, with average wind speeds between 3-6 knots at all three Automated Surface Observing Systems (ASOS) sites in Las Vegas on June 11 and 12. Figure 45 shows that surface winds speeds from meteorological sites in the Las Vegas region throughout June 11 and 12 also indicated calm-to-light and variable winds limited dispersion each day, which allowed smoke to linger over the area.

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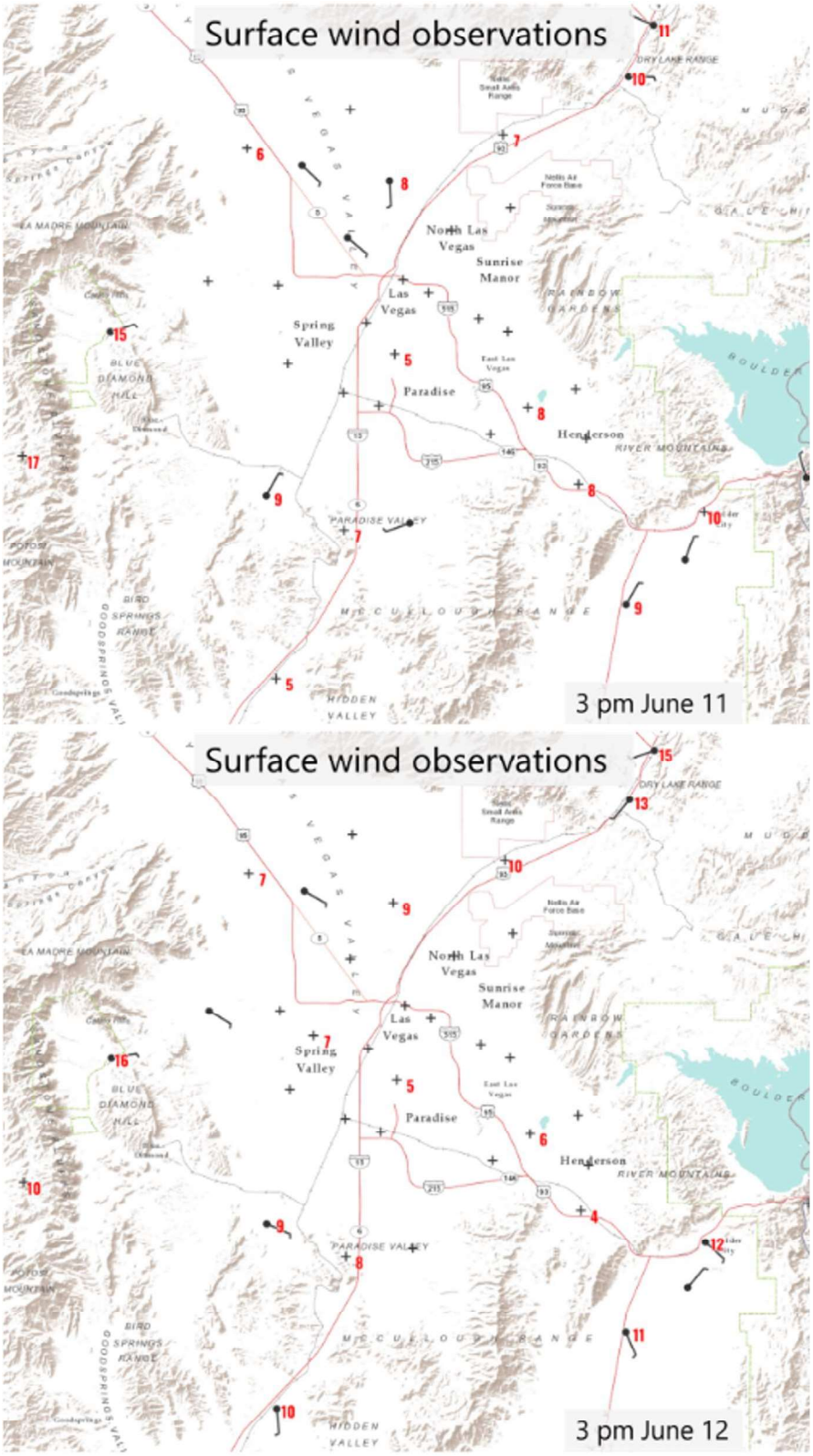

Figure 45. Light and variable surface winds are observed during the afternoons of June 11 and June 12, 2021, in the Las Vegas Valley. Wind speeds are in mph.

4.1.4 Surface Impacts

The smoke plume from the Sandy Valley Fire spread over Las Vegas during the evening of June 10, 2021. Figure 46 through Figure 48 show photos taken from the M Resort in Las Vegas between 18:30 and 19:30 PST, where the smoke plume first becomes visible at 18:30 PST in the north-facing camera (top left pane). Over the next hour, the plume spreads into view of the northeast and northwest facing camera as it expands across the valley. This prominent smoke plume was a news-worthy occurrence reported on by KTNV; their report, "Sandy Valley Fire southwest of Las Vegas grows to 1,500 acres, human-caused", provided videos of the growing smoke plume (https://www.ktnv.com/news/crews-respond-to-fire-southwest-of-las-vegas-near-sandy-valley-road-highway-160).

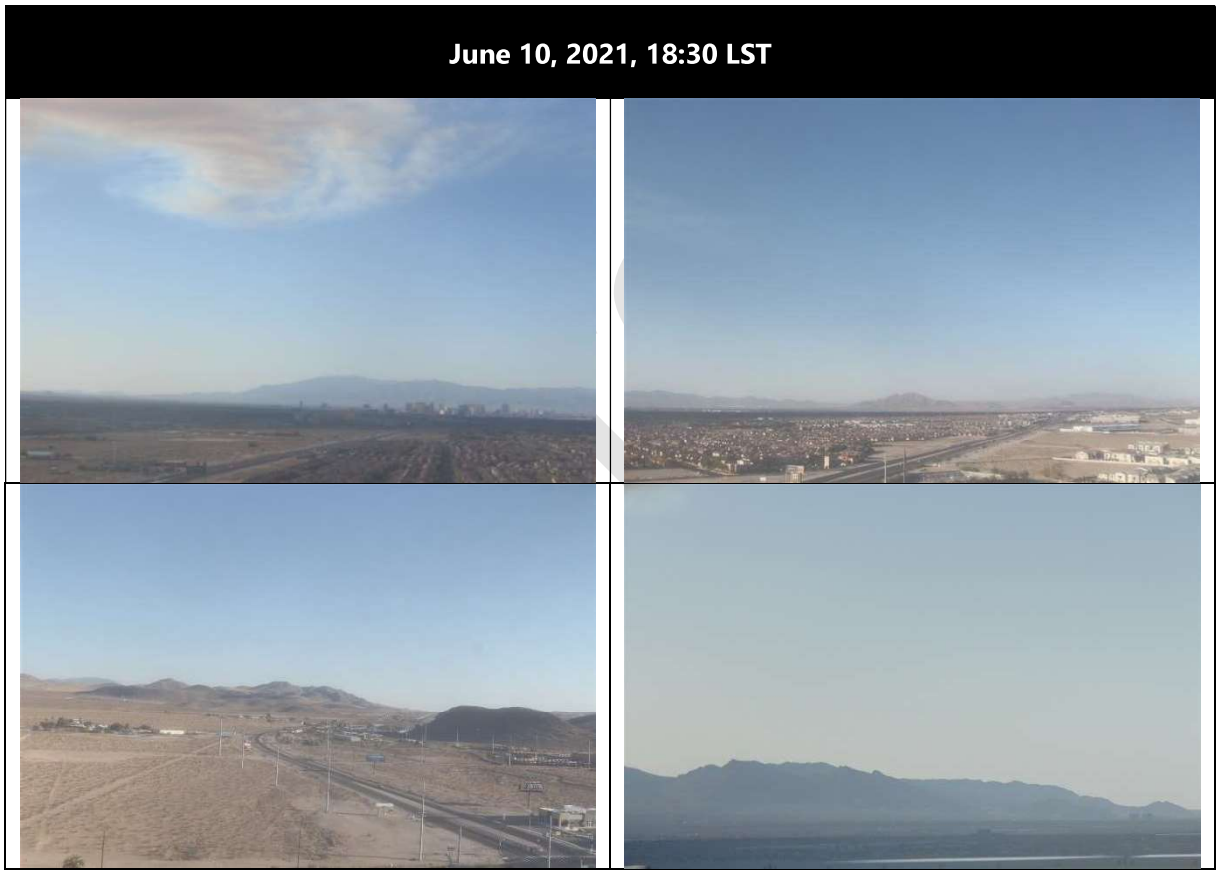

Figure 46. Camera Images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions taken from the M Resort Hotel in Clark County, NV, on June 10, 2021, at 18:30 PST. (Local standard time [LST] are used interchangeably with PST in this document.)

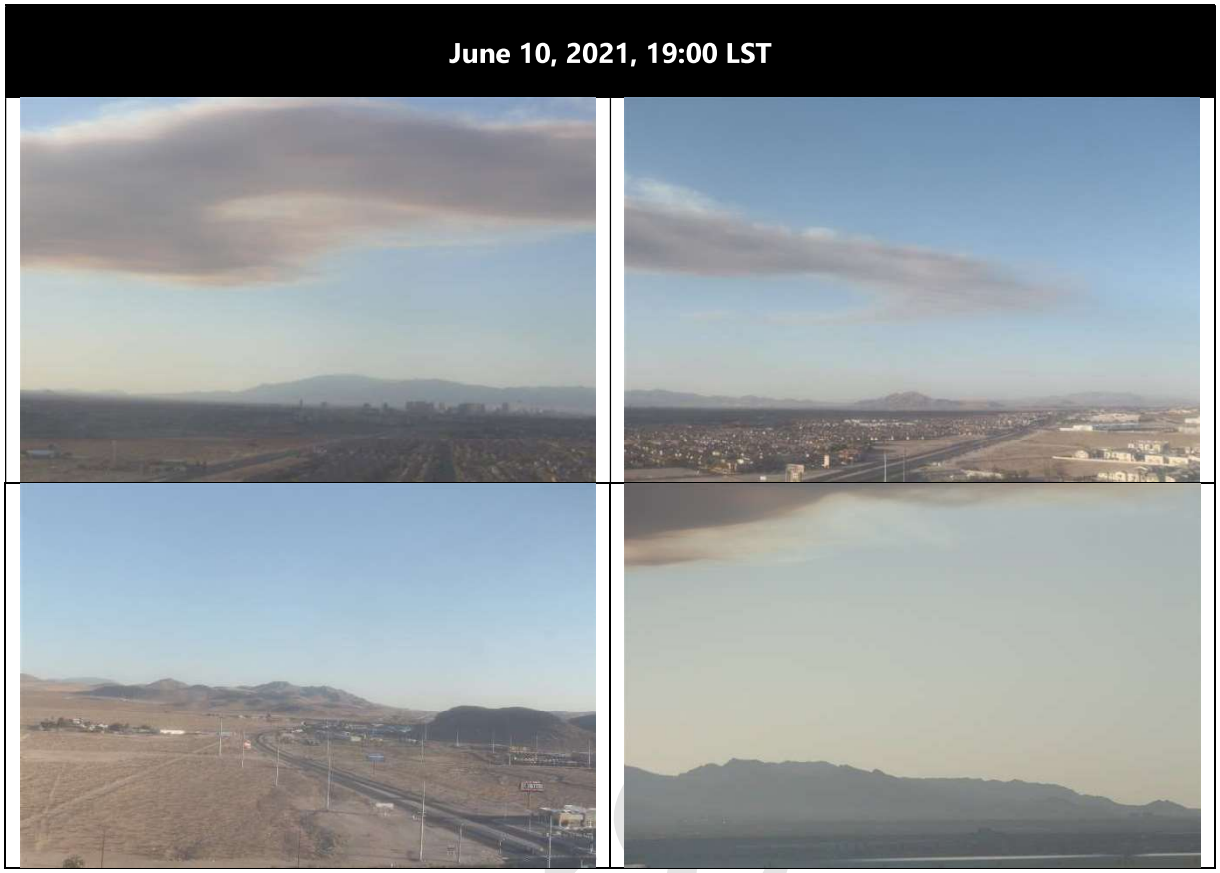

Figure 47. Camera Images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions taken from the M Resort Hotel in Clark County, NV, on June 10, 2021, at 19:00 PST.

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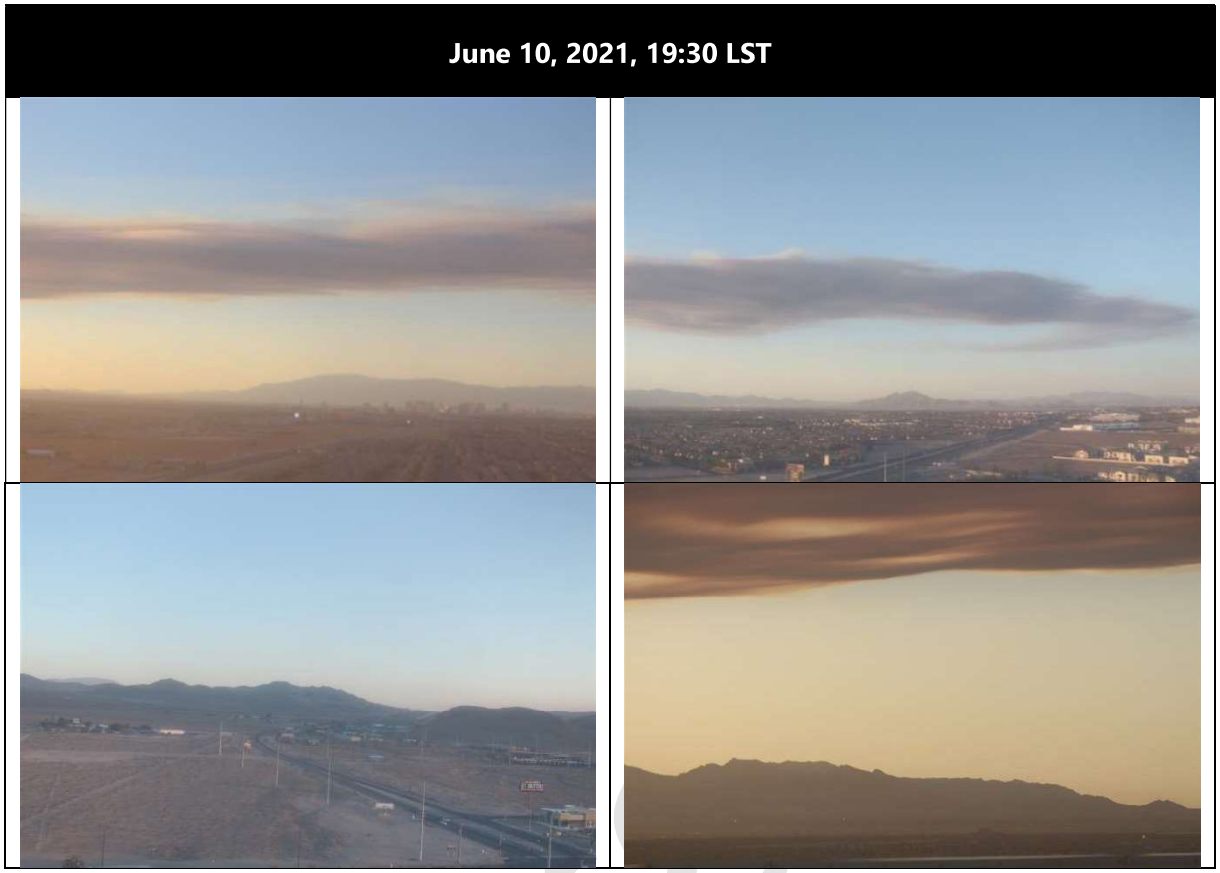

Figure 48. Camera Images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions taken from the M Resort Hotel in Clark County, NV, on June 10, 2021, at 19:30 PST.

$PM_{2.5}$, CO, and NO_2 concentrations were enhanced in Clark County overnight between June 10 and 11 as smoke from the Sandy Valley Fire entered the region and mixed towards the surface, which provides further evidence that wildfire smoke was present as an atypical influence on ozone during the exclusion period. Figure 49(a) shows hourly $PM_{2.5}$ concentrations at the Green Valley site (one of the affected sites) overlaid on the 10th-90th percentile hourly concentrations during ozone season (May to October), calculated using data from 2017-2021. $PM_{2.5}$ concentrations rose sharply to a high peak concentration of 17.3 µg/m^3 at the Green Valley site as smoke moved into the area, reaching concentrations that far exceed the 90th percentile average concentration between 23:00 PST on June 10 and 03:00 PST on June 11.

Figure 49(b) shows hourly CO concentrations at the Green Valley site during the same period, alongside the 5-yr seasonal 10th-90th percentile range of diurnal CO concentrations. The overnight CO concentration did not decrease to an expected overnight low, but instead remained enhanced well above the 90th percentile concentration between 23:00 PST on June 10 and 03:00 PST on June 11, the same time that $PM_{2.5}$ was enhanced.

NO_2 concentrations in Clark County were also enhanced between June 10 and 11, as shown in **Figure 49(c)**. Concentrations exceeded the 90th percentile concentration on the evening of June 11. Data is shown from the Joe Neal site because NO_2 data is not collected at the Green Valley site.

The ratio of $PM_{2.5}$-to-PM_{10} concentrations was also examined for evidence that wildfire smoke entered Clark County. Increases in this ratio are indicative of wildfire smoke. **Figure 49(d)** shows a time series of data collected at the Jean site showing the ratio of $PM_{2.5}$-to-PM_{10} concentrations from June 10 through June 13 compared to the ozone season mean and 5th - 95 percentile range for available data between 2017-2021. The Jean site is upwind of Clark County and along the trajectory route between the Sandy Valley Fire and the Las Vegas Valley, allowing for examining the $PM_{2.5}$-to-PM_{10} ratios in the absence of anthropogenic particulate emissions. During the evening of June 10 and morning of June 11, ratios exceeded the 5-yr hourly average and the 95th percentile, and reached approximately 0.75, which is indicative of wildfire smoke entering the area and in agreement with the HYSPLIT back trajectory (Figure 41) which showed the smoke plume passed through the Jean monitoring station as it entered the valley. These observations provide further evidence that ground-level wildfire smoke entered Clark County on June 10 and 11 containing increased $PM_{2.5}$ concentrations and enhanced $PM_{2.5}$ to PM_{10} ratios immediately prior to the atypical ozone events occurring on June 11 and 12.

Time series data for $PM_{2.5}$, CO, and NO_2, and $PM_{2.5}$-to-PM_{10} ratios at all other affected sites is shown in **Figure 50 through Figure 53.**

The concurrence of increased $PM_{2.5}$, CO, and NO_2 concentrations, the enhanced $PM_{2.5}$-to-PM_{10} ratio in Clark County overnight between June 10 and 11, and the imagery showing a smoke plume over the region, provide strong evidence that surface-level smoke was present in Clark County during the exclusion period. Increased concentrations of $PM_{2.5}$ on June 11 is consistent with transport of more particulate matter during the flaming portion of a quickly spreading fire. By June 12, the fire had been significantly contained, and was more likely to be smoldering (producing more gaseous pollutants than particulate). This is consistent with the increased NO_2 and CO concentrations during the later days of the fire while the $PM_{2.5}$ and $PM_{2.5}$-to-PM_{10} ratios return to near normal. This combined evidence suggests that the Sandy Valley Fire provided an atypical source of ozone and ozone precursors that caused enhanced ozone concentrations on June 11 and 12, 2021.

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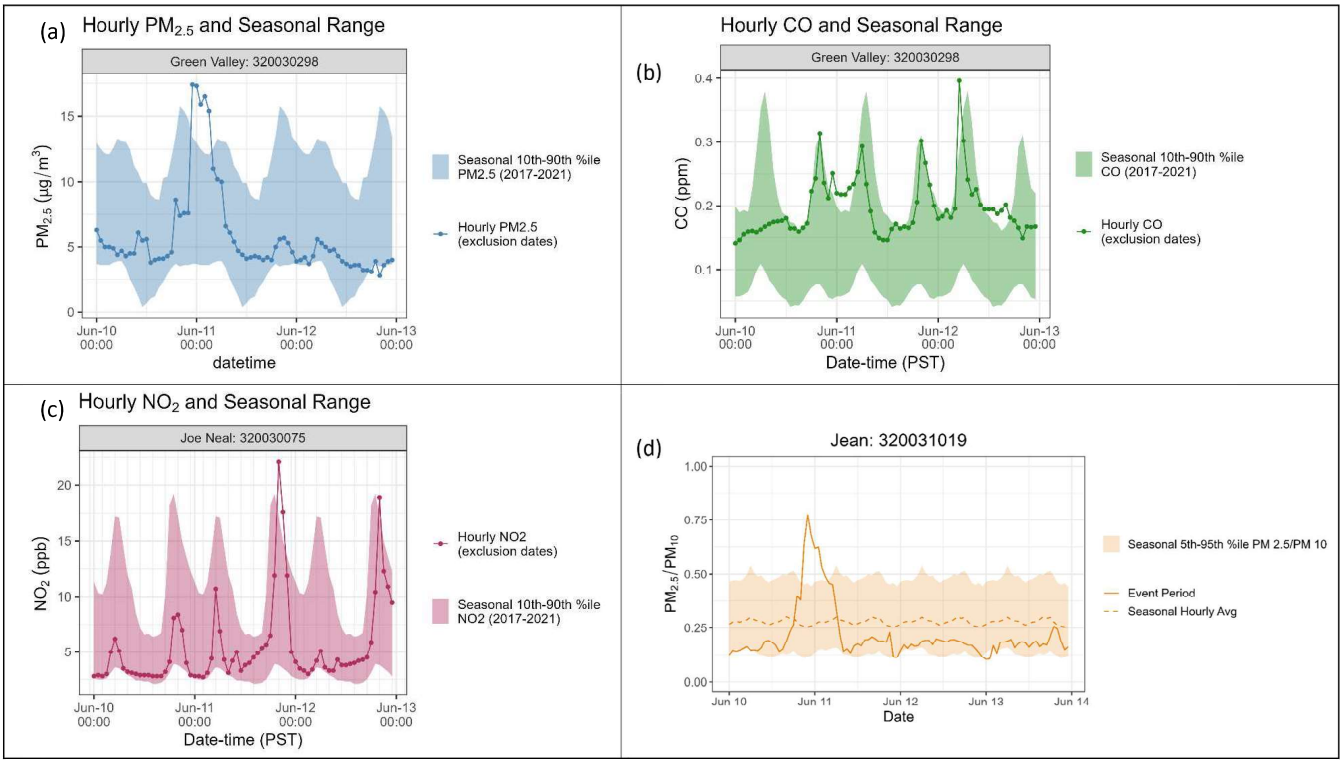

Figure 49. (a) Hourly $PM_{2.5}$ measurements overlaid on the 10th-90th percentile diurnal concentration at the Green Valley site. (b) Hourly CO measurements overlaid on the 10th-90th percentile diurnal concentration at the Green Valley site. (c) Hourly NO_2 measurements overlaid on the 10th-90th percentile diurnal concentration at the Jerome Mack-NCore site. (d) Ratio of $PM_{2.5}/PM_{10}$ concentrations at the Jean site during the June 11 and June 12 event period. The 10th-90th percentile and 5th-95th percentile concentration in each figure is calculated for each site and parameter across the ozone production season (May-October) of 2017-2021.

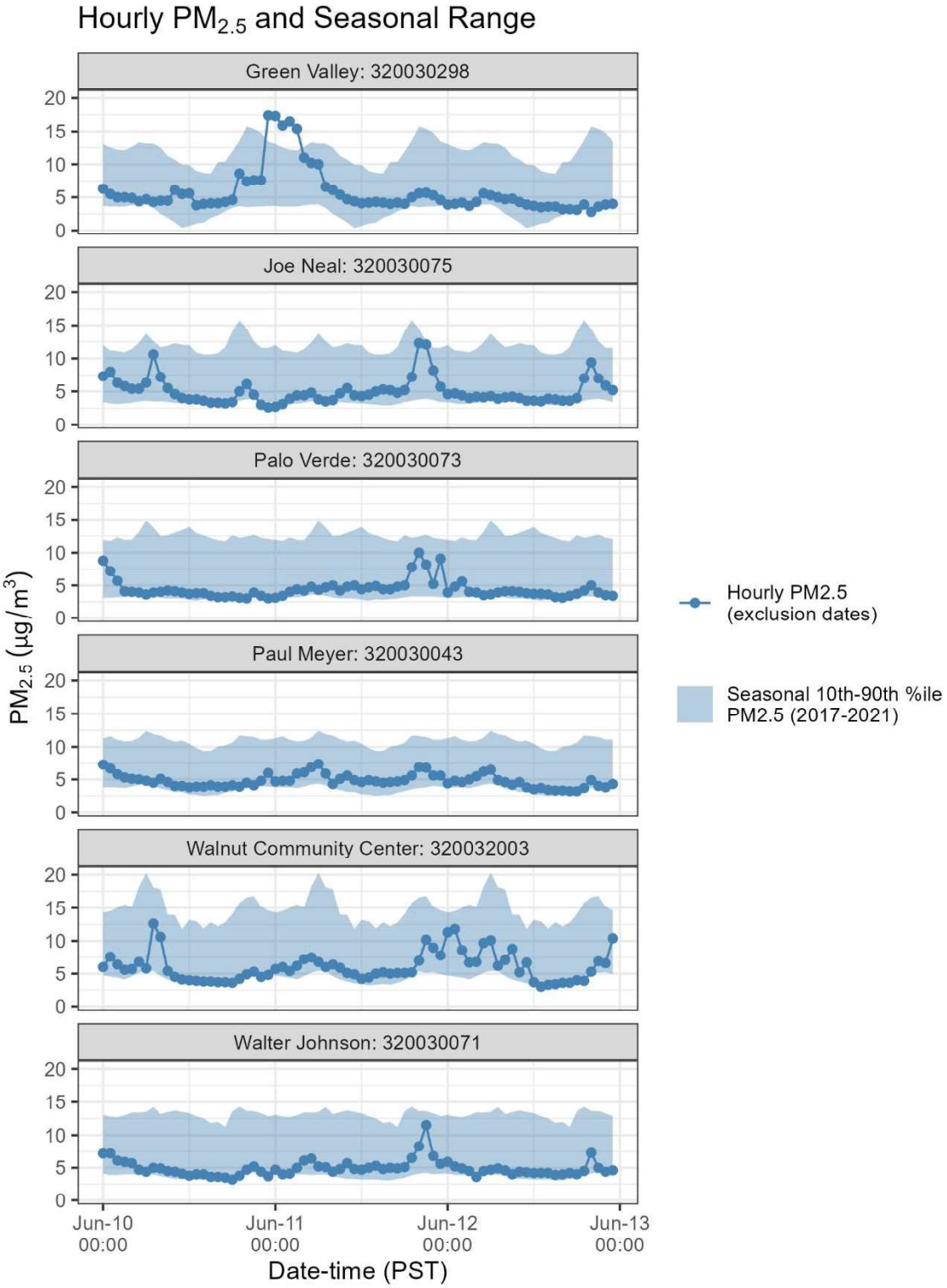

Figure 50. Hourly $PM_{2.5}$ measurements overlaid on the 10th-90th percentile diurnal concentration at all affected sites.

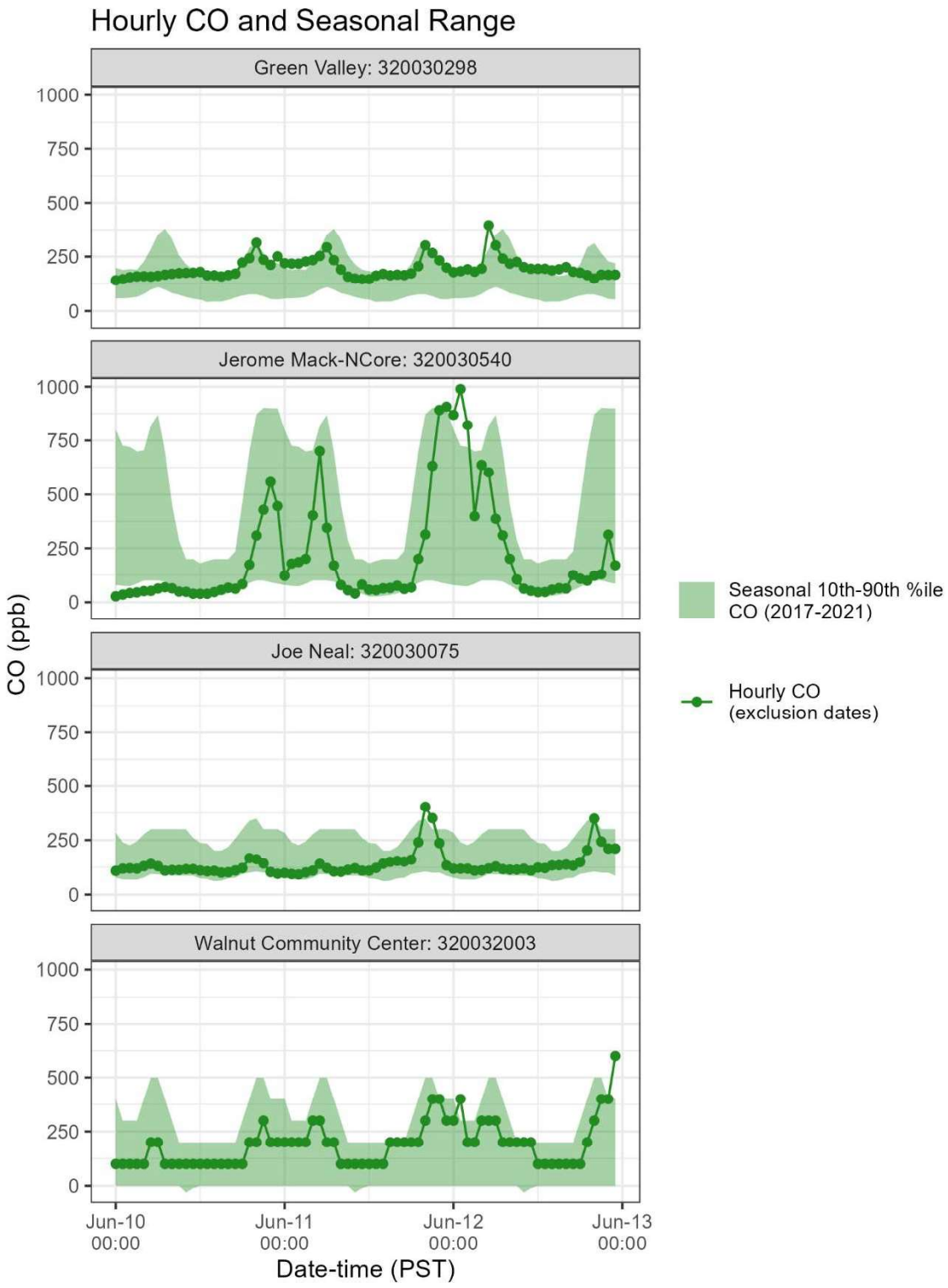

Figure 51. Hourly CO measurements overlaid on the 10th-90th percentile diurnal concentration at all affected sites.

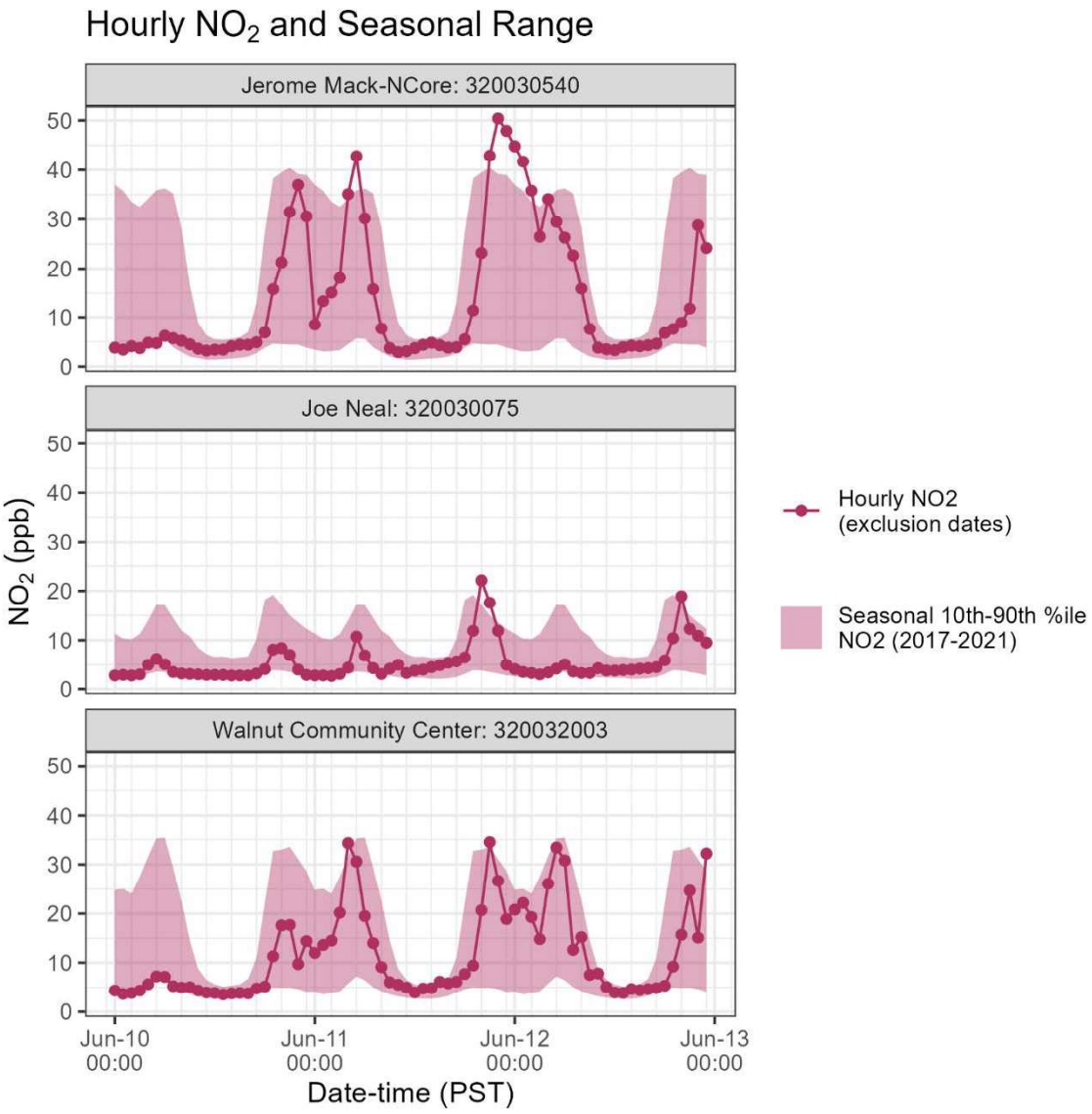

Figure 52. Hourly NO_2 measurements overlaid on the 10th-90th percentile diurnal concentration at all affected sites.

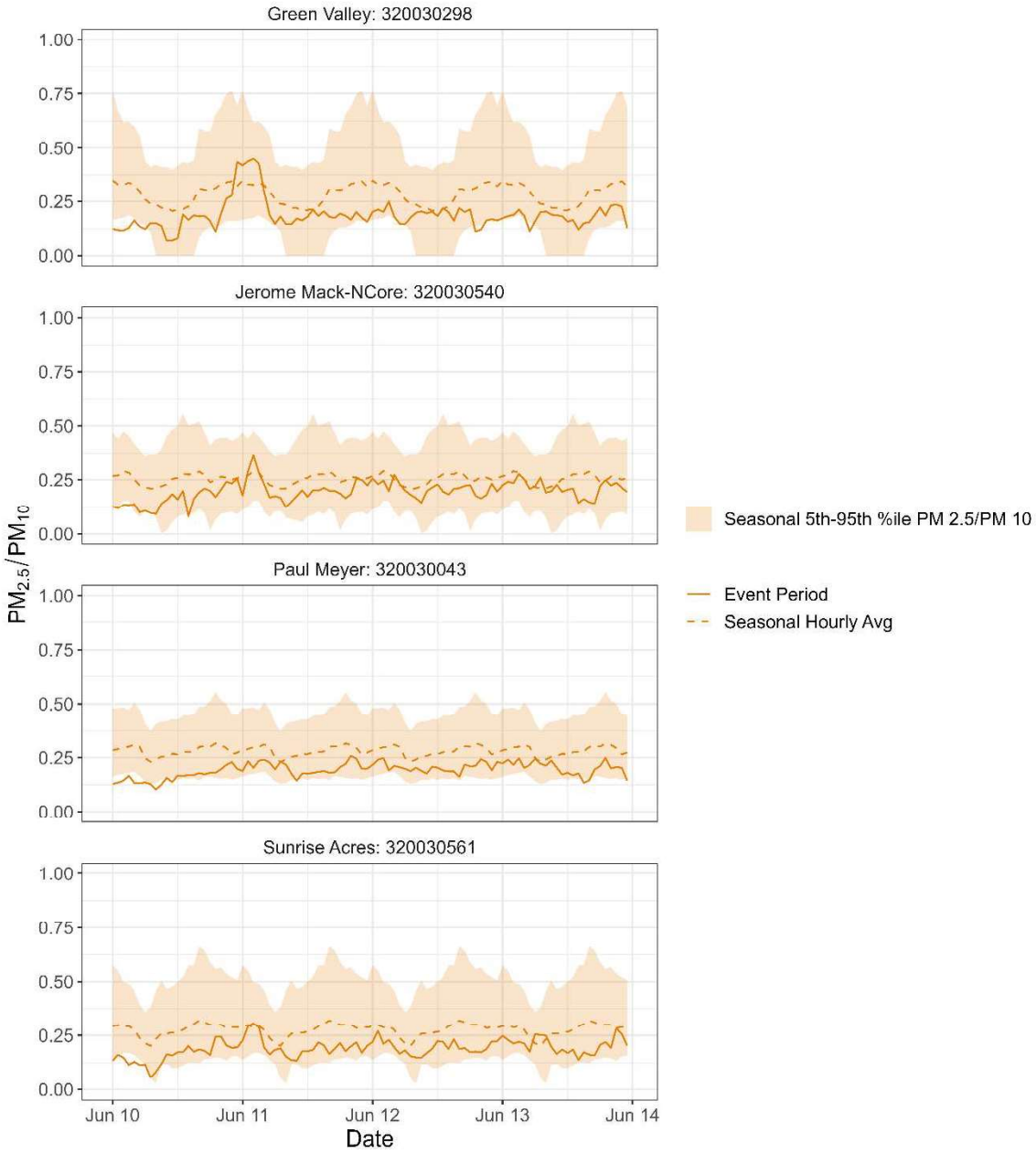

Figure 53. Hourly $PM_{2.5}$-to-PM_{10} measurement ratios overlaid on the 10th-90th percentile diurnal concentration at all affected sites.

4.1.5 Event Statistics

Table 10 summarizes the measurements of ozone, $PM_{2.5}$, CO, and NO_2 concentrations on June 11 and 12, 2021, as well as the percentile rank of the observation compared to the previous five years of ozone season data (May 1-October 31, 2017-2021). Ozone MDA8 measurements ranged from the 93rd to 97th percentile on June 11-12.

24-hr average $PM_{2.5}$ measurements were scattered, ranging from the 15th-75th percentile. As shown in Figure 49(a), peak hourly concentrations are split across the end of June 10 and the beginning of June 11, with lower concentrations (<7 ppb) on either end of the observed spike. As a result, the 24-hr average $PM_{2.5}$ concentrations do not adequately capture the observed hourly anomalies.

CO and NO_2 measurements are not measured at all affected sites and less than five years of data is available for comparison at most sites where it is measured. Data from the Jerome Mack site is thus also included for additional context on enhanced CO and NO_2 observations across the region. In general, CO 1-hr daily maximum measurements in Clark County were somewhat higher than typical ozone season values, ranging from 300-989 ppb, or the 47th-87th percentile for each site. NO_2 1-hr daily maximum observations ranged from 22.1 to 50.4 ppb, or the 70th-96th percentile for each site.

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Table 10. Percentile of pollutant measurements on exclusion day compared with most recent five years* (2017-2021). The percentile rank is calculated across the ozone production season (May 1-October 31) of 2017-2021. Data from nearby sites not identified for exclusion are shown in grey italics.

Date	Site Name	Site Code	Ozone		$PM_{2.5}$		CO		NO_2	
			Ozone MDA8 (ppb)	Percent Rank	$PM_{2.5}$ 24-hr Avg ($\mu g/m^3$)	Percent Rank	CO 1-hr Daily Max (ppb)	Percent Rank	NO_2 1-hr Daily Max (ppb)	Percent Rank
6/11/2021	Paul Meyer	320030043	72	96.4	5.4	40.5	--	--	--	--
6/11/2021	Walter Johnson	320030071	72	94.7	5.5	35.8*	--	--	--	--
6/11/2021	Joe Neal	320030075	73	96.6	5.3	38.3*	404	87.4*	22.1	81.7
6/11/2021	Green Valley	320030298	71	96.2	7.4	71.8	302	61.8*	--	--
6/11/2021	Walnut Comm. Center	320032003	72	96.1*	6	24.8*	400	47.7*	34.5	70.6*
6/11/2021	*Jerome Mack-NCore*	*320030540*	--	--	--	--	*907*	*79.6*	*50.4*	*96.8*
6/12/2021	Walter Johnson	320030071	71	93.2	4.5	15.8*	--	--	--	--
6/12/2021	Palo Verde	320030073	71	97.3	3.9	17*	--	--	--	--
6/12/2021	*Jerome Mack-NCore*	*320030540*	--	--	--	--	*989*	*81.8*	*44.8*	*89*

*Sites that have less than five years of data available for a given parameter.

4.2 June 16-17, 2021

4.2.1 Event Summary

The unrepresentative ozone event took place on June 16-17, 2021, and affected five sites in Clark County, Nevada: Palo Verde, Joe Neal, Paul Meyer, Walter Johnson, and Mountain's Edge. The MDA8 concentrations at the effected sites ranged from 71-75 ppb: 74 ppb at Palo Verde, 72 ppb at Joe Neal, and 71 ppb at Paul Meyer and Walter Johnson on June 16, and 75 ppb at Mountain's Edge and 72 ppb at Paul Meyer on June 17. Time series graphs showing hourly ozone concentrations that exceeded the ozone season means and 10th-90th percentiles (calculated using May 1-October 31, 2017-2021) at each site are shown in Figure 54.

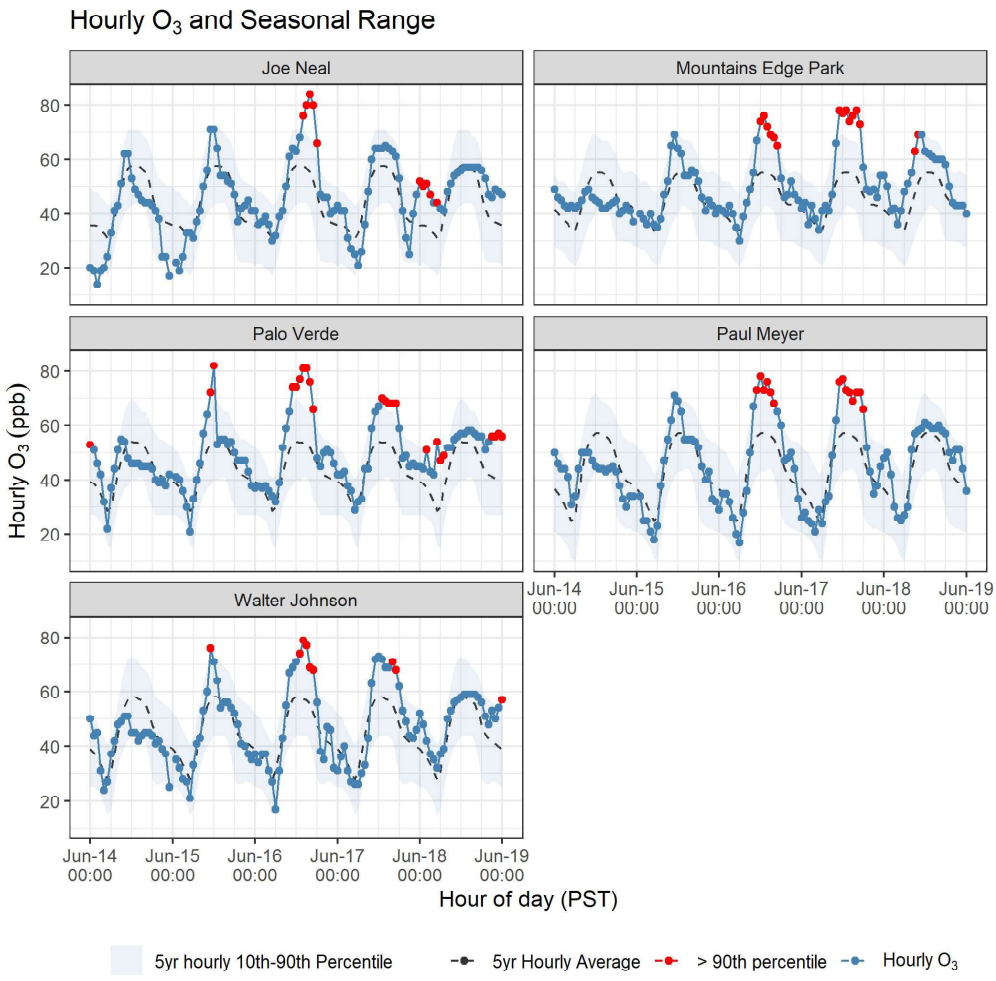

Figure 54. Hourly ozone concentrations (ppb) compared to 5-yr* ozone season (May 1-October 31, 2017-2021) hourly means and 10-90th percentiles. *Note: data from the Mountain's Edge site are only available for June 1-October 31, 2021.

On June 16, hourly ozone measurements rose sharply above (>10%) the mean beginning as early as 08:00 PST and exceeded the 90th percentile between 11:00-18:00 PST. On June 17, hourly ozone measurements began rising sharply above the mean at 10:00 PST and surpassed 90th percentile between 11:00-17:00 PST.

Four major wildfires with significant emissions – the Johnson Fire event in New Mexico and the Telegraph, Pinnacle, and Slate Fires in Arizona – were identified to be the major contributors to the regional wildfire smoke that precipitated the event. Evidence indicating this is an unrepresentative event for assessing base and future ozone design value assessments includes (1) HYSPLIT dispersion modeling showing accumulation of smoke in Clark County, (2) the presence of visible smoke in camera images, and (3) $PM_{2.5}$ concentrations above the 5-yr 90th percentile. Enhanced CO and NO_2 concentrations as well as $PM_{2.5}$-to-PM_{10} ratios provide additional support for the influence of wildfire smoke during this time period.

4.2.2 Identification of Wildfires

Numerous wildfires were active during the June 16-17, 2021, exclusion days and contributed to regional smoke. As mentioned above, four major wildfires with significant emissions that contributed to the regional smoke were identified: the Johnson Fire event in New Mexico, and the Telegraph, Pinnacle and Slate Fires in Arizona (Figure 55). Regional smoke was present in mid-June 2021 throughout the southwest U.S., and this was verified for the days of June 14-17 through visualization of smoke and wildfire detection geodata provided by the NOAA HMS (Figure 56). Table 11 presents the state location, total acres within the fire perimeter, and the start and containment dates for each fire based on data from the WFIGS Current Interagency Fire Perimeters.[6]

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[6] McClure et al. (2023) Consistent, high-accuracy mapping of daily and sub-daily wildfire growth with satellite observations. International Journal of Wildland Fire 32, 694-708. Available at https://www.publish.csiro.au/wf/ExportCitation/WF22048.

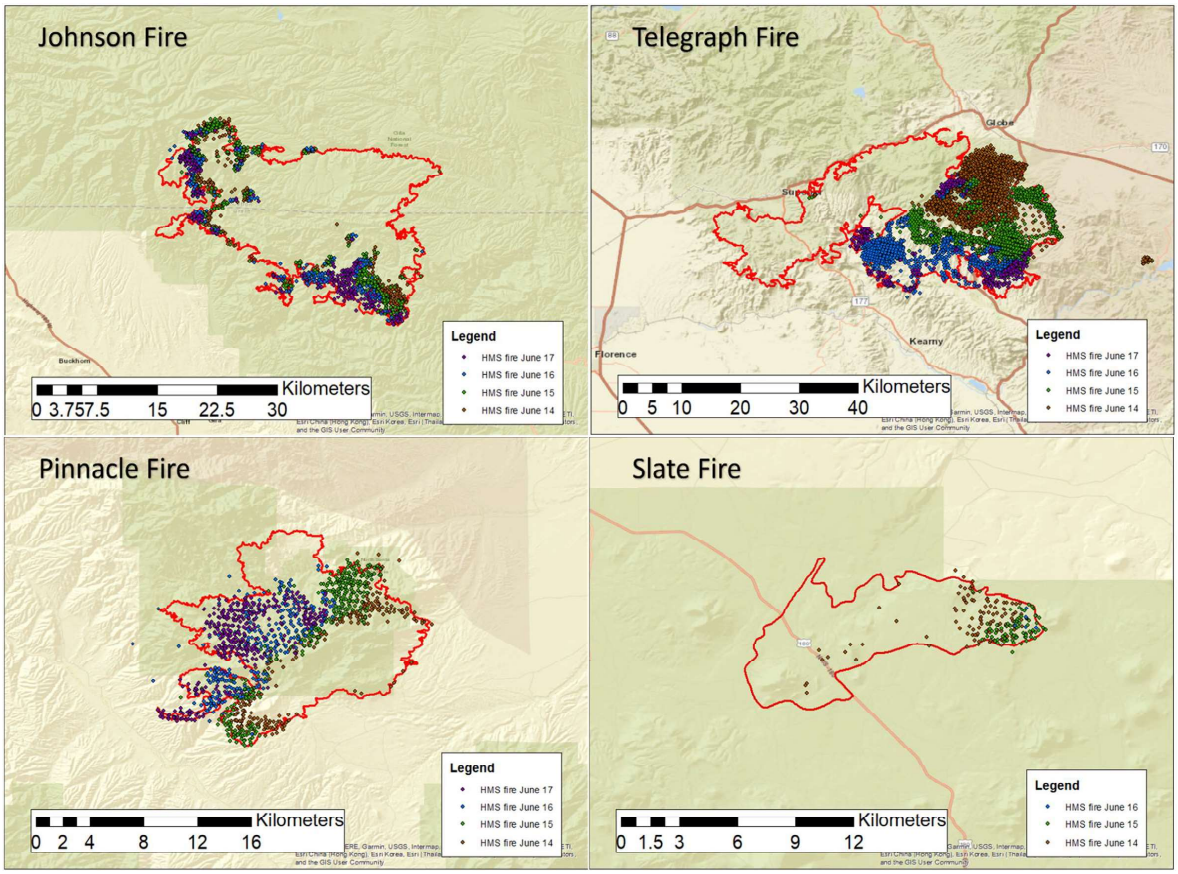

Figure 55. Full fire perimeters (red) and HMS fire detections for the Johnson, Telegraph, Pinnacle, and Slate Fires for June 14-17, 2021.

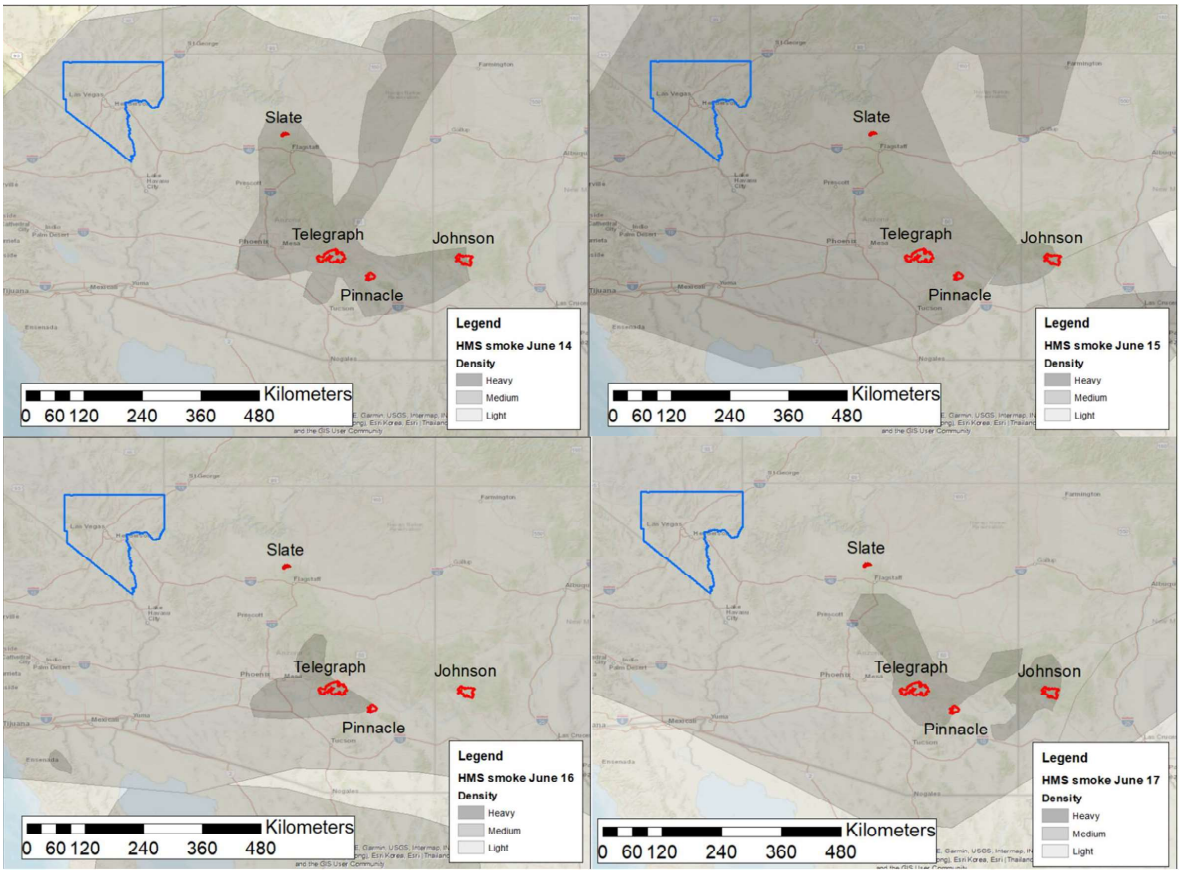

Figure 56. HMS smoke boundaries for June 14-17, 2021, are included with qualitative smoke density. Fire perimeters from the major fires contributing to the exclusion date are shown in red and the Clark County, NV, boundary is shown in blue.

Table 11. Wildfires affecting Clark County on the exclusion days. The fire name, state location, total acreage, acres burned on or before the exclusion days, and the start and containment dates are included.

Wildfire Name	State	Total Acres	Acres Burned On or Before Exclusion Days	Start Date	Containment Date
Johnson	New Mexico	94,732	73,069 (June 15)[7]	May 20	July 22
Telegraph	Arizona	179,678	171,242 (June 17)[8]	June 4	July 3
Pinnacle	Arizona	34,394	17,453 (June 17)[9]	June 10	July 16
Slate	Arizona	11,435	11,435 (June 17)[8]	June 7	July 6

4.2.3 Dispersion Modeling and Regional Analysis

HYSPLIT dispersion modelling was performed for the June 16-18, 2021, period. Dispersion runs were initiated at 00:00 PST from the four identified active fires impacting the exclusion date. Global Data Assimilation System (GDAS) data at 1.0° horizontal resolution was used for meteorological input. Output from the dispersion modeling was integrated over a 48-hr period, from June 16 at 00:00 PST through June 18 at 00:00 PST. This time period was chosen to correspond with the initial increase of observed $PM_{2.5}$ concentrations in Clark County. The accumulation of smoke in the 0-100 m vertical layer for the 24-hr period is shown in Figure 57.

The HYSPLIT dispersion modeling shows that smoke from multiple fires mixed to produce a dense layer of smoke that blanketed the Southwestern U.S. region, including Clark County, NV. The modeling results are consistent with the HMS smoke plume data (shown in gray in Figure 57); HMS is an independent smoke identification database. The results of the dispersion modeling show that smoke from multiple fires reached Clark County on June 16-17, 2021, and the smoke was present in the lower mixed layer of the atmosphere, impacting surface conditions.

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[7] https://nmfireinfo.com/2021/06/15/gila-nf-johnson-fire-update-for-june-15-2021/
[8] https://www.azcentral.com/story/news/local/arizona-wildfires/2021/06/17/telegraph-mescal-wildfires-evacuations-el-capitan-dripping-springs-wind-spirit-hagen-ranch/7729359002/
[9] https://www.azcentral.com/story/news/local/arizona-wildfires/2021/06/17/winchester-backbone-pinnacle-slate-cornville-wildfires-burn-arizona/7730847002/

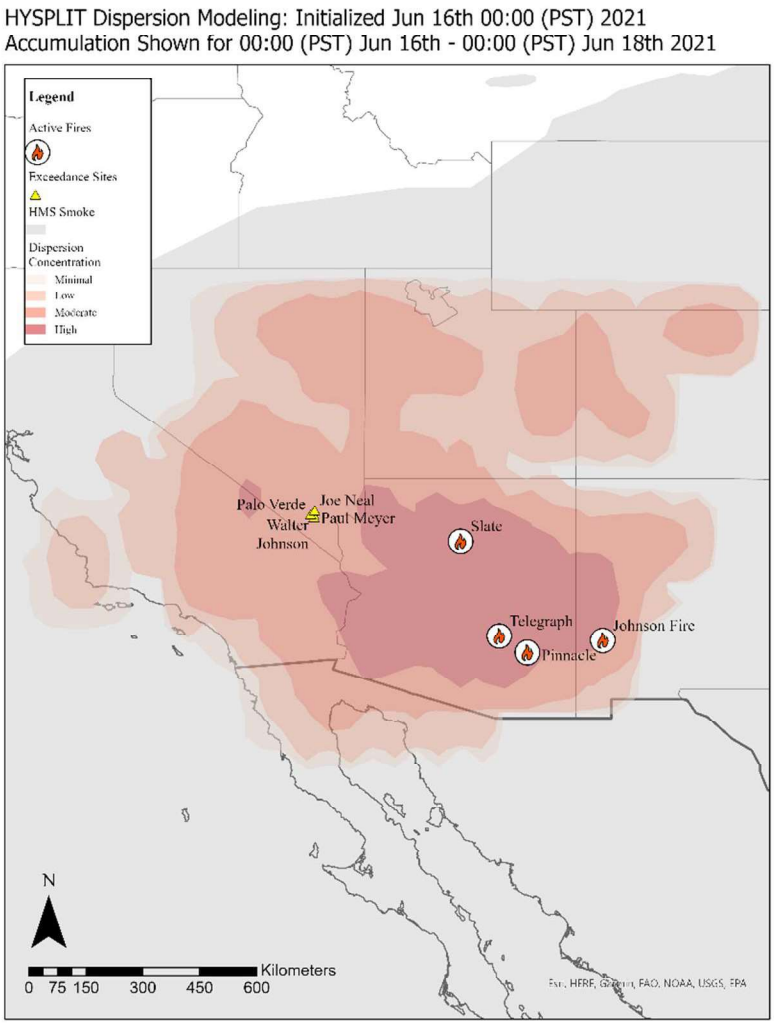

Figure 57. HYSPLIT dispersion modeling for the large fires (labeled as "Active Fires") in Arizona and New Mexico. GDAS 1.0° meteorological data was used, and dispersion was initiated on June 6, 2021, at 00:00 PST to model the regional smoke observed in satellite and HMS products. HMS smoke is shown in gray and qualitative concentrations of particulate matter are shown in shades of red. Accumulation of particulate matter is shown in the 0-100 m vertical layer for 00:00 PST on June 16 through 00:00 PST on June 18, 2021.

Clockwise air flow around upper-level high pressure near the Four Corners transported smoke from fires in Arizona into Clark County, NV (Figure 58). The vertical atmospheric profile for June 16, 2021 (Figure 59), indicates a deep planetary boundary layer (PBL) of approximately 19,000 feet (5,800 meters) over Las Vegas. Smoke from fires in Arizona originated at an elevation of 7,000 feet (2,100 meters) and became entrained in a clockwise airflow pattern at 700 mb (approximately 10,000 feet) near the Four Corners. This flow pattern is consistent with the dispersion modeling results.

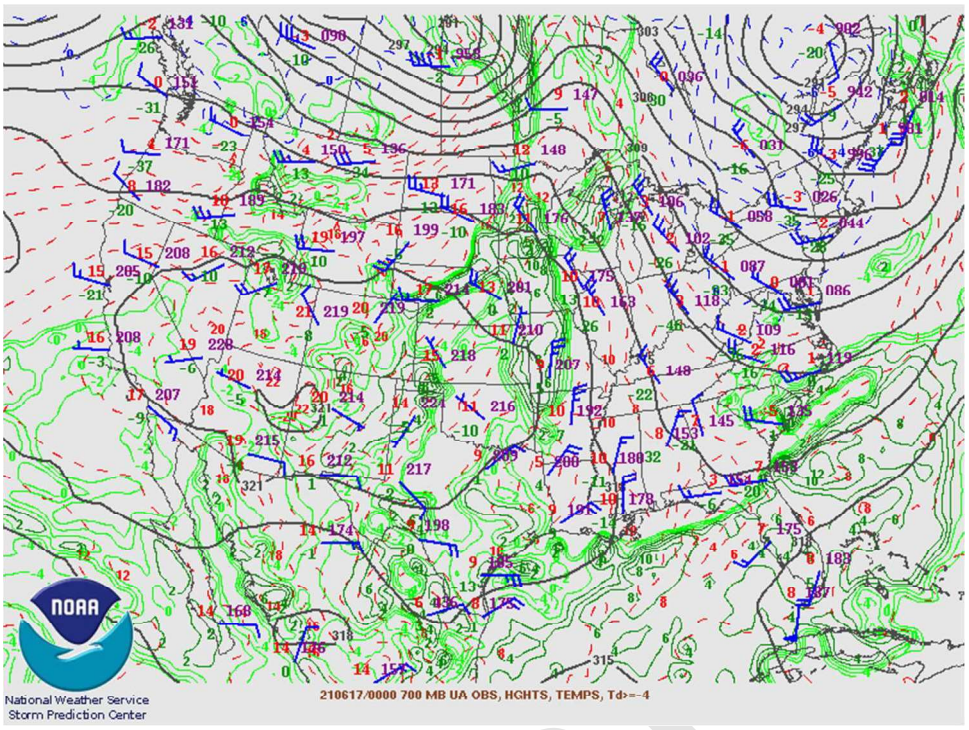

Figure 58. Map of 700-mb (approx. 10,000 feet ASL) air flow. Map valid at 00:00 UTC on June 17, 2021 (16:00 PST on June 16, 2021).

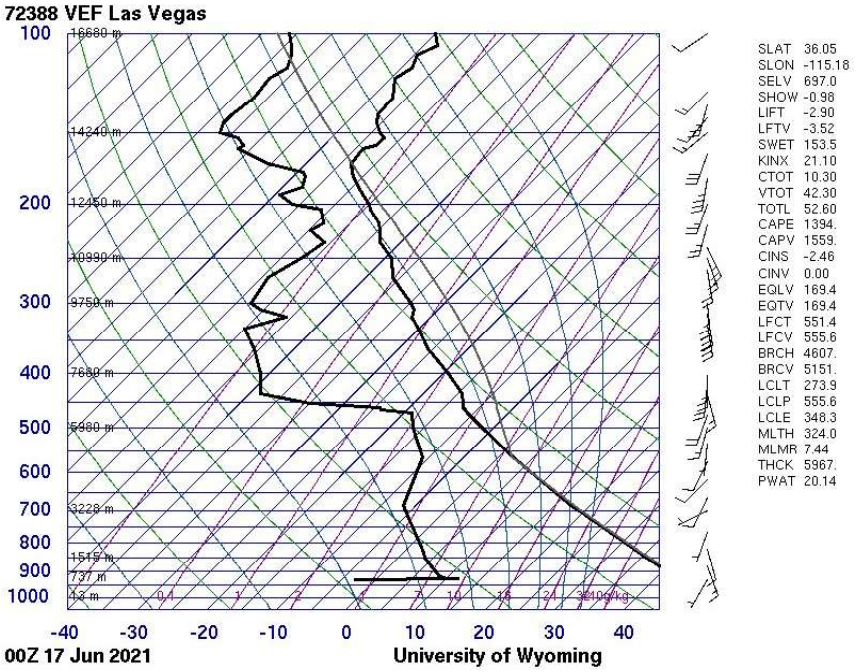

Figure 59. Sounding from Las Vegas, Nevada, at 00:00 UTC on June 17 (16:00 PST on June 16), 2021, where x-axis shows temperature (°C) and y-axis shows pressure (mb). Retrieved from https://weather.uwyo.edu/upperair/sounding.html.

4.2.4 Surface Impacts

The presence of wildfire smoke during the exclusion dates is evident by comparing the visibility conditions on the morning of June 15 (Figure 60) to the conditions on the exclusion dates of June 16-17 (Figure 61 and Figure 62). Local and regional smoke from the fires identified in Section 4.2.2 is visible in Clark County on both June 16 and 17 at 09:00 PST, when ozone photochemical production typically starts to accelerate. The presence of local and regional smoke had an atypical influence on ozone and ozone precursors in the Clark County area and caused higher than normal ozone concentrations on the exclusion date. Ground observations from KLAS local news, shown in Table 12, confirm that smoke from the Arizona wildfires contributed to haze reported in the remarks section of the news report.

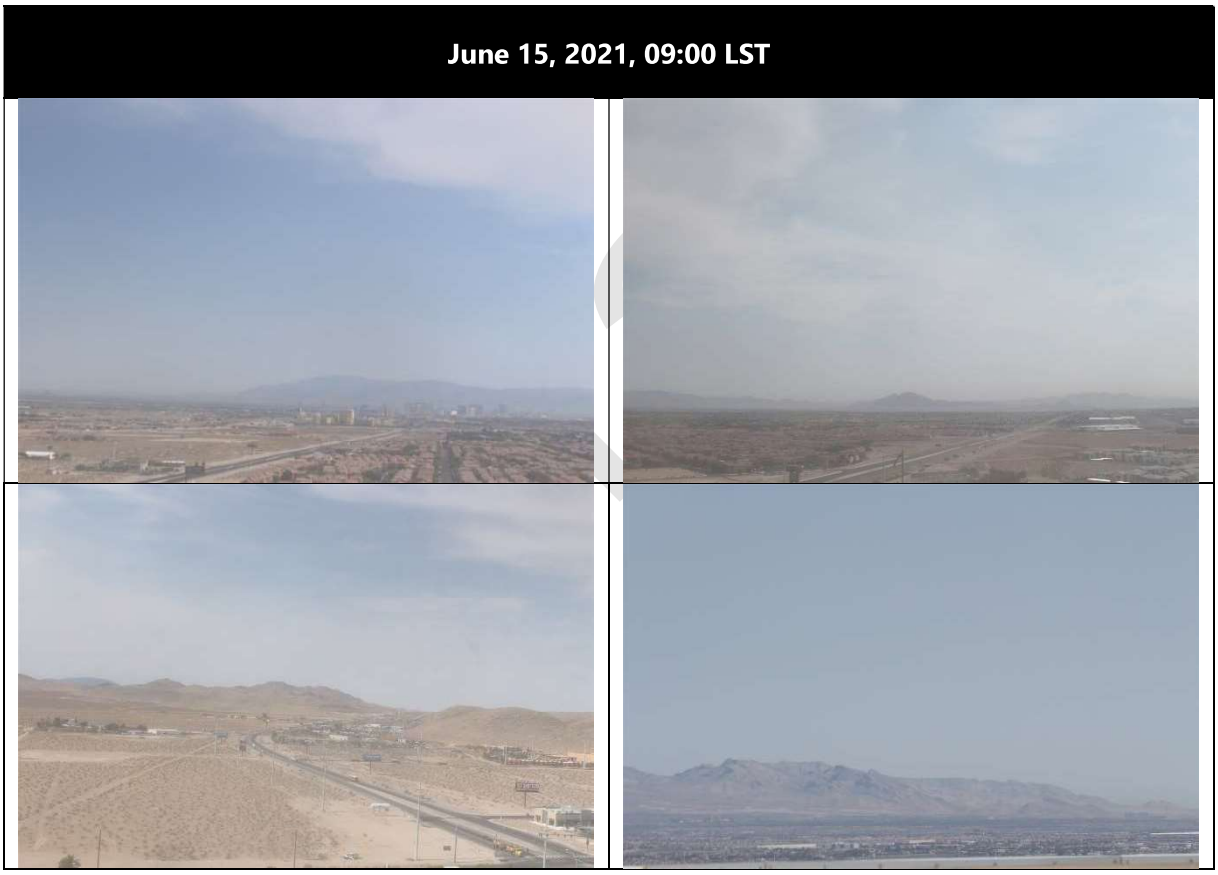

Figure 60. Camera images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions, taken from the M Resort Hotel in Clark County, NV, on June 15, 2021, at 09:00 LST.

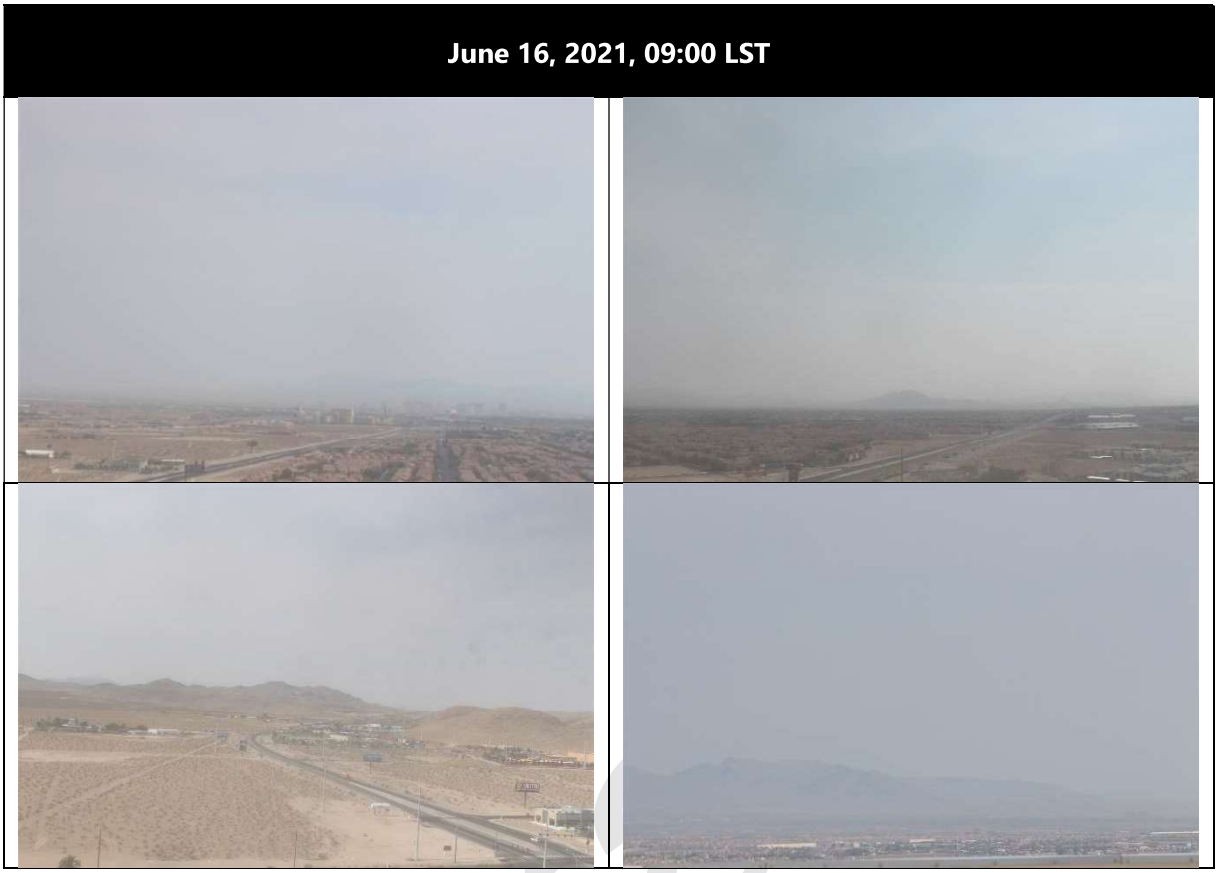

Figure 61. Camera images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions, taken from the M Resort Hotel in Clark County, NV, on June 16, 2021, at 09:00 LST.

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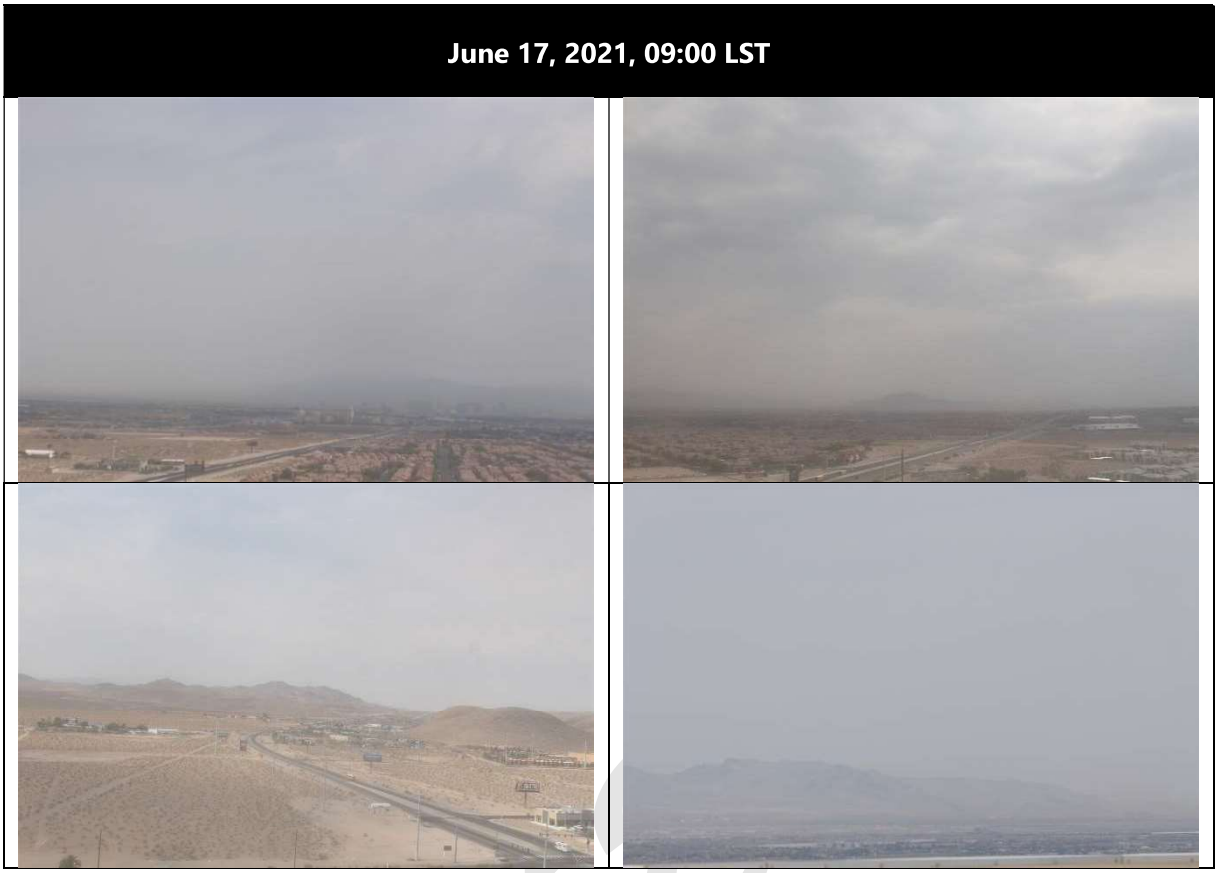

Figure 62. Camera images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions, taken from the M Resort Hotel in Clark County, NV, on June 17, 2021, at 09:00 LST.

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Table 12. Hourly ASOS Aviation Routine Weather Report (METAR) reports from KLAS local news on June 16 and 17, 2021 (June 17 and 18, 2021, in UTC). Smoke from Arizona wildfires contributed to periodic haze which was reported in the remarks section of the news report. VRB indicated variable wind speeds.

Time on June 17 and 18 (UTC)	Time on June 16 and 17 (PST)	Wind Direction / Speed	Sky Conditions
00:56	16:56	120 / 05 KT	HAZY
01:56	17:56	110 / 04 KT	HAZY
02:56	18:56	160 / 04 KT	HAZY
21:56	13:56	070 / 12 KT	HAZY
22:56	14:56	330 / 04 KT	HAZY
23:56	15:56	360 / 06 KT	HAZY
00:56	16:56	VRB / 03 KT	HAZY
01:56	17:56	060 / 03 KT	HAZY
02:56	18:56	260 / 05 KT	HAZY
03:56	19:56	220 / 03 KT	HAZY

$PM_{2.5}$, CO, and NO_2 concentrations were enhanced in Clark County during the exclusion period, providing further evidence that wildfire smoke was present in the region as an atypical influence on ozone concentrations. Figure 63 shows hourly $PM_{2.5}$ concentrations for the two-week period surrounding the exclusion dates overlaid on the 10th-90th percentile hourly concentrations during ozone season (May to October), calculated using available data from 2017-2021. $PM_{2.5}$ concentrations peaked between June 15 and 16 as wildfire smoke moved into the region. $PM_{2.5}$ concentrations remained enhanced throughout the exclusion dates. $PM_{2.5}$ at all event-affected sites exceeded the 90th percentile average concentrations on June 16 and 17, 2021.

Figure 64 shows daily maximum 1-hr CO concentrations for the period surrounding the exclusion dates and the 5-yr 10th-90th percentile range of daily maximum 1-hr CO concentrations for the month of June. Between June 16 and 17, all CO measurement sites exceeded the 90th percentile daily maximum 1-hr CO concentration. Note that some sites also show noticeable spikes in CO concentrations in the days prior to the exclusion dates, which are likely due to the local Sandy Valley wildfire on June 11-12 (see Ozone TSD – June 11-12, 2021).

Further evidence that wildfire smoke was present in the area can be seen in the comparison of NO_2 concentrations during the exclusion dates to the expected seasonal range. Figure 65 shows hourly NO_2 concentrations during the exclusion dates overlaid with the 10th-90th percentile hourly concentrations during ozone season (May to October), calculated using data from 2017-2021. Data is shown from the Joe Neal site, which was the only site with elevated ozone during the exclusion dates

that also measures NO_2 concentrations. NO_2 concentrations in Clark County were elevated above the 90th percentile concentrations during the exclusion period, reaching a peak during the morning of June 17.

The ratio of $PM_{2.5}$-to-PM_{10} concentrations was also examined to determine if wildfire smoke entered Clark County on or before the exclusion dates. Increases in this ratio are indicative of wildfire smoke. Figure 66 and Figure 67 show a time series graph of the $PM_{2.5}$-to-PM_{10} ratio from June 15 through June 18 at all affected sites, compared to the ozone season mean and 5th-95th percentile range for available data between 2017-2021. The $PM_{2.5}$-to-PM_{10} ratios at all affected sites (Figure 66) are generally above the 5-yr seasonal hourly average during the day on June 16 and 17. Ratios exceeded the 95th percentile and increased above 0.5 in the late morning on June 16, indicating that $PM_{2.5}$ concentrations contributed the majority of total $PM_{2.5}$ and PM_{10} during these hours. A similar pattern is present in some non-affected sites (e.g., Garrett Jr. High, Figure 67). These observations provide evidence that wildfire smoke containing increased levels of $PM_{2.5}$ enhanced the $PM_{2.5}$-to-PM_{10} ratios in Clark County on June 16 and June 17, immediately prior to and during the atypical ozone events that occurred on June 16 and 17.

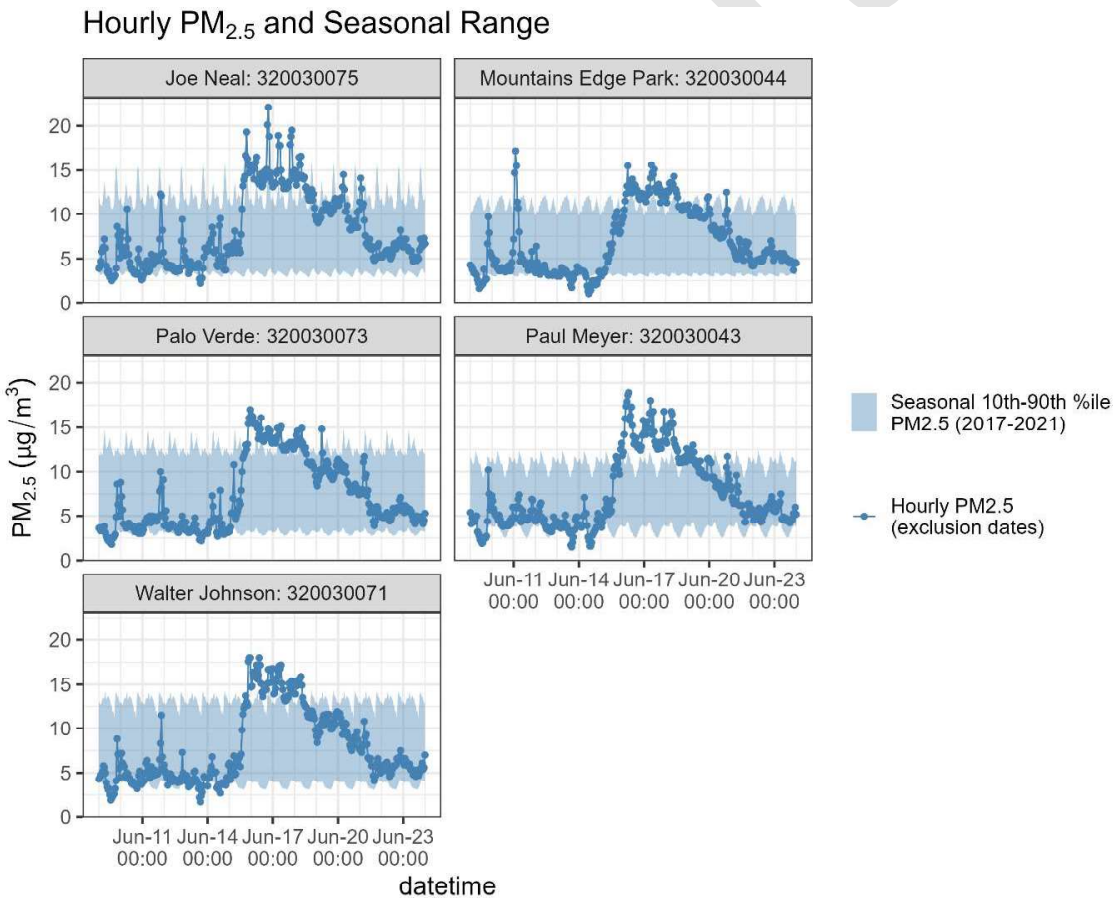

Figure 63. Hourly $PM_{2.5}$ measurements overlaid on the 10th-90th percentile diurnal concentration at each event-affected measurement site. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

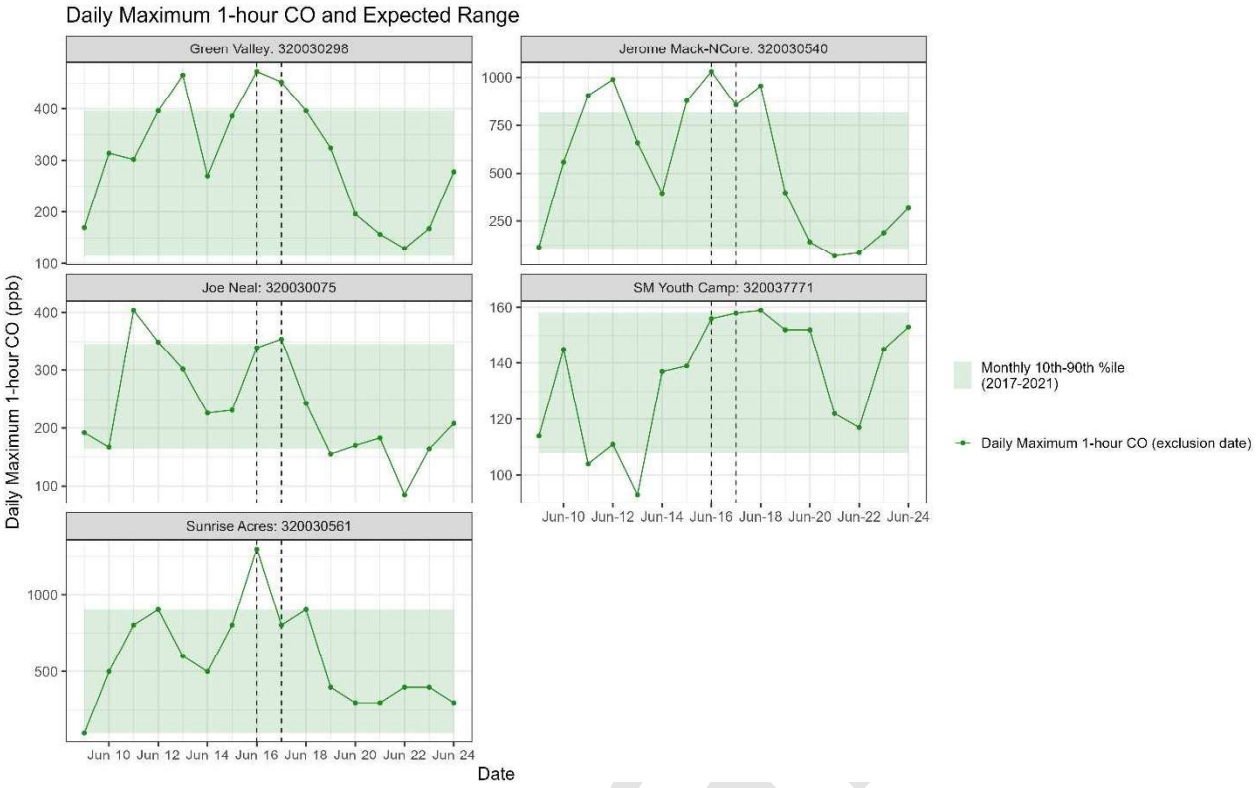

Figure 64. Daily maximum hour CO measurements overlaid on the month of June 10th-90th percentile daily maximum concentration at all Clark County CO measurement sites. The 10th-90th percentile concentration is calculated across June 2017-2021.

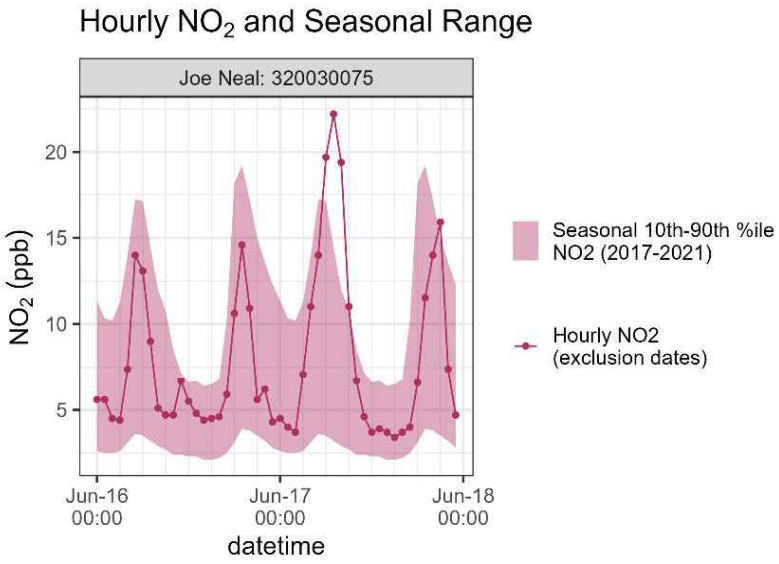

Figure 65. Hourly NO_2 measurements overlaid on the 10th-90th percentile diurnal concentration at the Joe Neal site. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

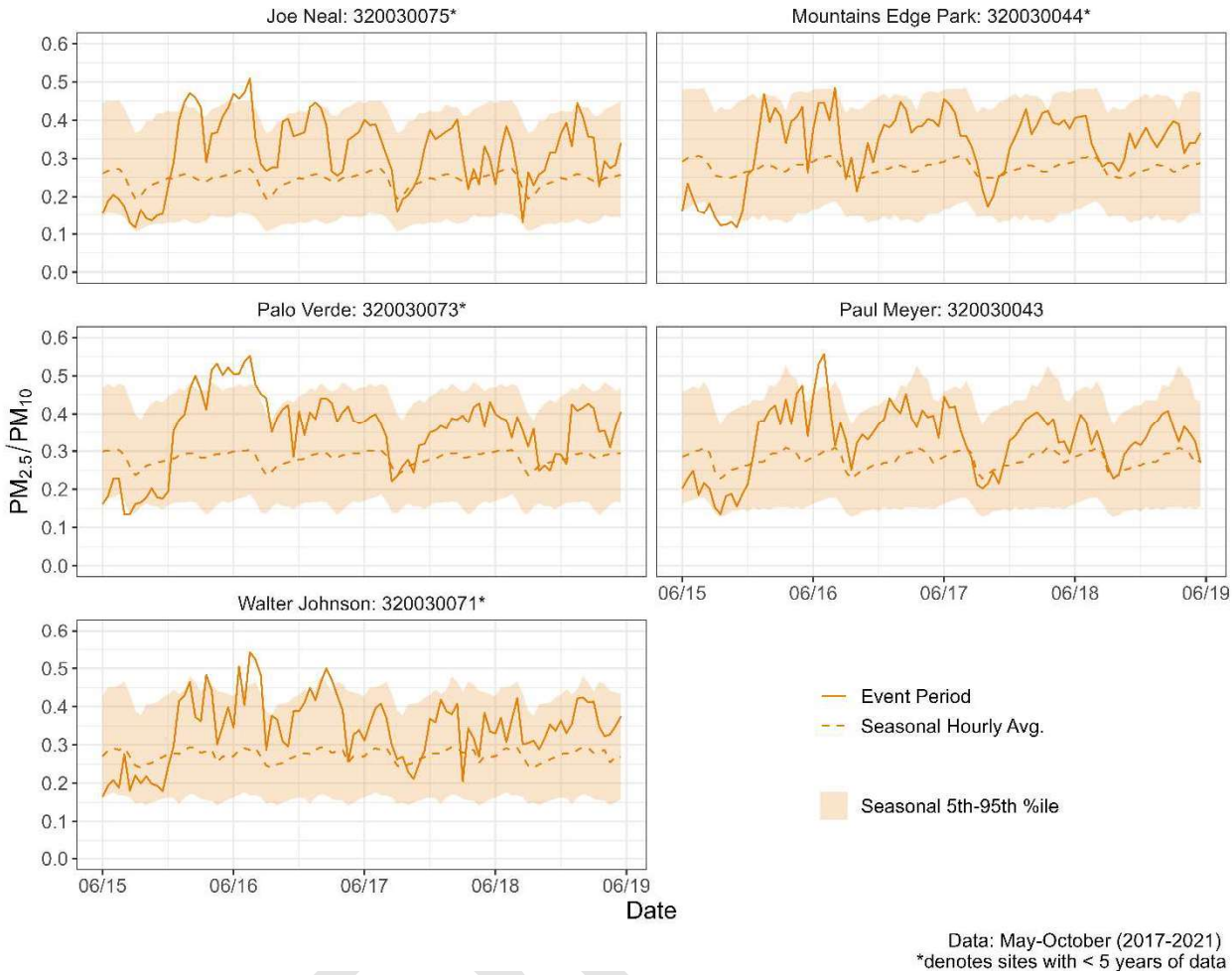

Figure 66. Ratio of $PM_{2.5}$-to-PM_{10} concentrations at the affected sites during the June 16 and June 17 event period. The 5-yr average $PM_{2.5}$-to-PM_{10} diurnal ratio is displayed as a dotted line, and the 5th-95th percentile range is shown as a shaded ribbon. The 5th-95th percentile concentration range is calculated across the ozone production season (May-October) of 2017-2021.

Figure 67. Ratio of $PM_{2.5}$-to-PM_{10} concentrations at the non-affected sites during the June 16 and June 17 event period. The 5-yr average $PM_{2.5}$-to-PM_{10} diurnal ratio is displayed as a dotted line, and the 5th-95th percentile range is shown as a shaded ribbon. The 5th-95th percentile concentration range is calculated across the ozone production season (May-October) of 2017-2021.

4.2.5 Event Statistics

Table 13 summarizes the daily measurements of ozone, $PM_{2.5}$, and CO concentrations on the exclusion dates, June 16 and 17, as well as the percentile rank of the observation compared to the previous five years of data (2017-2021). Ozone MDA8 measurements were above the 95th percentile at the Paul Meyer, Palo Verde, and Joe Neal sites on June 16, 2021, as well as at the Paul Meyer and Mountain's Edge sites on June 17, 2021. $PM_{2.5}$ measurements were above the 90th percentile at all sites on both days. In general, CO measurements in Clark County, Nevada, were higher than typical values for June. Of the sites proposed to be a part of the exclusion event, only the Joe Neal site has a CO monitor, and the value on June 16 was in the 89th percentile. CO measurements for representative sites in Clark County that have at least five years of data (Jerome Mack and Sunrise Acres) are also included for additional context for the elevated CO observations across the region, and show values greater than the 99th percentile for June 16 and greater than the 75th percentile for June 17.

Table 13. Percentile of pollutant measurements on exclusion day compared with most recent five years* (2017-2021). The percentile rank is calculated across the ozone production season (May 1-October 31) of 2017-2021 for ozone and $PM_{2.5}$, and across June 2017-2021 for CO. Data from nearby sites not identified for exclusion are shown in grey italics.

Date	Site Name	Site Code	Ozone		$PM_{2.5}$		CO	
			Ozone MDA8 (ppb)	Percent Rank	$PM_{2.5}$ 24-hr Avg ($\mu g/m^3$)	Percent Rank	CO 1-hr Daily Max (ppb)	Percent Rank (June)
6/16/2021	Paul Meyer	320030043	71	95.4	14.6	95.3		
6/16/2021	Walter Johnson	320030071	71	93.2	15.6	94.8*		
6/16/2021	Palo Verde	320030073	74	98.4	14.6	94.0*		
6/16/2021	Joe Neal	320030075	72	95.7	15.2	95.5*	339	89.3*
6/16/2021	*Jerome Mack-NCore*	*320030540*					*1,030*	*99.3*
6/16/2021	*Sunrise Acres*	*320030561*					*1,300*	*100*
6/17/2021	Paul Meyer	320030043	72	96.4	14.4	95.1		
6/17/2021	Mountain's Edge	320030044	75	98.6*	12.8	93.5*		
6/17/2021	*Jerome Mack-NCore*	*320030540*					856	91.9
6/17/2021	*Sunrise Acres*	*320030561*					800	76.9

*Sites that have less than five years of data available for a given parameter.

4.3 July 20, 2021

4.3.1 Event Summary

The unrepresentative ozone event took place on July 20, 2021, and affected four sites in Clark County, Nevada: Green Valley, Joe Neal, Walnut Community Center, and Walter Johnson. The MDA8 concentrations at the effected sites ranged from 71-74 ppb: 74 ppb at Walnut Community Center, and 71 ppb at Joe Neal, Green Valley, and Walter Johnson. Time series graphs showing hourly ozone concentrations that exceeded the seasonal hourly means (calculated using May 1-October 31, 2017-2021) and 10th-90th hourly percentiles at each site are shown in Figure 68. On July 20, hourly ozone measurements rose sharply above (>10%) the mean beginning as early as 09:00 PST, and measurements exceeded the 90th percentile between 11:00 to 18:00 PST.

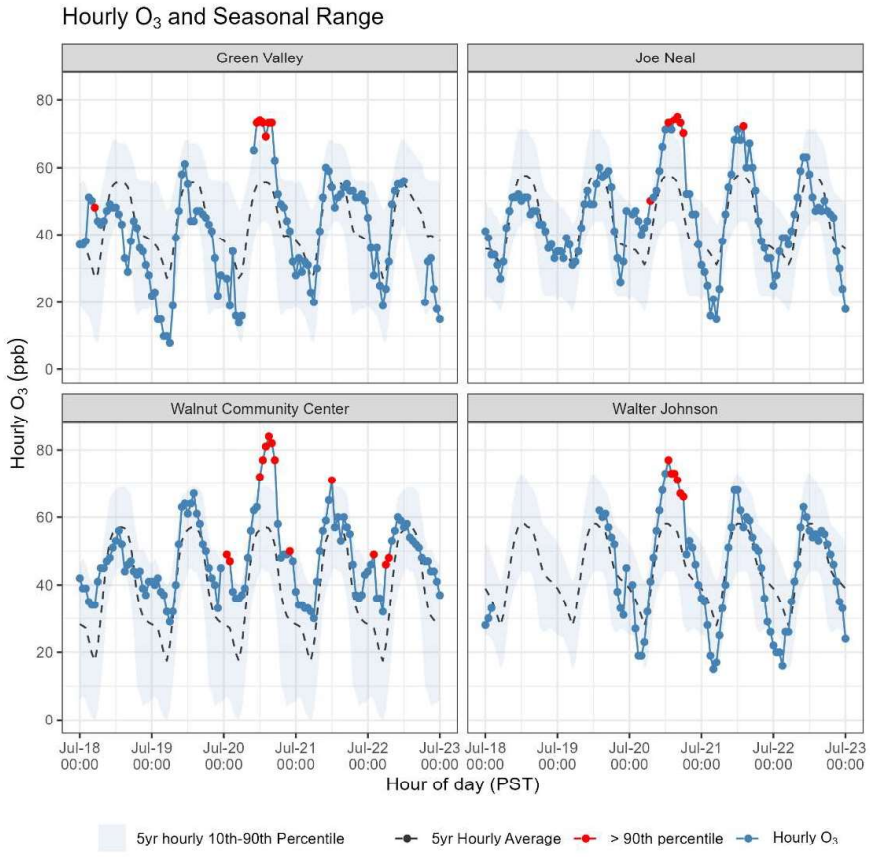

Figure 68. Hourly ozone concentrations (ppb) compared to 5-yr* ozone season (May 1-October 31) hourly means and 10th-90th percentiles. *Note: data from the Walnut Community Center site are only available for June 1-October 31, 2021.

Regional wildfire smoke from the Tamarack, Dixie, and Bootleg Fires were identified to likely contribute significant emissions that led to this event. Major evidence for wildfire smoke transport beginning July 18 includes (1) HMS smoke perimeters over Clark County; (2) HYSPLIT dispersion modeling showing accumulation of smoke in Clark County from July 18-20; (3) enhanced $PM_{2.5}$, CO, and NO_2 concentrations during expected daily minima. The combined evidence suggests that regional wildfire smoke entered the area on July 18 and lingered through the early morning on July 20, influencing the atypical ozone event that occurred on July 20, which is an unrepresentative event for base and future design value ozone assessments.

4.3.2 Identification of Wildfires

Numerous wildfires were active on July 20, 2021, the exclusion day, and contributed to regional smoke. Three major wildfires with significant emissions that contributed to the regional smoke were identified: the Tamarack and Dixie Fires in California and the Bootleg Fire in Oregon (Figure 69). Regional smoke from these fires was present during mid-late July 2021 throughout the northwest/western U.S., which was verified for the days of July 18-20 through visualization of smoke and wildfire detection geodata provided by the NOAA HMS (Figure 70). Table 14 presents the state location, total acres within the fire perimeter, actively burning acres on or burned by the exclusion day, and the start and containment dates for each fire based on data from the WFIGS Current Interagency Fire Perimeters and the Satellite Fire Occurrence and Growth database.[10]

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[10] McClure et al. (2023) Consistent, high-accuracy mapping of daily and sub-daily wildfire growth with satellite observations. International Journal of Wildland Fire 32, 694-708. Available at https://www.publish.csiro.au/wf/ExportCitation/WF22048.

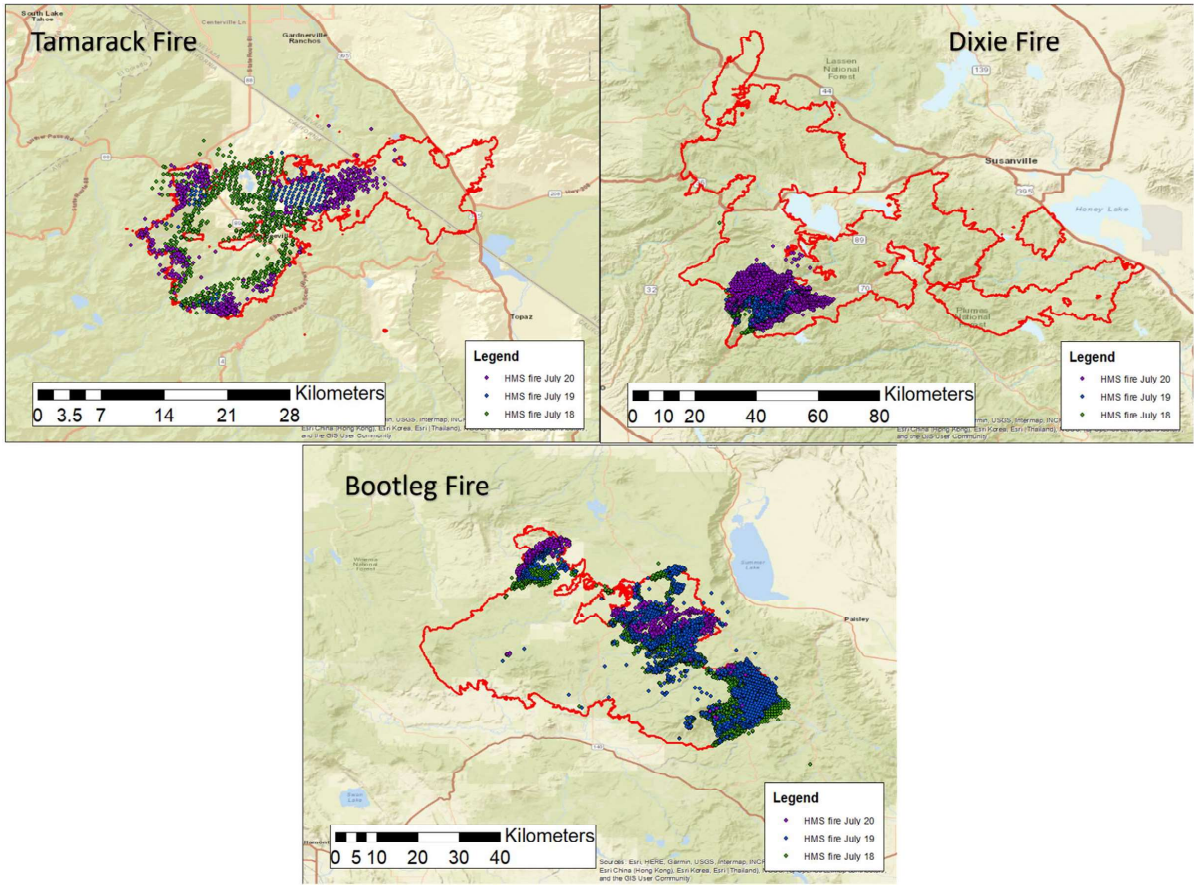

Figure 69. Final fire perimeters (red) and HMS fire detections for the Tamarack, Dixie, and Bootleg Fires from July 18-20, 2021.

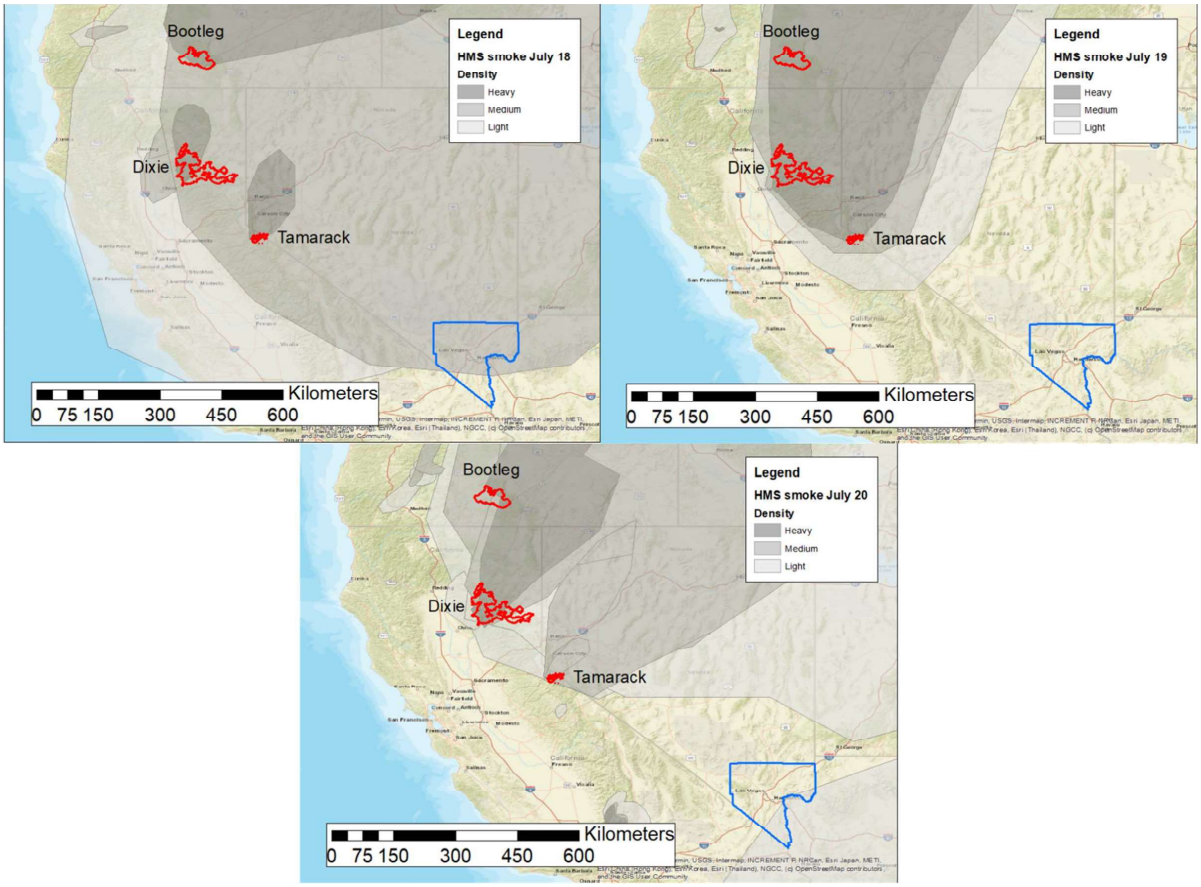

Figure 70. Maps of HMS smoke boundaries for July 18-20, 2021, with qualitative smoke density. Fire perimeters from the major fires contributing to the exclusion date are shown in red and the Clark County, NV, boundary is shown in blue.

Table 14. Wildfires affecting Clark County on the exclusion day. Where active acres are not available, cumulative acres burned are listed in italics.

Wildfire Name	State	Total Acres	Active Acres on or by July 20	Start Date	Containment Date
Tamarack	California	68,637	12,292	July 4	October 16
Dixie	California	963,309	40,820	July 14	October 15
Bootleg	Oregon	413,765	*388,359*	July 6	August 14

4.3.3 Dispersion Modeling and Regional Analysis

HYSPLIT dispersion modelling was performed from July 13 through 20, 2021. Dispersion was initiated on July 13 at 12:00 PST from the three identified active fires impacting the exclusion date and modeled through the exclusion date to simulate the smoke patterns observed in satellite imagery and HMS smoke data. GDAS data at 1.0° horizontal resolution was used for meteorological input. Output from the dispersion modeling was integrated over a 48-hr period, from July 18 at 18:00 PST through July 20 at 18:00 PST. This time period was chosen to correspond with the initial increase of observed $PM_{2.5}$ concentrations in Clark County. The accumulation of smoke at 0-100 m for the 48-hr period is shown in Figure 71.

The HYSPLIT dispersion modeling shows that smoke from multiple fires produced a dense layer of smoke that wrapped around a high-pressure system and spread throughout the region, including Clark County, Nevada. The modeling results are consistent with the HMS smoke plume (shown in gray in Figure 71); HMS is an independent smoke identification database. The dispersion results show that smoke from multiple fires reached Clark County on July 20, 2021, and the smoke was present in the lower mixed layer, impacting the surface conditions. These results are also consistent with upper-air meteorological analyses shown in Figure 72, which indicate that a high-pressure system along the Nevada/Utah border generated southeasterly winds aloft into southern Nevada, allowing smoke to be transported into Clark County.

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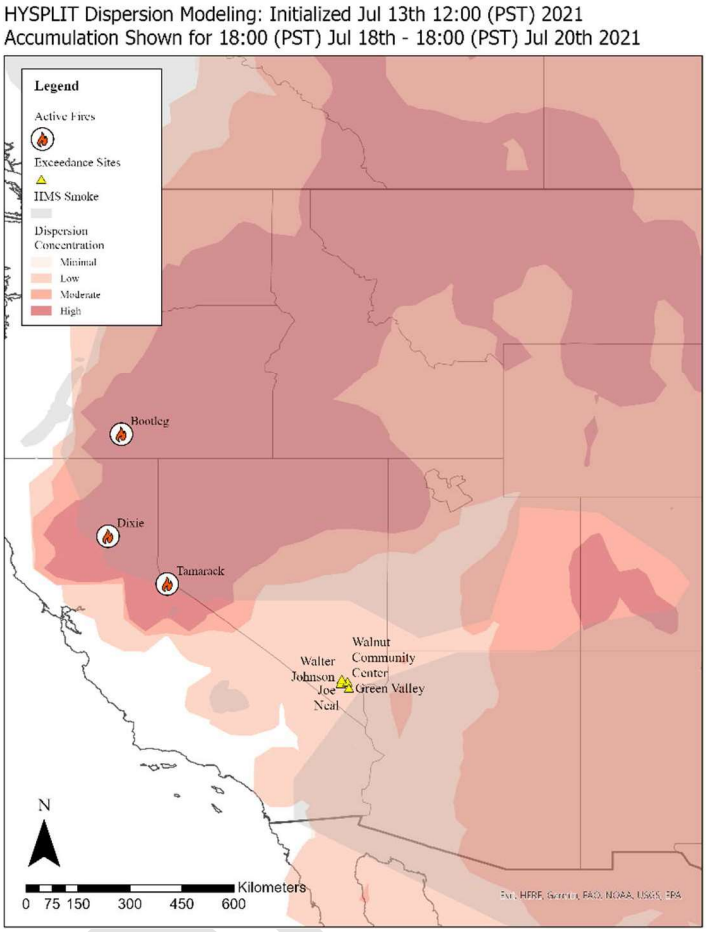

Figure 71. HYSPLIT dispersion modeling for three large fires (labeled as "Active Fires") in California and Oregon. GDAS 1.0° meteorological data was used, and dispersion was initiated on July 13, 2021, at 12:00 PST to model the regional smoke observed in satellite and HMS products. HMS smoke is shown in gray and qualitative concentrations of particulate matter are shown in shades of red. Accumulation of particulate matter is shown at 0-100 m for 18:00 PST on July 18 through 18:00 PST on July 20, 2021.

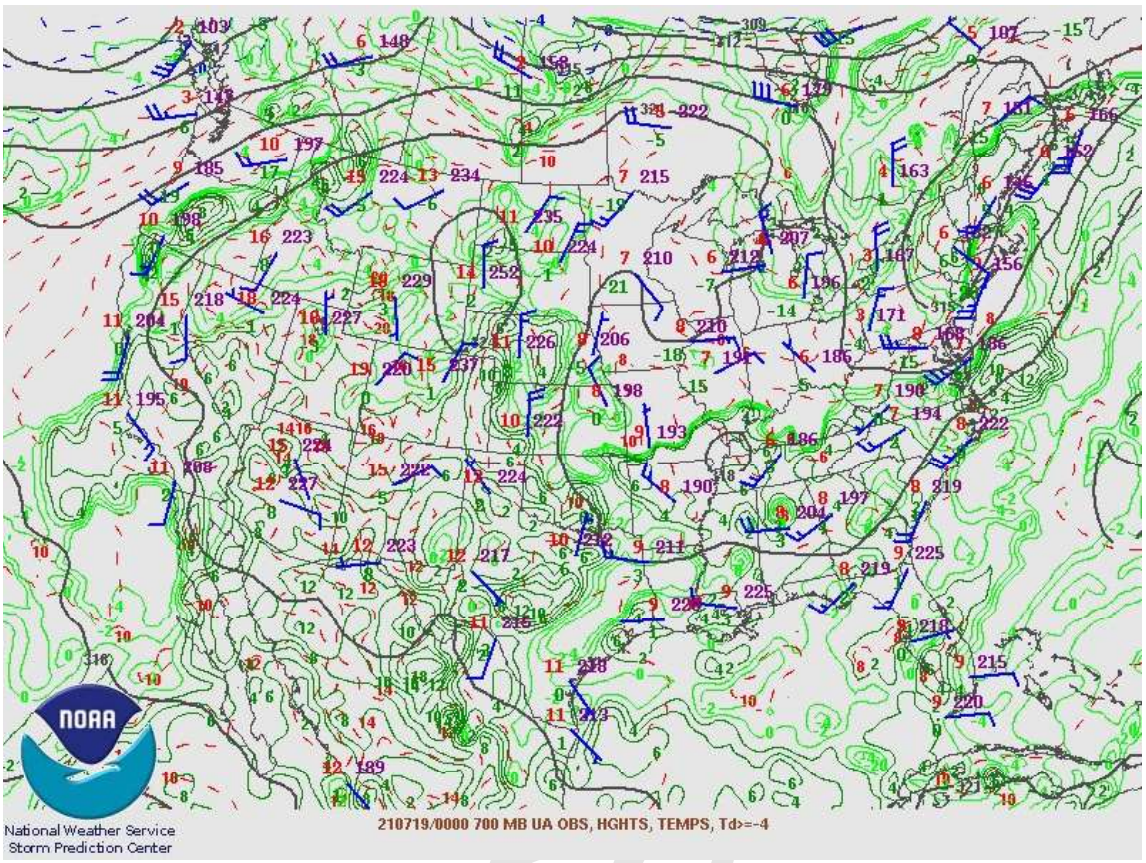

Figure 72. 700-mb map valid at 00:00 UTC on July 19, 2021 (16:00 PST on July 18, 2021). Upper-level high pressure along the Nevada/Utah border generated southeasterly winds aloft into southern Nevada, allowing smoke to be transported into Clark County.

4.3.4 Surface Impacts

The movement of wildfire smoke into the area on July 18 is shown by elevated concentrations of $PM_{2.5}$, CO, and NO_2 during expected diurnal minimums, shown in Figure 73 through Figure 75. The 10th-90th percentile range shown in Figure 73 through Figure 75 are calculated using five years of data (2017-2021) during the ozone season (May – October). A spike in $PM_{2.5}$ above the 90th percentile diurnal concentration was measured at both the Green Valley and Jean sites at 14:00 PST on July 18 (Figure 73, dashed line). This increase in $PM_{2.5}$ concentration occurs in the afternoon when daily $PM_{2.5}$ measurements are expected to be at a minimum.

Both CO (Figure 74) and NO_2 concentrations (Figure 75) also show concentrations above the 90th percentile diurnal concentration during the afternoon of July 18. Near 16:00 PST (first dashed line), CO and NO_2 measurements show increases to a local maximum, again a time period in the diurnal cycle where concentrations are expected to be at a minimum. This pattern is mirrored at the three measurement sites in Clark County for NO_2 concentrations, and was repeated on the following day, July 19 near 13:00 PST (second dashed line).

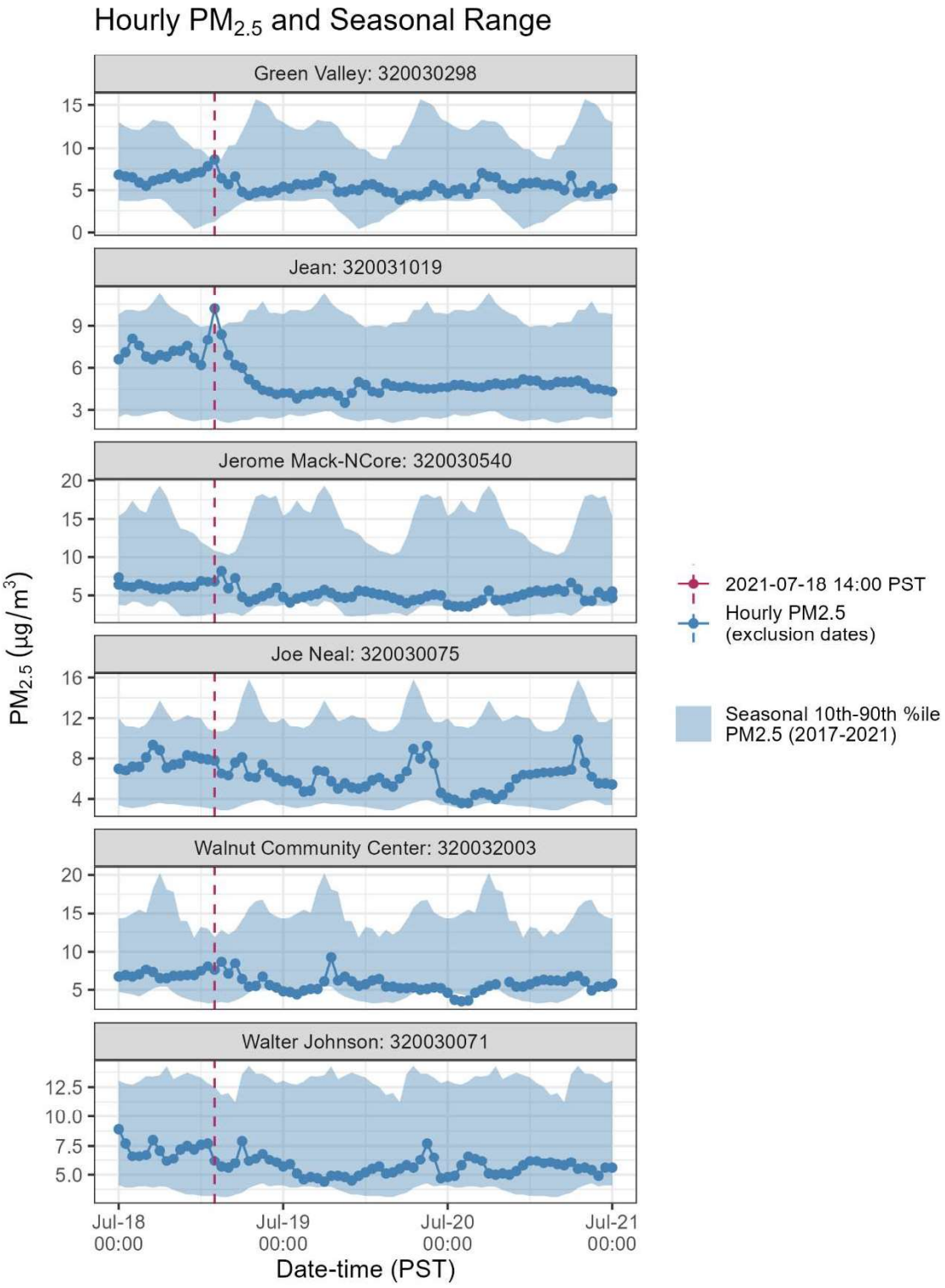

Figure 73. Hourly $PM_{2.5}$ measurements overlaid on the 10th-90th percentile diurnal concentration at the affected sites. The dashed line is 14:00 PST on July 18, 2021. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

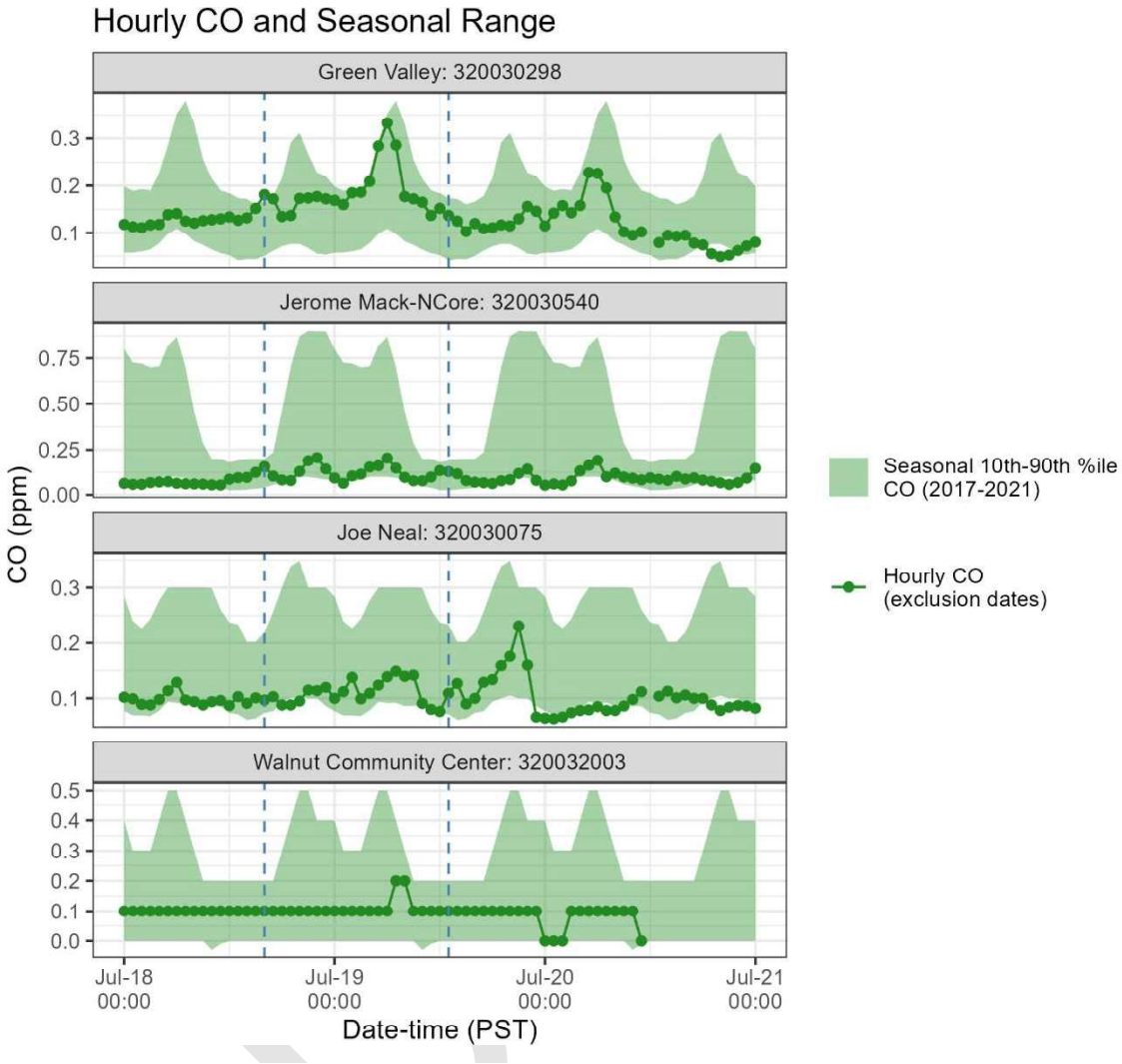

Figure 74. Hourly CO measurements overlaid on the 10th-90th percentile diurnal concentration at representative (Jerome Mack-NCore) and affected sites (Green Valley, Joe Neal, and Walnut Community Center). The dashed lines are (1) 13:00 PST on July 18, 2021, and (2) 16:00 PST on July 19, 2021. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

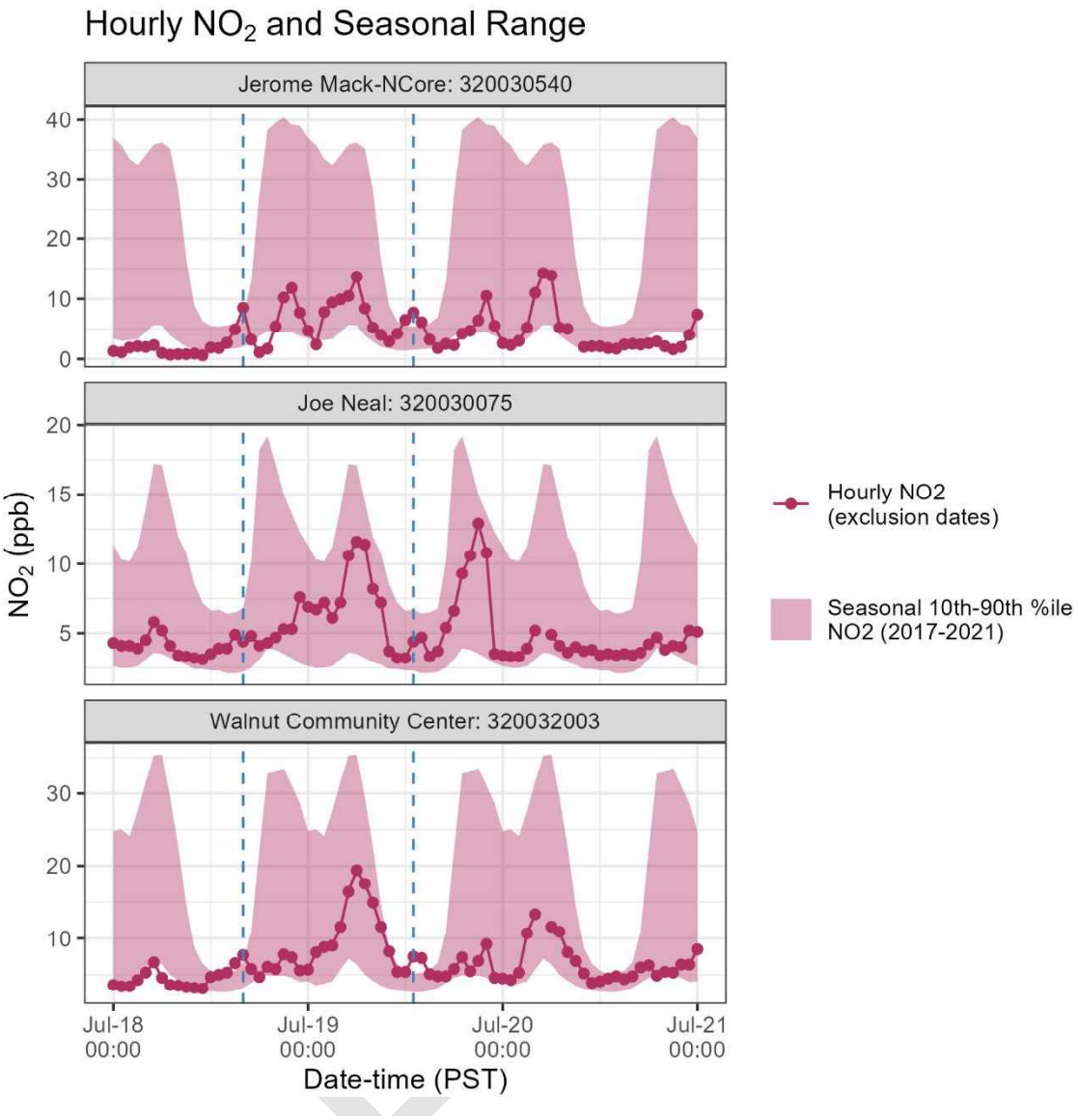

Figure 75. Hourly NO_2 measurements overlaid on the 10th-90th percentile diurnal concentration at representative (Jerome Mack-NCore) and affected sites (Joe Neal and Walnut Community Center). The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

The ratio of $PM_{2.5}$-to-PM_{10} concentrations was also examined to determine if wildfire smoke entered Clark County on or before the exclusion dates. Increases in this ratio are indicative of wildfire smoke. Figure 76 shows a time series of the $PM_{2.5}$-to-PM_{10} ratio from July 18-July 22 at the Jean monitoring site (upwind of Clark County's anthropogenic emissions), compared to the ozone season mean and 5th-95th percentile range for available data between 2017-2021. Measurements from the Jean site show an above-normal enhancement of the $PM_{2.5}$-to-PM_{10} ratio starting late on July 18 and continuing through early morning on July 20. This observation compliments the $PM_{2.5}$, CO, and NO_2 enhancements that occurred July 18-19, suggesting that wildfire smoke entered the area on July 18 and lingered through early morning on July 20, influencing the atypical ozone event that occurred on

July 20. The $PM_{2.5}$-to-PM_{10} ratio at other affected sites, shown in Figure 77 do not show the clear trend observed in the upwind Jean site. The Jean site is upwind of Clark County's anthropogenic emissions, and thus gives an indication of regional background levels at the time of the event.

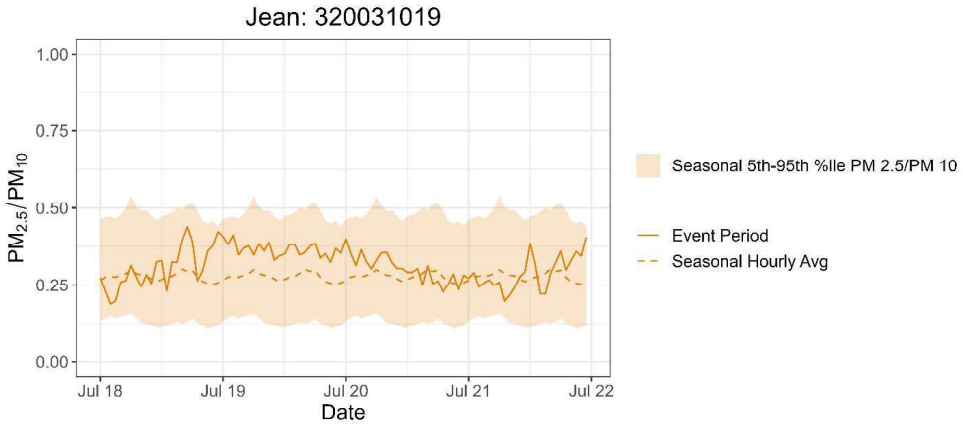

Figure 76. Ratio of $PM_{2.5}$-to-PM_{10} concentrations at the Jean site before and during the July 20 event period. The 5-yr average $PM_{2.5}$-to-PM_{10} diurnal ratio is displayed as a dotted line, and the 5th-95th percentile range is shown as a shaded ribbon. The 5th-95th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

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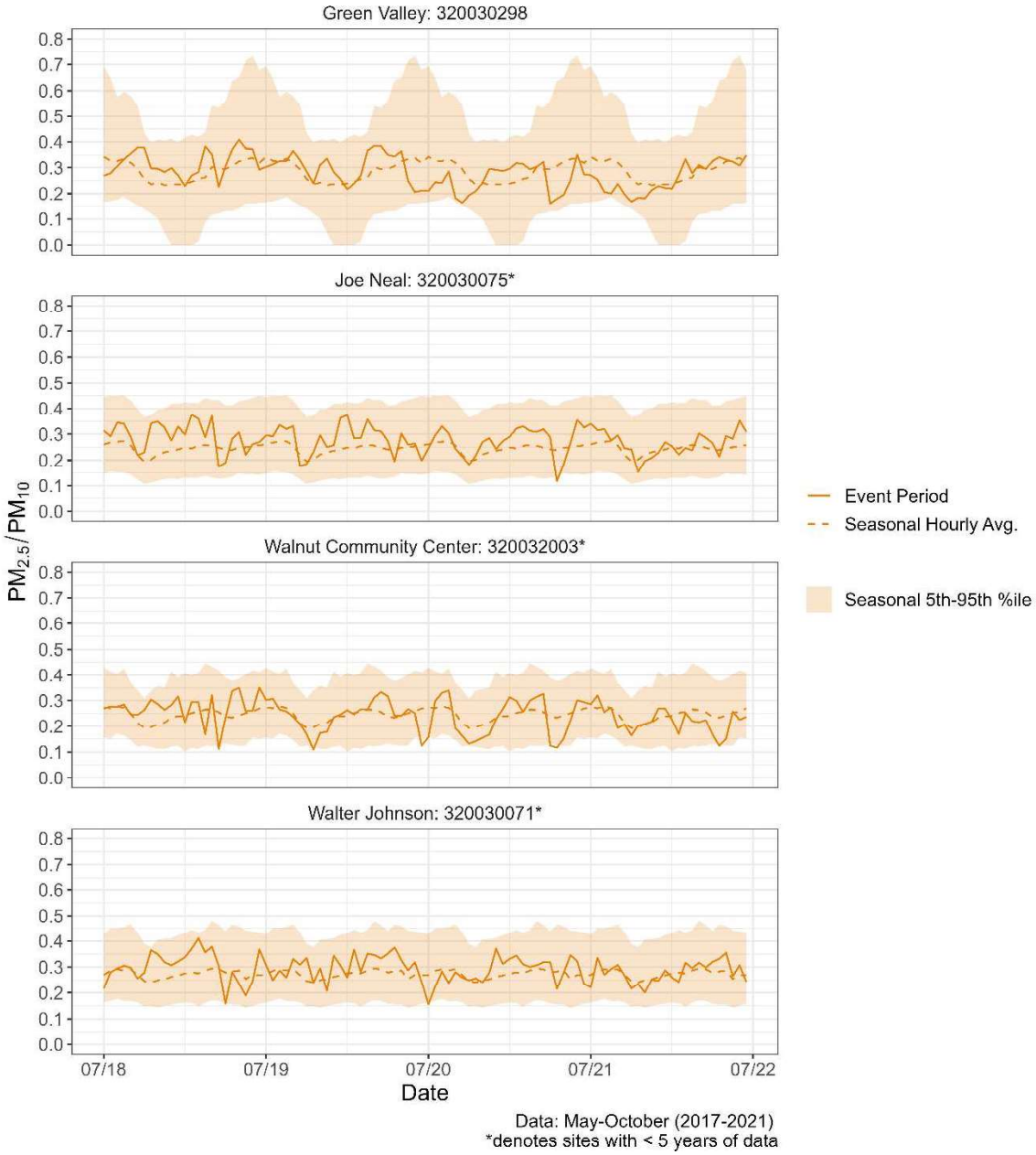

Figure 77. Ratio of $PM_{2.5}$-to-PM_{10} concentrations at all affected sites before and during the July 20 event period. The 5-yr average $PM_{2.5}$-to-PM_{10} diurnal ratio is displayed as a dotted line, and the 5th-95th percentile range is shown as a shaded ribbon. The 5th-95th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

To confirm the lingering presence of smoke between July 18-19 and the exclusion date of July 20, meteorological data is shown in Figure 78. An hourly temperature, wind, and visibility timeseries for data collected at the Harry Reid International Airport beginning on July 18 shows light and variable winds from the evening of July 18 through 20, allowing pollutants to accumulate after the injection of smoke overnight on July 18-19 in southern Clark County, NV, and produce atypical levels of ozone on July 20.

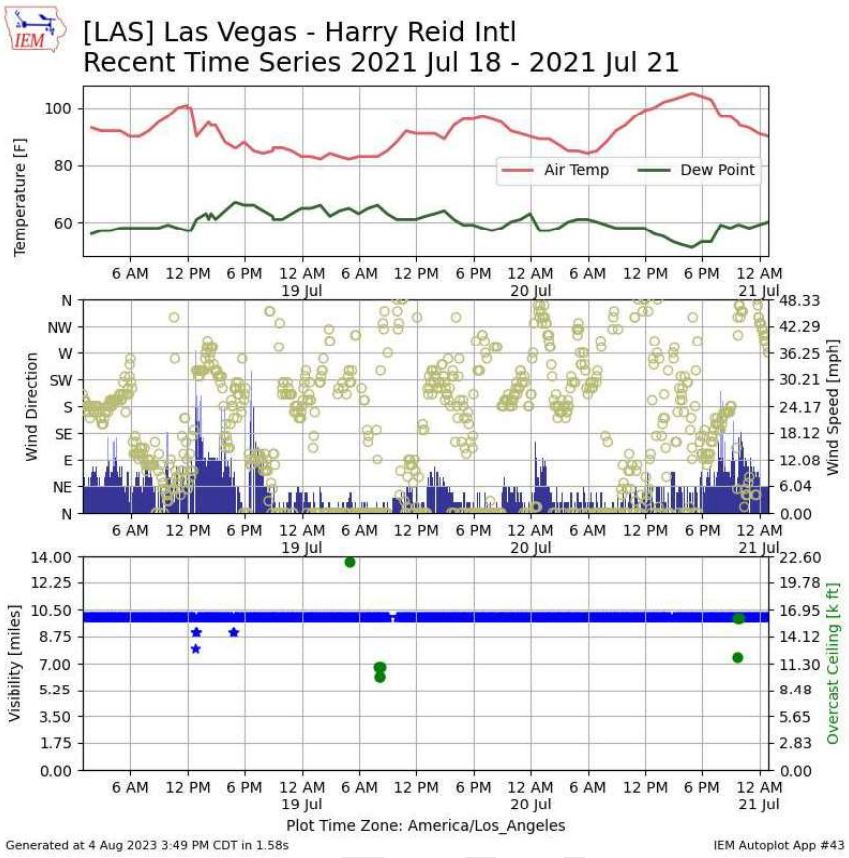

Figure 78. Timeseries of hourly ASOS temperature, wind, visibility measurements at the Harry Reid International Airport, beginning July 18, 2021. Light and variable winds from the evening of July 18 through July 20 allowed pollutants to accumulate in southern Clark County, NV.

4.3.5 Event Statistics

Table 15 and Table 16 summarize the daily measurements of ozone, $PM_{2.5}$, CO, and NO_2 concentrations leading up to the exclusion day, as well as the percentile rank of the observation compared to the previous five years of data (2017-2021). As highlighted in Figure 73 through Figure 75, $PM_{2.5}$, CO, and NO_2 concentrations began to see enhancements during typical afternoon minima on July 18. These anomalies are most clearly visualized in Figure 73 through Figure 75, and average daily measurements do not accurately capture the hour-to-hour anomalies. Therefore, in addition to the daily measurement statistics for these pollutants (Table 15), in Table 16 a 6-hr averaging period during the expected daily minimum period (12:00-18:00 PST) was used to compare exclusion dates to the previous five years of data. On July 18, these 6-hr average $PM_{2.5}$ concentrations ranked from the 70th-80th percentile, CO concentrations ranged from the 28th-67th percentile, and NO_2 concentrations ranged from the 24th-70th percentile. Afternoon $PM_{2.5}$ concentrations at most sites remained elevated above the 50th percentile through July 20. Ozone MDA8 measurements were low before the influx of wildfire-related emissions (10th-25th percentile on July 18), and then ranged from the 93rd-98th percentile on July 20.

Table 15. Percentile of pollutant measurements on the exclusion day compared with most recent five years* (2017-2021). The percentile rank is calculated across the ozone production season (May 1-October 31) of 2017-2021. Data from nearby sites not identified for exclusion are shown in grey italics.

Date	Site Name	Site Code	Ozone		$PM_{2.5}$		CO		NO_2	
			Ozone MDA-8 (ppb)	Percent Rank	$PM_{2.5}$ 24-hr Avg ($\mu g/m^3$)	Percent Rank	CO 1-hr Daily Max (ppb)	Percent Rank	NO_2 1-hr Daily Max (ppb)	Percent Rank
7/18/2021	Joe Neal	320030075	49	22.1	7.3	70.1*	129	3.6*	7.6	10.4
7/18/2021	Green Valley	320030298	46	17.8	6.1	53	181	23.6*	--	--
7/18/2021	Walnut Comm. Center	320032003	49	25.5*	6.8	37.9*	100	5.2*	7.8	4.6*
7/18/2021	*Jerome Mack-NCore*	*320030540*	*43*	*15*	*6*	*34.5*	*207*	*18.4*	*11.8*	*12.2*
7/18/2021	*Jean*	*320031019*	*45*	*11.9*	*6.6*	*73.5*	--	--	--	--
7/19/2021	Walter Johnson	320030071	57	47.5	5.3	31.4*	--	--	--	--
7/19/2021	Joe Neal	320030075	55	41.4	6	53.8*	231	36.7*	12.9	37.3
7/19/2021	Green Valley	320030298	50	28	5.2	33.3	333	70*	--	--
7/19/2021	Walnut Comm. Center	320032003	61	67.3*	5.5	14.4*	200	18.3*	19.4	27.5*
7/19/2021	*Jerome Mack-NCore*	*320030540*	*52*	*47.3*	*4.8*	*16.7*	*204*	*18.2*	*13.7*	*15.4*
7/19/2021	*Jean*	*320031019*	*49*	*24*	*4.3*	*36.4*	--	--	--	--
7/20/2021	Walter Johnson	320030071	71	93.2	5.6	38.8*	--	--	--	--
7/20/2021	Joe Neal	320030075	71	94.6	5.6	45.1*	113	2.2*	5.2	2.8
7/20/2021	Green Valley	320030298	71	96.2	5.4	36.7	228	37.8*	--	--
7/20/2021	Walnut Comm. Center	320032003	74	98*	5.4	13.1*	100	5.2*	13.3	13.1*
7/20/2021	*Jerome Mack-NCore*	*320030540*	*68*	*96.5*	*4.8*	*16.7*	*192*	*11.3*	*14.3*	*16.1*
7/20/2021	*Jean*	*320031019*	*54*	*46.7*	*4.8*	*46.5*	--	--	--	--

*Sites that have less than five years of data available for a given parameter.

Table 16. Percentile of pollutant measurement between 12:00 and 18:00 PST on the exclusion day compared with most recent five years* (2017-2021). The percentile rank is calculated across the ozone production season (May 1-October 31) of 2017-2021. Data from nearby sites not identified for exclusion are shown in grey italics.

Date	Site Name	Site Code	Ozone		$PM_{2.5}$		CO		NO_2	
			Ozone MDA-8 (ppb)	Percent Rank	$PM_{2.5}$ 12:00 – 18:00 PST Mean (µg/m³)	Percent Rank	CO 12:00 – 18:00 PST mean (ppb)	Percent Rank	NO_2 12:00 – 18:00 PST mean (ppb)	Percent Rank
7/18/2021	Green Valley	320030298	46	17.8	6.7	72.2	147.6	67.7*	--	--
7/18/2021	Joe Neal	320030075	49	22.1	7.5	79.1*	95.7	28.5*	4.21	41.8
7/18/2021	Walnut Comm. Center	320032003	49	25.5*	7.7	80.6*	100.0	30.2*	5.69	70.4*
7/19/2021	Walter Johnson	320030071	NA	--	NA	--	--	--	--	--
7/18/2021	*Jerome Mack-NCore*	*320030540*	*43*	*15*	*6.7*	*72.2*	*106.7*	*41.5*	*3.44*	*24.2*
7/18/2021	*Jean*	*320031019*	*45*	*11.9*	*7.4*	*78.6*	*--*	*--*	*--*	*--*
7/19/2021	Green Valley	320030298	50	28	4.9	45.3	122.4	53.2*	--	--
7/19/2021	Joe Neal	320030075	55	41.4	5.8	61*	109.3	43.1*	4.47	48
7/19/2021	Walnut Comm. Center	320032003	61	67.3*	5.6	58*	100.0	30.2*	5.81	72.3*
7/19/2021	Walter Johnson	320030071	57	47.5	5.4	54.8*	--	--	--	--
7/19/2021	*Jerome Mack-NCore*	*320030540*	*52*	*47.3*	*4.9*	*45.3*	*94.1*	*27.9*	*4.30*	*44.2*
7/19/2021	*Jean*	*320031019*	*49*	*24*	*4.6*	*39.7*	*--*	*--*	*--*	*--*
7/20/2021	Green Valley	320030298	71	96.2	5.7	59.7	85.7	24.1*	--	--
7/20/2021	Joe Neal	320030075	71	94.6	6.6	71.3*	104.0	40.4*	3.57	26.8
7/20/2021	Walnut Comm. Center	320032003	74	98*	6.2	66.6*	--	--	4.99	59.7*
7/20/2021	Walter Johnson	320030071	71	93.2	6	63.6*	--	--	--	--
7/20/2021	*Jerome Mack-NCore*	*320030540*	*68*	*96.5*	*5.7*	*59.7*	*89.4*	*26.1*	*2.21*	*7.7*
7/20/2021	*Jean*	*320031019*	*54*	*46.7*	*5*	*47.5*	*--*	*--*	*--*	*--*

*Sites that have less than five years of data available for a given parameter.

4.4 August 2-3, 2021

4.4.1 Event Summary

The unrepresentative ozone event took place on August 2-3, 2021. The event affected eight sites in Clark County, Nevada, on August 2, and seven sites on August 3. The MDA8 concentrations at the effected sites ranged from 72-78 ppb on August 2: 78 ppb at Palo Verde and Walnut Community Center, 77 ppb at Liberty High School, 75 ppb at Joe Neal and Mountain's Edge, 74 ppb at Green Valley, and 72 ppb at Jerome Mack-NCore. On August 3, the MDA8 concentrations at the effected sites ranged from 72-80 ppb: 80 ppb at Mountain's Edge, 77 ppb at Walter Johnson and Paul Meyer, 76 ppb at Liberty High School, 75 ppb at Palo Verde, 74 ppb at Walter Johnson, 73 ppb at Joe Neal, and 72 ppb at Green Valley.

On August 2, hourly ozone measurements exceeded the 90th percentiles late in the day between 19:00-23:00 PST, and throughout August 3 from 09:00 to 19:00 PST. Time series graphs showing hourly ozone concentrations that exceeded the seasonal means (calculated using data from May 1-October 31, 2017-2021) and 10th-90th percentiles at each site are shown in Figure 79.

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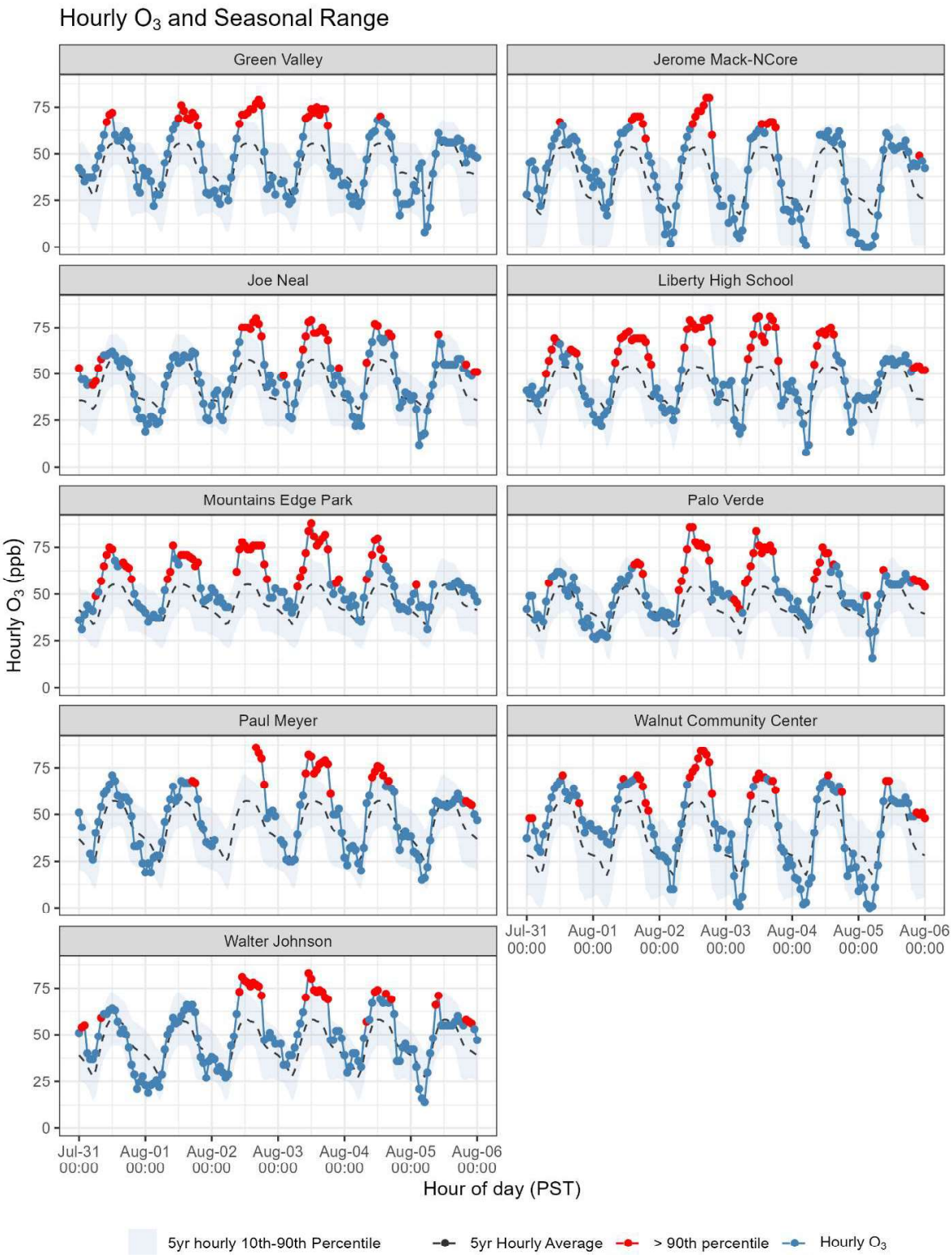

Figure 79. Hourly ozone concentrations (ppb) compared to 5-yr* ozone season (May 1-October 31) hourly means and 10-90th percentiles. *Note: data from the Liberty High School, Mountain's Edge, and Walnut Community Center sites began less than five years ago.

An abundance of regional wildfire smoke was identified as a major contributor to this event. In particular, the Dixie, Monument, and Haypress River Complex Fires in California were major contributors of smoke, from which smoke initially traveled northeast (July 31-August 1), and then circled back around towards Clark County by August 2-3. Strong evidence of smoke enhancing ozone concentrations include (1) both HMS smoke boundaries and HYSPLIT dispersion modeling independently indicating the presence of smoke in Clark County and (2) increasing hourly $PM_{2.5}$ concentrations, hourly CO concentrations, and $PM_{2.5}$-to-PM_{10} ratios. This combination of evidence indicates that this is an unrepresentative event for assessing base and future ozone design values.

4.4.2 Identification of Wildfires

Numerous wildfires throughout the western U.S. were active on August 2 and 3, 2021. The Dixie, Monument and Haypress River Complex Fires in California (Figure 80) had significant emissions that contributed to the regional smoke. These fires created widespread regional smoke that was present during late July and early August 2021 throughout the northwest/western U.S. The presence of widespread smoke was verified for the days of July 31-August 3 through visualization of smoke and wildfire detection geodata provided by the NOAA HMS (Figure 81). The HMS plots show smoke from the California fires initially traveling northeast (July 31-August 1), and then circling back around towards Clark County by August 2-3. Table 17 lists the state location, total acres within the fire perimeter, actively burning acres on the exclusion day, and the start and containment dates for each fire based on data from the WFIGS Current Interagency Fire Perimeters and the Satellite Fire Occurrence and Growth database.[11]

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[11] McClure et al. (2023) Consistent, high-accuracy mapping of daily and sub-daily wildfire growth with satellite observations. International Journal of Wildland Fire 32, 694-708. Available at https://www.publish.csiro.au/wf/ExportCitation/WF22048.

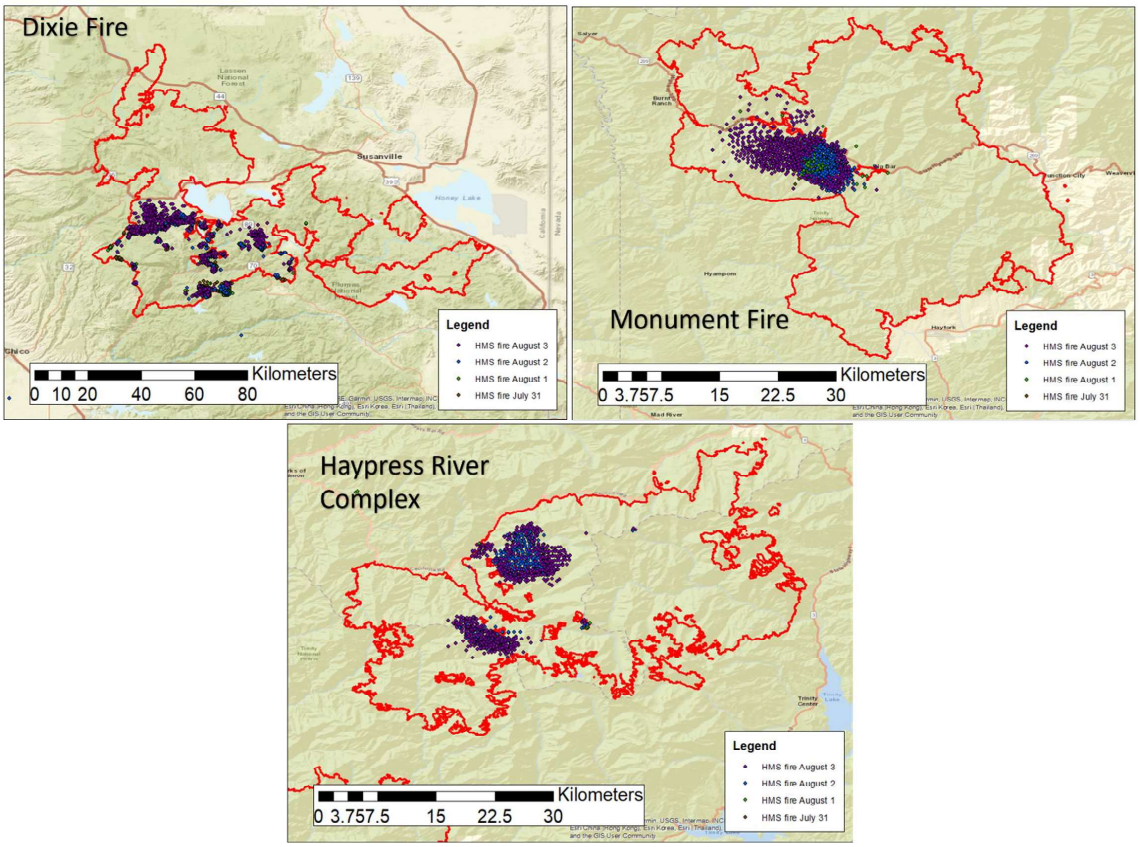

Figure 80. Final fire perimeters (red) and HMS fire detections for the Dixie, Monument, and Haypress River Complex Fires during July 31-August 3, 2021.

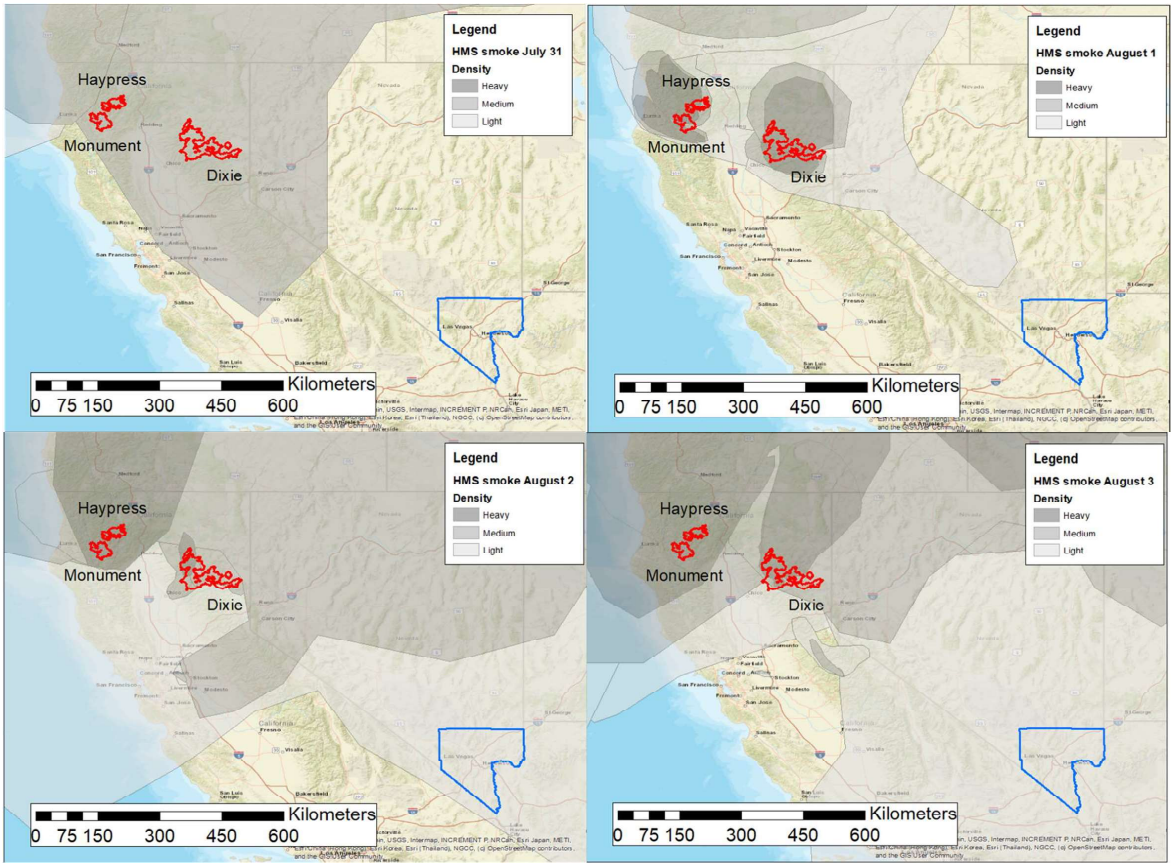

Figure 81. HMS smoke boundaries for July 31-August 3, 2021, with qualitative smoke density. Fire perimeters from the major fires contributing to the exclusion date are shown in red and the Clark County, NV, boundary is shown in blue.

Table 17. Wildfires affecting Clark County on the exclusion days. The fire name, state location, total acreage, active acreage burning on the exclusion day, and the start and containment dates are included.

Wildfire Name	State	Total Acres	Active Acres August 2	Active Acres August 3	Start Date	Containment Date
Dixie	California	963,309	24,180	22,459	July 14	October 15
Monument	California	223,124	6,279	8,883	July 31	October 20
Haypress River Complex	California	199,343	7,619	10,964	July 31	October 25

4.4.3 Dispersion Modeling and Regional Analysis

HYSPLIT dispersion modeling was performed for July 31-August 3, 2021. Dispersion was initiated at 00:00 PST from the three identified active fires impacting the exclusion date. GDAS data at 1.0° horizontal resolution was used for meteorological input. Output from the dispersion modeling was integrated over a 48-hr period, from August 2 at 00:00 PST through August 4 at 00:00 PST. This time range was chosen to correspond with the initial increase of observed $PM_{2.5}$ concentrations in Clark County. The accumulation of smoke at 0-100 m for the 24-hr period is shown in Figure 82.

The results of the HYSPLIT dispersion modeling show that smoke from multiple fires produced a dense layer of smoke that blanketed the western U.S. region, including Clark County, NV. The modeling results are consistent with the HMS smoke plume data (shown in gray in Figure 82); HMS is an independent smoke identification database. The dispersion results show smoke from multiple fires reached Clark County on August 2-3, 2021, and the smoke was present in the lower mixed layer, impacting the surface conditions.

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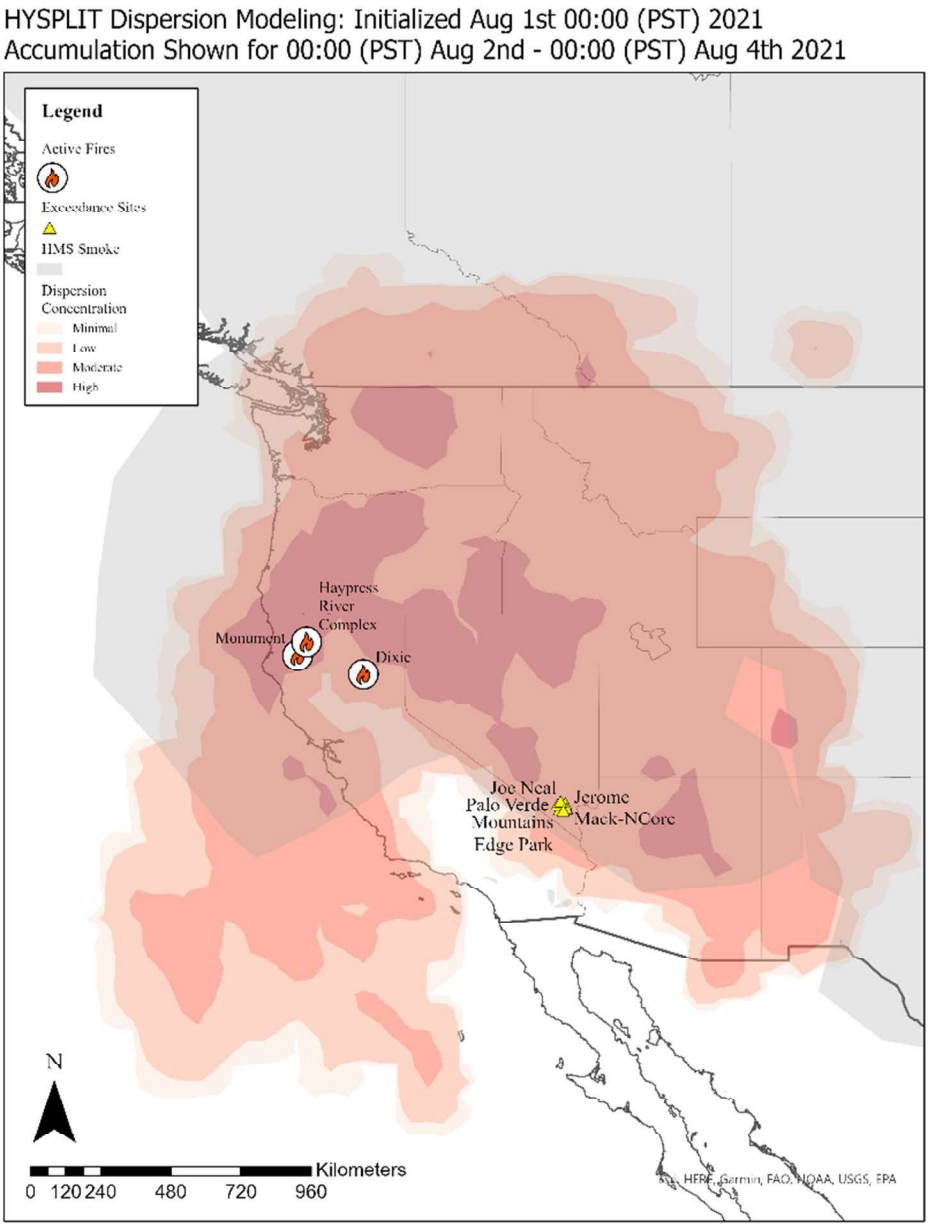

Figure 82. Results of the HYSPLIT dispersion modeling for three large fires (labeled as "Active Fires") in California. GDAS 1.0° meteorological data was used, and dispersion was initiated on August 1, 2021, at 00:00 PST to model the regional smoke observed in satellite and HMS products. HMS smoke is shown in gray and qualitative concentrations of particulate matter are shown in shades of red. Accumulation of particulate matter is shown at 0-100 m for 00:00 PST on August 2 through 00:00 PST on August 4, 2021.

Regional weather conditions were mild as a high-pressure system moved eastward during August 1-3, 2021 (Figure 83). This is consistent with the dispersion modeling results, which show widespread smoke from California wildfires (shown in Figure 82).

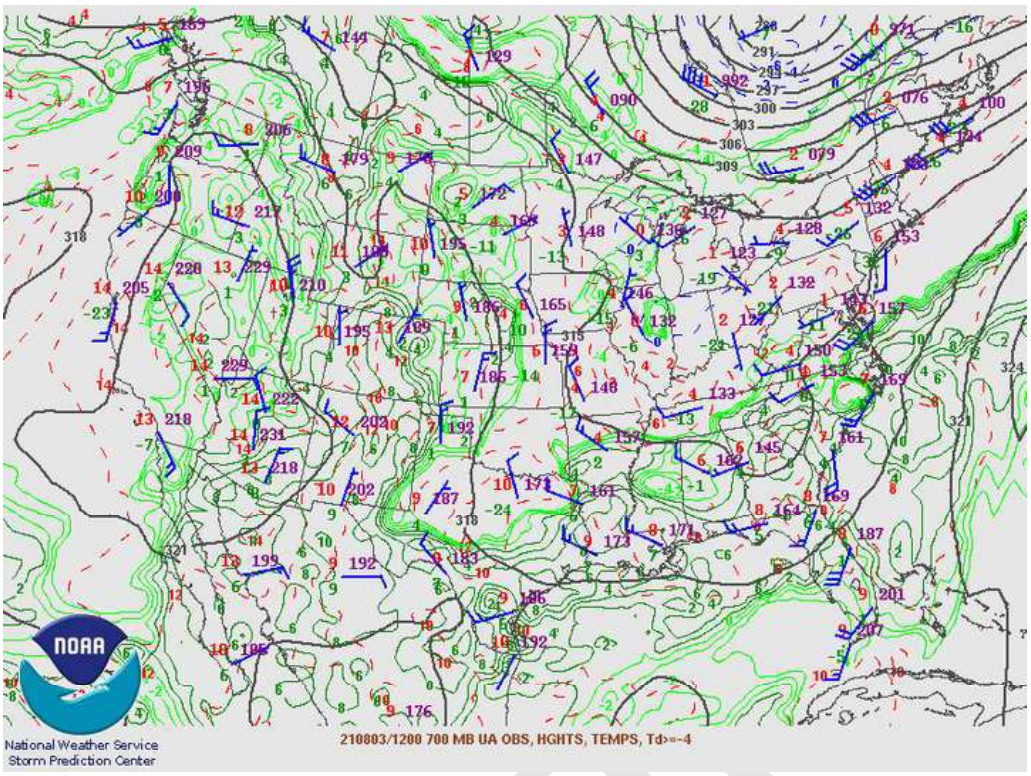

Figure 83. 700-mb map valid at 12:00 UTC (04:00 PST) on August 3, 2021. Upper-level high pressure over Nevada aided widespread transport of smoke into Clark County, NV.

4.4.4 Surface Impacts

The presence of wildfire smoke during the exclusion dates is evident by comparing the visibility conditions prior to the exclusion dates, on the evening of August 1 (Figure 84), to the exclusion dates of August 2-3 (Figure 85 and Figure 86). Local and regional smoke from the three fires identified in Section 4.4.2 is visible in Clark County on both August 2 and 3 at 16:00 LST (16:00 PST), which is a time of day when the photochemical production of ozone typically declines. Local and regional smoke is an atypical influence on ozone and ozone precursors in the Clark County area and, in this case, caused atypical ozone concentrations on the exclusion dates. Smoke was also identified in the KLAS (Las Vegas) METAR report (reported as "FU," meaning smoke)[12] on August 3, 2021, confirming that smoke was observed at the surface in Clark County.

[12] Available from Iowa Environmental Mesonet, accessed Sept 6, 2023. https://mesonet.agron.iastate.edu/request/download.phtml?network=NV_ASOS

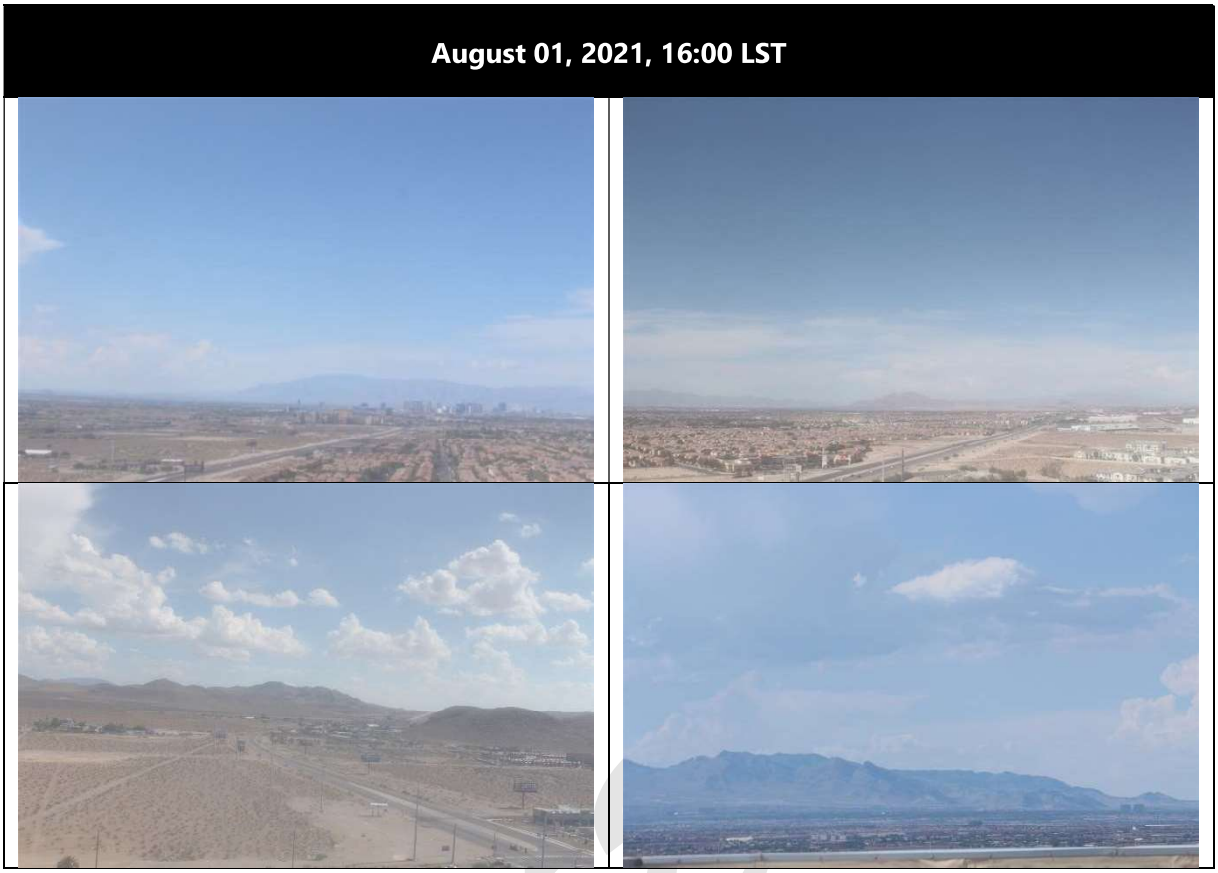

Figure 84. Camera images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions taken from the M Resort Hotel in Clark County, NV, on August 1 at 16:00 LST.

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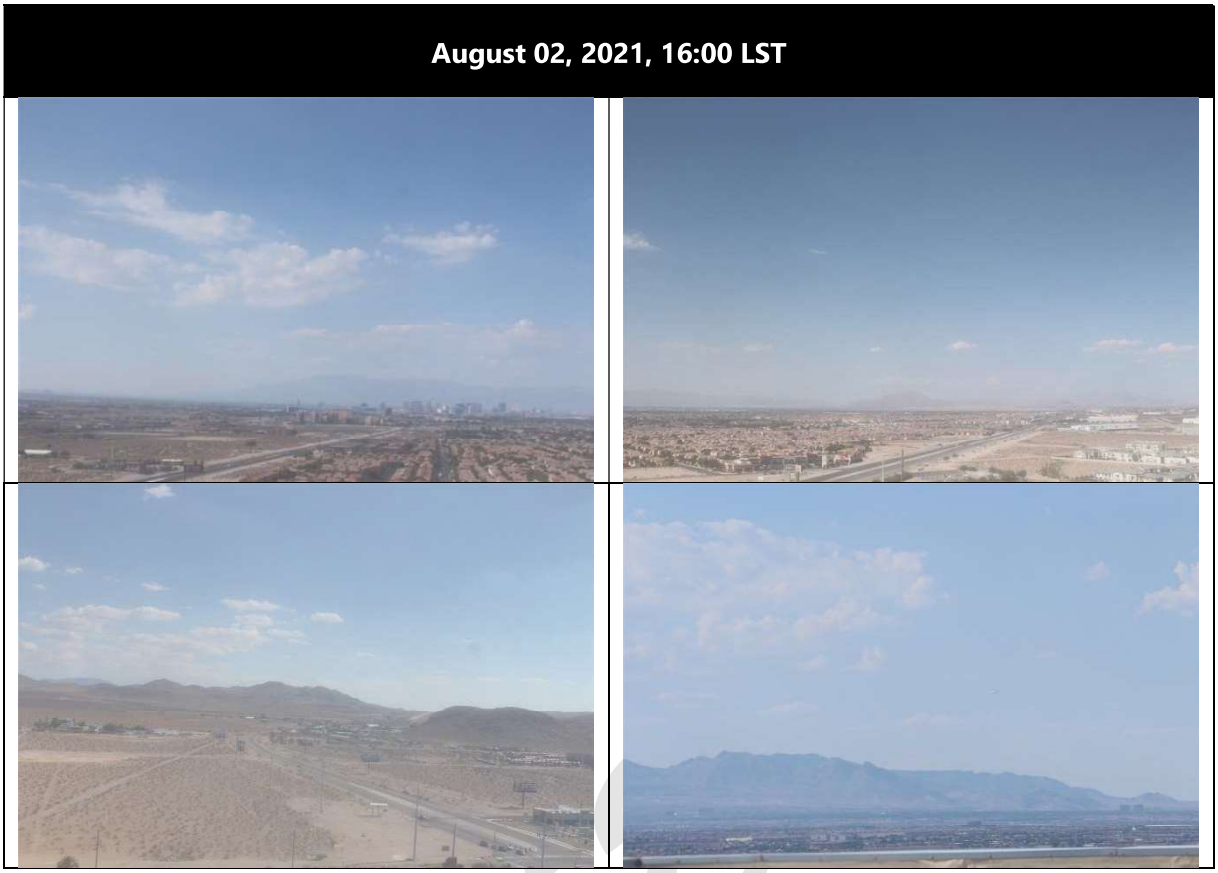

Figure 85. Camera images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions taken from the M Resort Hotel in Clark County, NV, on August 2 at 16:00 LST.

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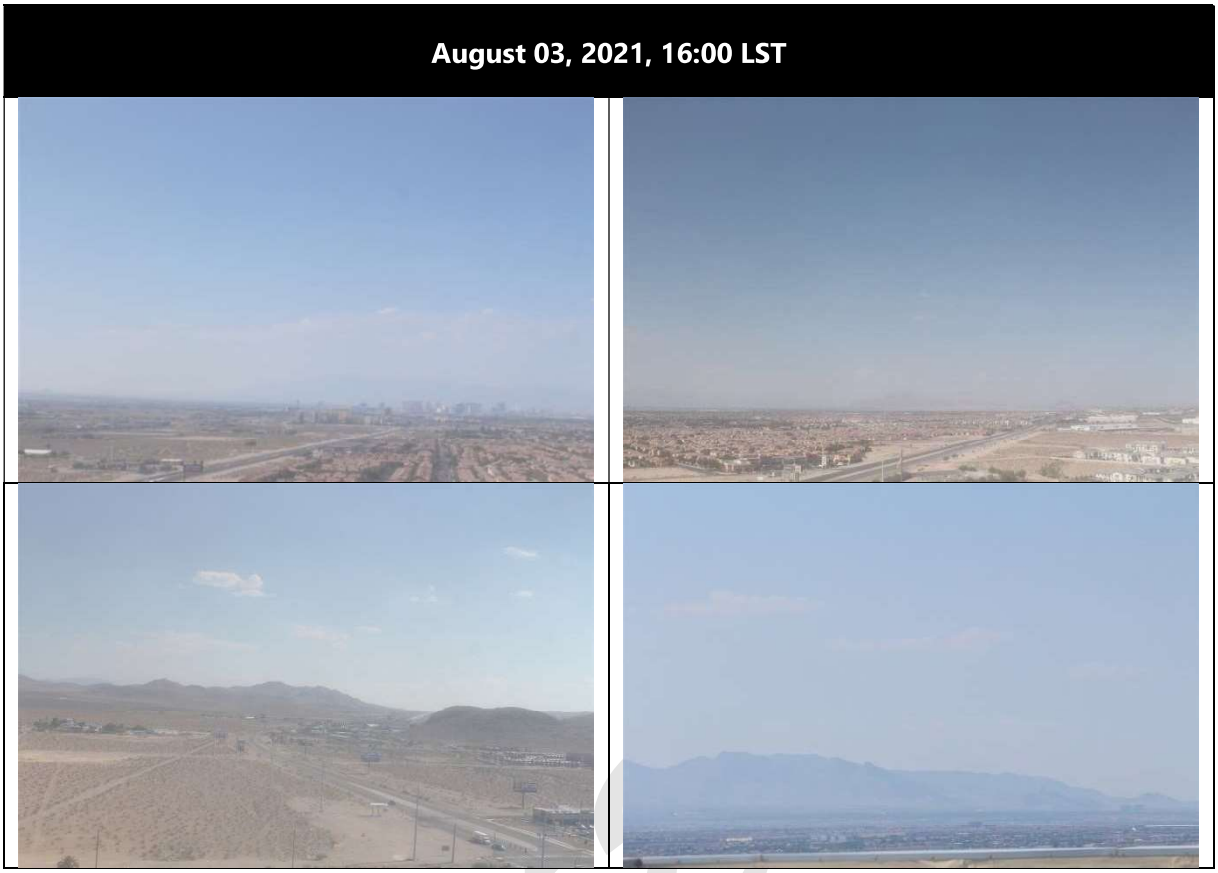

Figure 86. Camera images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions taken from the M Resort Hotel in Clark County, NV, on August 3 at 16:00 LST.

The presence of surface-level smoke in Clark County during the exclusion period is also indicated by enhanced $PM_{2.5}$ and CO concentrations. Figure 87 and Figure 88 show that $PM_{2.5}$ and CO concentrations steadily increased in the region between August 1 and August 3. The shaded area in the figures compares measurements to the diurnal 10th-90th percentile range, which is calculated across five years of data (2017-2021) collected during the ozone season (May – October). At the Green Valley site, $PM_{2.5}$ concentrations showed a peak on the evening of August 2, exceeding the diurnal 90th percentile concentration at 20:00 PST (dashed line in figures). Local maxima $PM_{2.5}$ concentrations also occurred concurrently at the Jerome Mack, Joe Neal, and Walnut Community Center sites. $PM_{2.5}$ concentrations continued to rise in the region and met or exceeded the diurnal 90th percentile concentration at each site on August 3.

CO concentrations at the Green Valley site exceeded the diurnal 90th percentile concentration at the same time that $PM_{2.5}$ concentrations peaked on the evening of August 2 (Figure 88). The combined enhancement of $PM_{2.5}$ and CO concentrations supports the presence of wildfire smoke in the region during the exclusion period. Time series of hourly NO_2 measurements are shown in Figure 89, which show the strongest evidence of enhancement the morning of August 3.

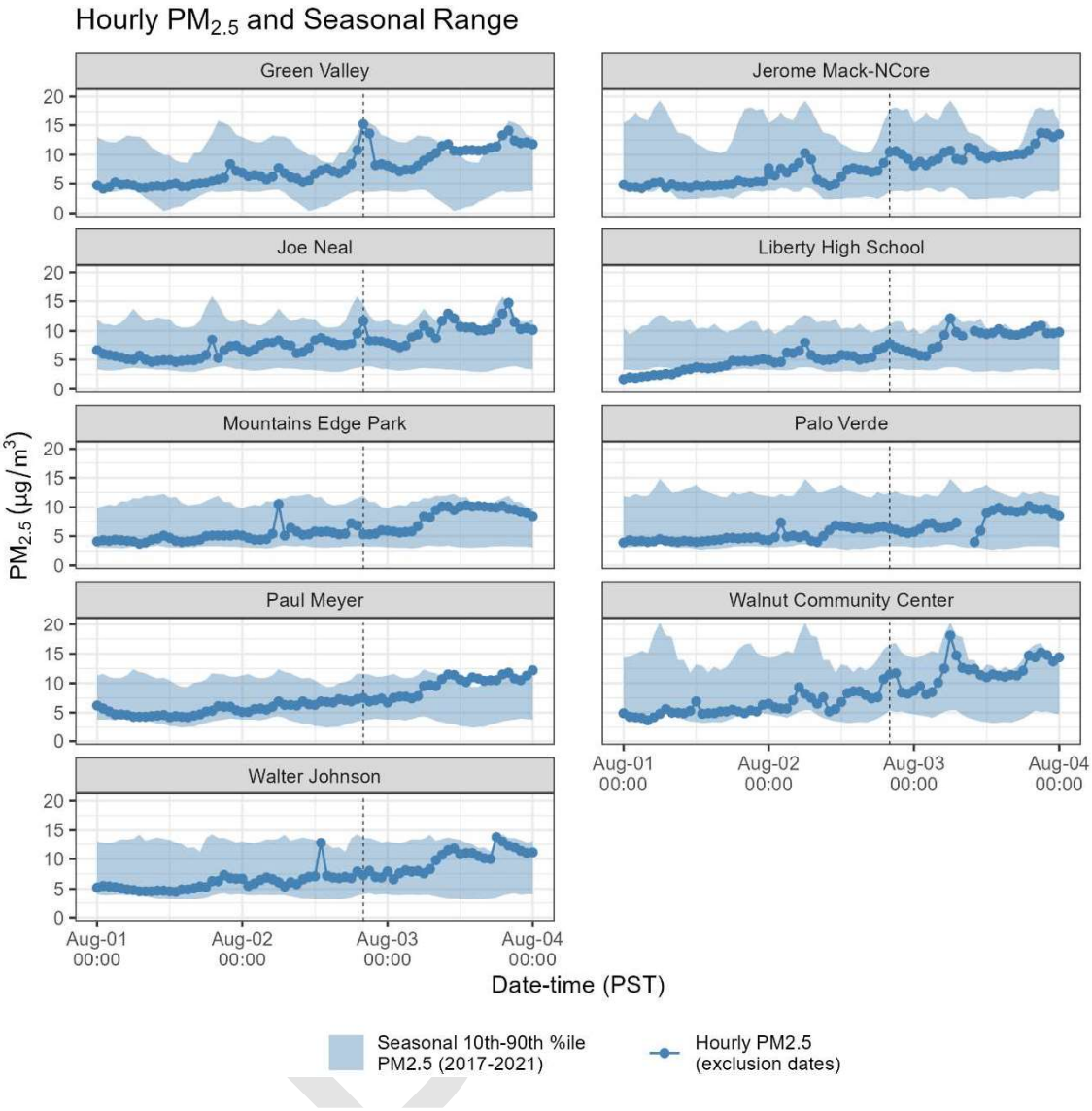

Figure 87. Hourly $PM_{2.5}$ measurements overlaid on the 10th-90th percentile diurnal concentration at affected sites. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021. The dashed line is August 2, 2021, at 20:00 PST.

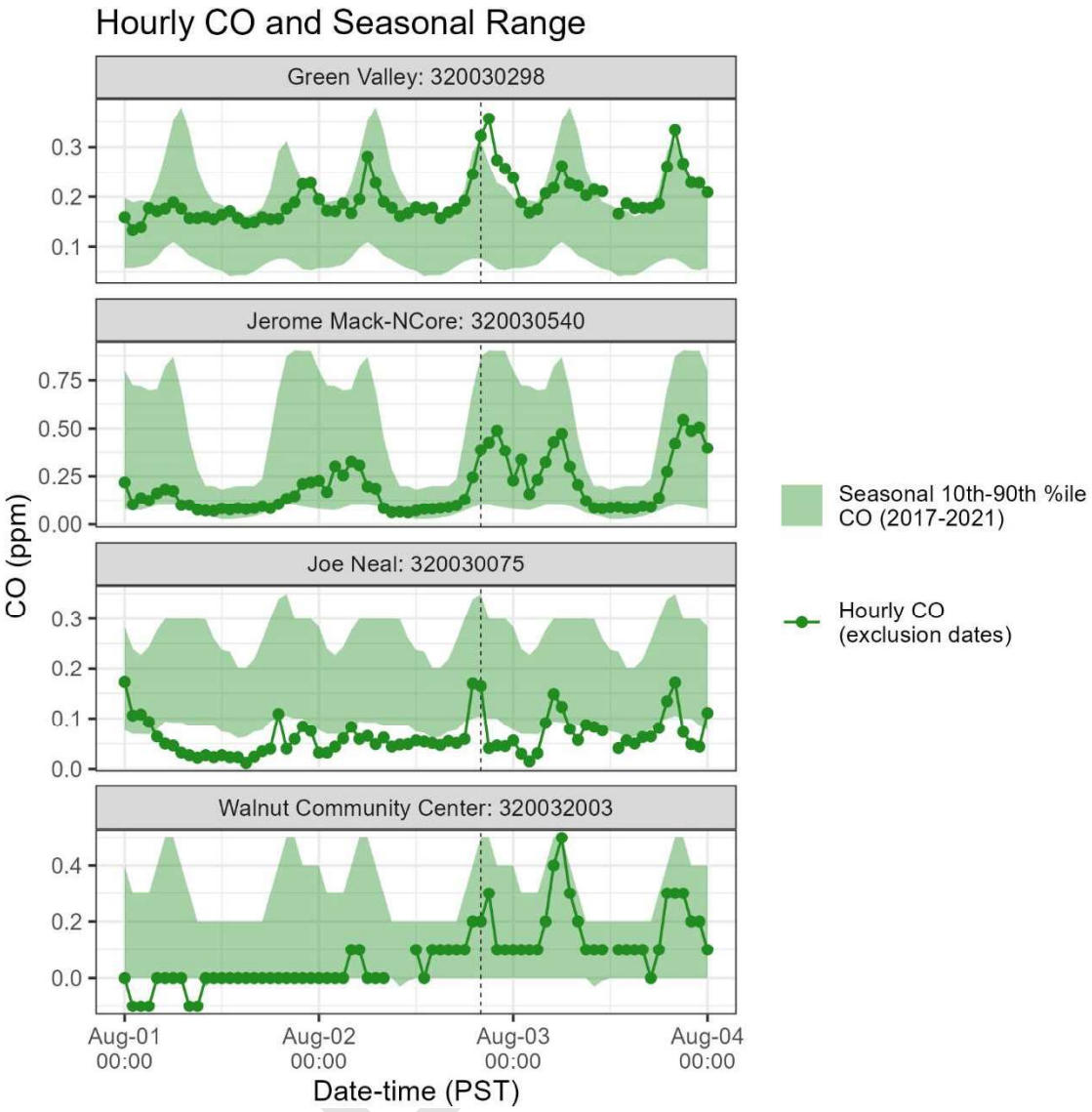

Figure 88. Hourly CO measurements overlaid on the 10th-90th percentile diurnal concentration at affected sites. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021. The dashed line is August 2, 2021, at 20:00 PST.

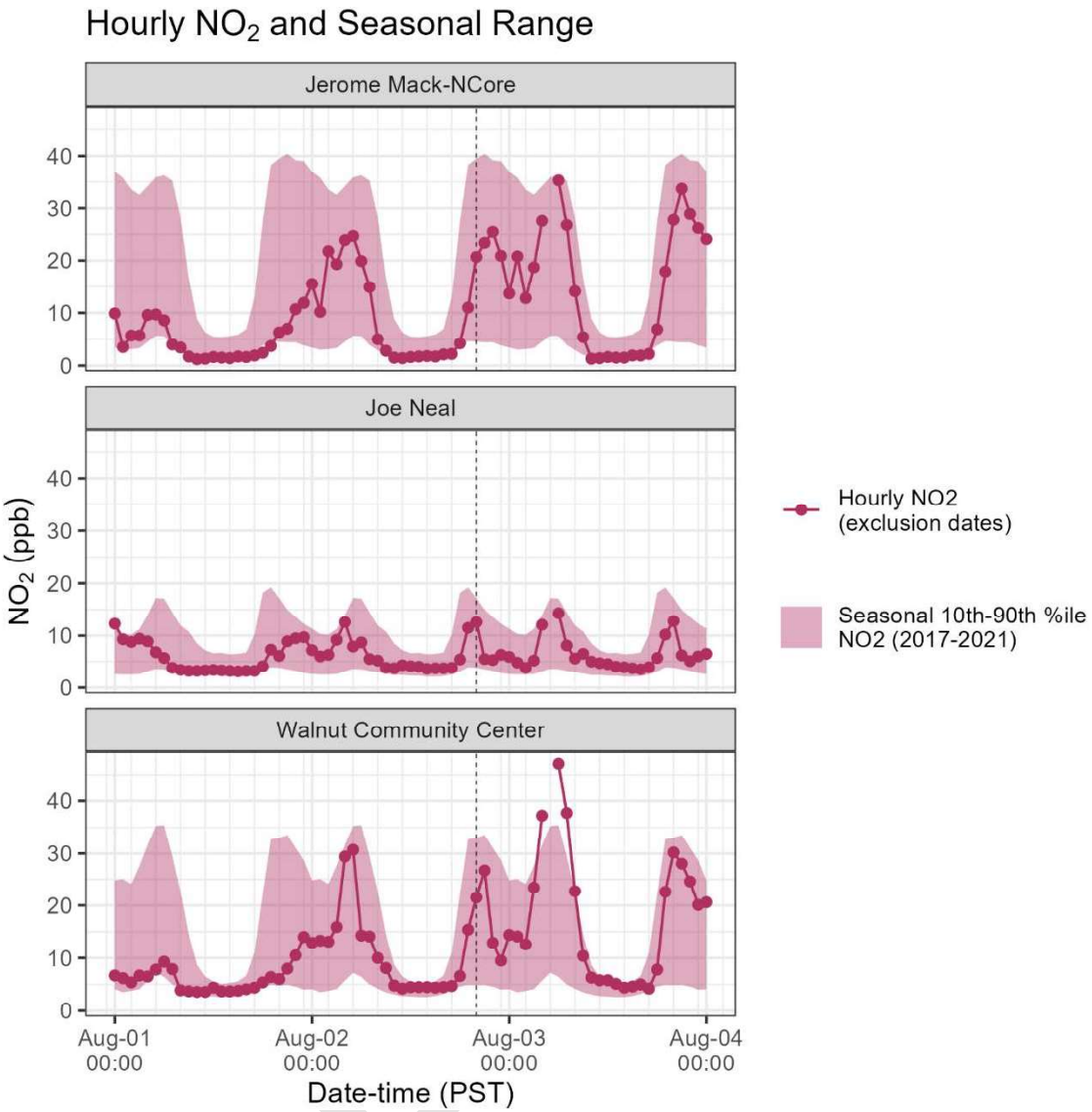

Figure 89. Hourly NO_2 measurements overlaid on the 10th-90th percentile diurnal concentration at affected sites. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021. The dashed line is August 2, 2021, at 20:00 PST.

The ratio of $PM_{2.5}$-to-PM_{10} concentrations was also examined to determine if wildfire smoke entered Clark County on or before the exclusion dates. Increases in this ratio are indicative of wildfire smoke. Figure 90 shows a time series of the $PM_{2.5}$-to-PM_{10} ratio from August 1-5 at the affected monitoring sites compared to the ozone season mean and 5th-95th percentile range for available data between 2017-2021. All sites show above average ratios starting late in the day on August 2 and continuing through the early morning of August 3. The same diurnal pattern persists during the day on August 3 and August 4. This observation coincides with the $PM_{2.5}$ and CO enhancements that occurred on August 2 and 3, suggesting that wildfire smoke entered the area on August 2 and lingered through August 4, and contributed to the atypical ozone event that occurred on August 2 and 3.

Figure 90. Ratio of $PM_{2.5}$-to-PM_{10} concentrations at affected sites, before and during the August 2 and 3 event period. The 5-yr* average $PM_{2.5}$-to-PM_{10} diurnal ratio is displayed as a dotted line, and the 5th-95th percentile range is shown as a shaded ribbon. The 5th-95th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021. *Sites where data collection began after 2017 are indicated.

4.4.5 Event Statistics

Table 18 summarizes the daily measurements of ozone, $PM_{2.5}$, CO, and NO_2 on the exclusion day, as well as the percentile rank of the observation compared to the previous five years of data (2017-2021). Ozone MDA8 measurements ranged from the 96th-99.5th percentile at most sites on both days. The 24-hr average $PM_{2.5}$ concentrations ranged from near the 50th-75th percentile on August 2, and from the 75th-90th percentile on August 3. A regional pattern of enhanced 1-hr daily maximum CO concentrations was not observed; however, some sites, such as Green Valley, showed local CO concentration enhancements. The 1-hr daily maximum of NO_2 concentration was similarly sensitive to location, with maximums observed on August 3 ranging from the 47th-98th percentiles.

Table 18. Percentile of pollutant measurements on the exclusion day compared with most recent five years* (2017-2021). The percentile rank is calculated across the ozone production season (May 1-October 31) of 2017-2021.

Date	Site Name	Site Code	Ozone		$PM_{2.5}$		CO		NO_2	
			Ozone MDA8 (ppb)	Percent Rank	PM2.5 24-hr Avg (µg/m3)	Percent Rank	CO 1-hr Daily Max (ppb)	Percent Rank	NO2 1-hr Daily Max (ppb)	Percent Rank
8/2/2021	Green Valley	320030298	74	98.7	7.6	74.4	357	77.9*	--	--
	Jerome Mack-NCore	320030540	72	98.5	7.6	59.1	489	44.5	25.5	34.5
	Joe Neal	320030075	75	97.8	7.8	74.5*	169	12.6*	12.6	35.9
	Liberty High School	320030299	77	99.5*	5.8	47.8*	--	--	--	--
	Mountain's Edge	320030044	75	98.6*	5.6	48.4*	--	--	--	--
	Palo Verde	320030073	78	99.8	5.7	53.6*	--	--	--	--
	Paul Meyer	320030043	69	92.1	6.5	60.7	--	--	--	--
	Walnut Comm. Center	320032003	78	98.7*	7.7	47.1*	300	32.7*	30.7	57.5*
	Walter Johnson	320030071	77	98.7	6.9	57.9*	--	--	--	--
8/3/2021	Green Valley	320030298	72	97.2	10.3	90.2	334	71.2*	--	--
	Jerome Mack-NCore	320030540	64	90.3	10.2	79.1	544	50.9	35.3	58.7
	Joe Neal	320030075	73	96.6	10.3	85.3*	171	13.3*	14.3	47.4
	Liberty High School	320030299	76	98.9*	9.1	83.7*	--	--	--	--
	Mountain's Edge	320030044	80	99.5*	8.7	80.5*	--	--	--	--
	Palo Verde	320030073	75	99.1	8	76.7*	--	--	--	--
	Paul Meyer	320030043	77	99.2	9.8	87.8	--	--	--	--
	Walnut Comm. Center	320032003	68	92.8*	12.1	85*	500	60.8*	47.1	98*
	Walter Johnson	320030071	74	96.7	10.1	82*	--	--	--	--

4.5 August 7, 2021

4.5.1 Event Summary

The unrepresentative ozone event took place on August 7, 2021, and affected twelve sites in Clark County, NV. Time series graphs showing hourly ozone concentrations that exceeded the seasonal means (calculated using May 1-October 31, 2017-2021) and 10th-90th percentiles at each site are shown in Figure 91.

On August 7, hourly ozone concentrations at most sites exceeded the 90th percentile between 08:00 to 19:00 PST and returned to near-mean concentrations overnight. The MDA8 ozone concentrations at the affected sites ranged from 73-87 ppb. Eight of the 12 sites had MDA8 ozone concentrations above 80 ppb, including the Indian Springs (87 ppb) and Green Valley (84 ppb) sites. The bottom of the range of concentrations occurred at the Jean and Virgin Valley High School (73 ppb at both), Jerome Mack-NCore (76 ppb), and Walnut Community Center (79 ppb) sites.

An abundance of regional wildfire smoke was identified as a major contributor to this event, particularly from the Dixie, Monument, Haypress River Complex, and Antelope Fires in California. Evidence of surface level wildfire smoke during the exclusion day includes (1) HYSPLIT dispersion modeling indicating the presence of smoke accumulation in Clark County, (2) remote sensing imagery and HMS smoke boundaries showing smoke over Clark County, (3) a drastic reduction in visibility based on camera images, and (4) enhanced ground-level concentrations greater than the seasonal 90th percentile simultaneously for $PM_{2.5}$, CO, and NO_2, and $PM_{2.5}$-to-PM_{10} ratios that aligned with ozone enhancement. This combination of evidence strongly indicates that this is an unrepresentative event for assessing base and future ozone design values.

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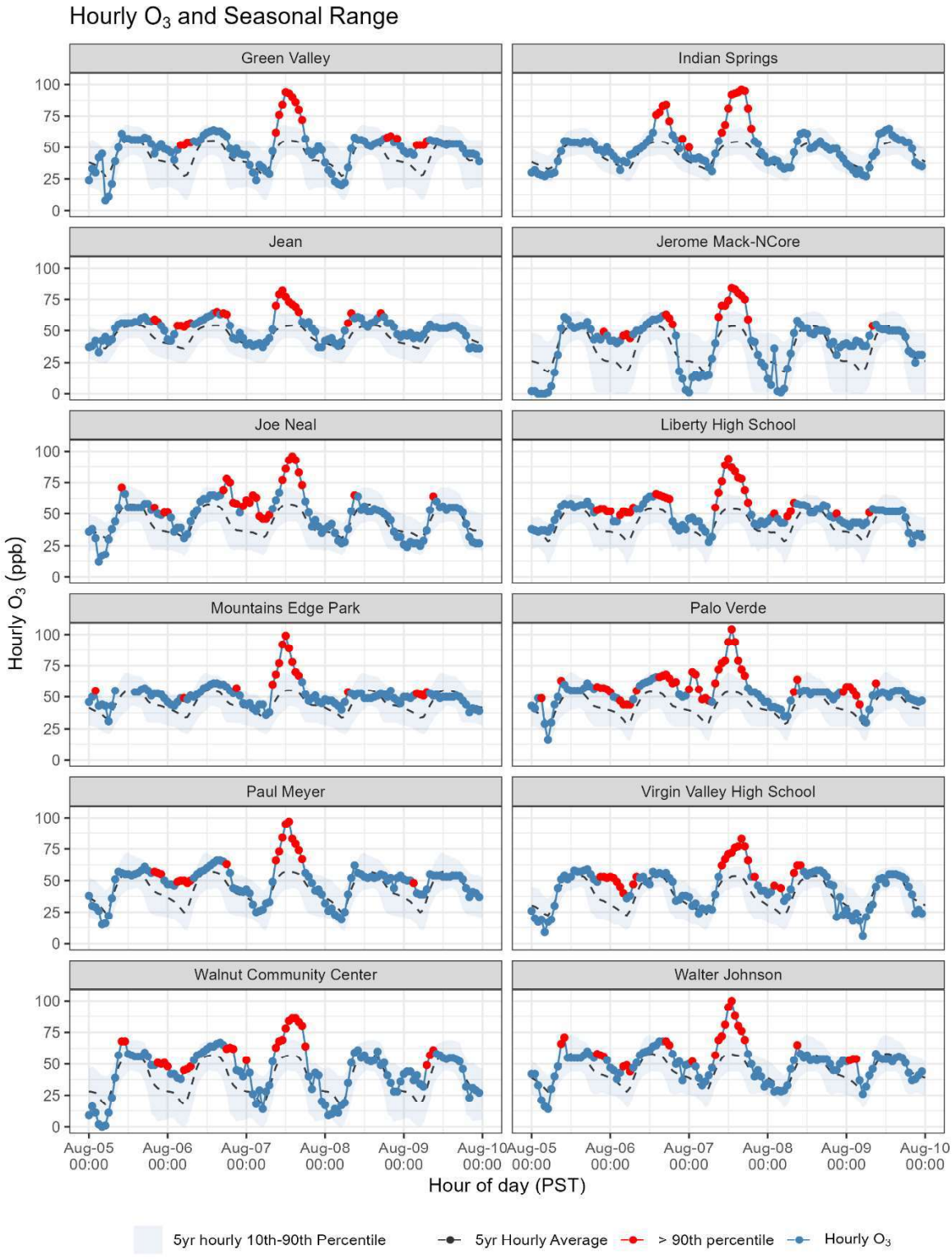

Figure 91. Hourly ozone concentrations (ppb) compared to 5-yr* ozone season (May 1-October 31) hourly means and 10-90th percentiles. *Note: data collection began in 2020 at the Mountain's Edge site, and in 2021 at the Liberty High School, Virgin Valley High School, and Walnut Community Center sites.

4.5.2 Identification of Wildfires

Numerous wildfires throughout the western U.S. were active on August 7, 2021, the exclusion day, and contributed to widespread regional smoke. Four major wildfires with significant smoke emissions contributed to regional smoke: the Dixie, Monument, Haypress River Complex and Antelope Fires in California (Figure 92). Regional smoke was present during early August 2021 throughout the northwest/western U.S., and this was verified for the days of August 5-7 through visualization of smoke and wildfire detection geodata provided by the NOAA HMS (Figure 93). Table 19 presents the state location, total acres within the fire perimeter, actively burning acres on the exclusion day, and the start and containment dates for each fire based on data from the WFGIS Current Interagency Fire Perimeters and the Satellite Fire Occurrence and Growth database.[13]

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[13] McClure et al. (2023) Consistent, high-accuracy mapping of daily and sub-daily wildfire growth with satellite observations. International Journal of Wildland Fire 32, 694-708. Available at https://www.publish.csiro.au/wf/ExportCitation/WF22048.

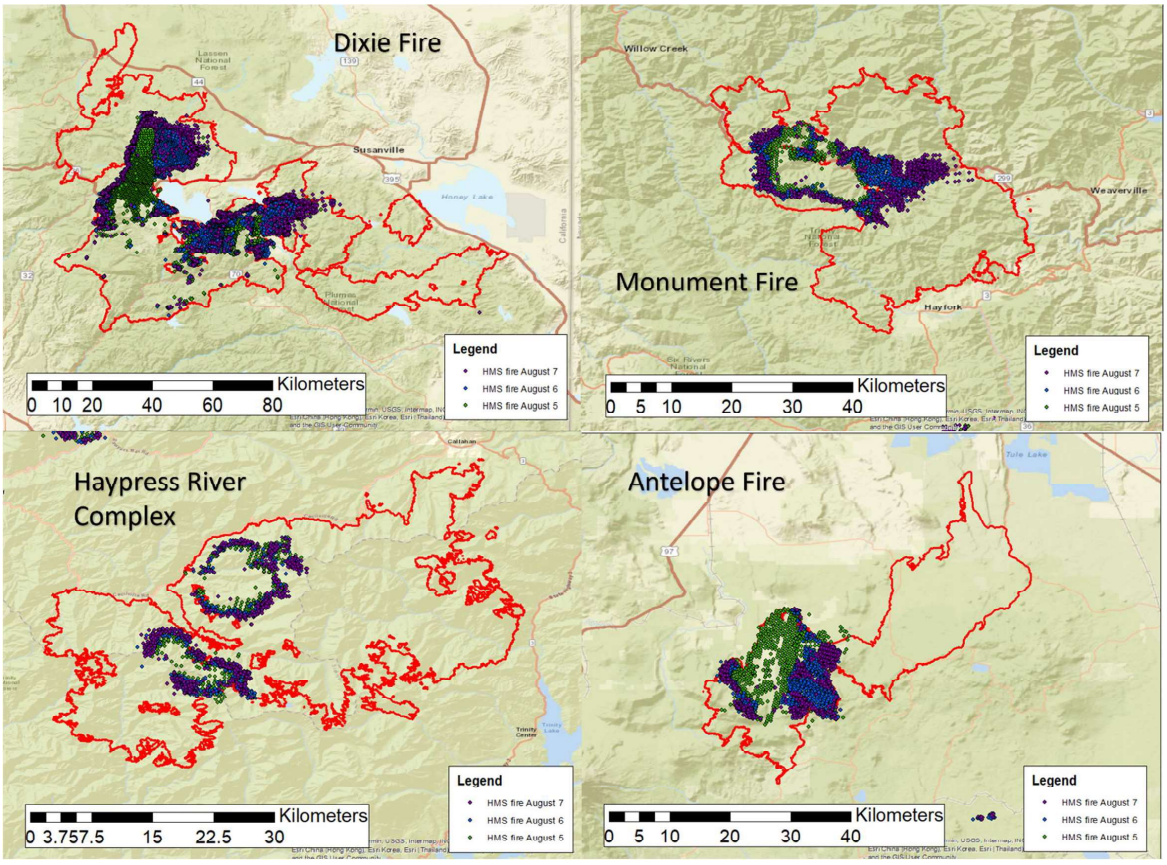

Figure 92. Final fire perimeters (red) and HMS fire detections for the Dixie, Monument, Haypress River Complex, and Antelope Fires during August 5-7, 2021.

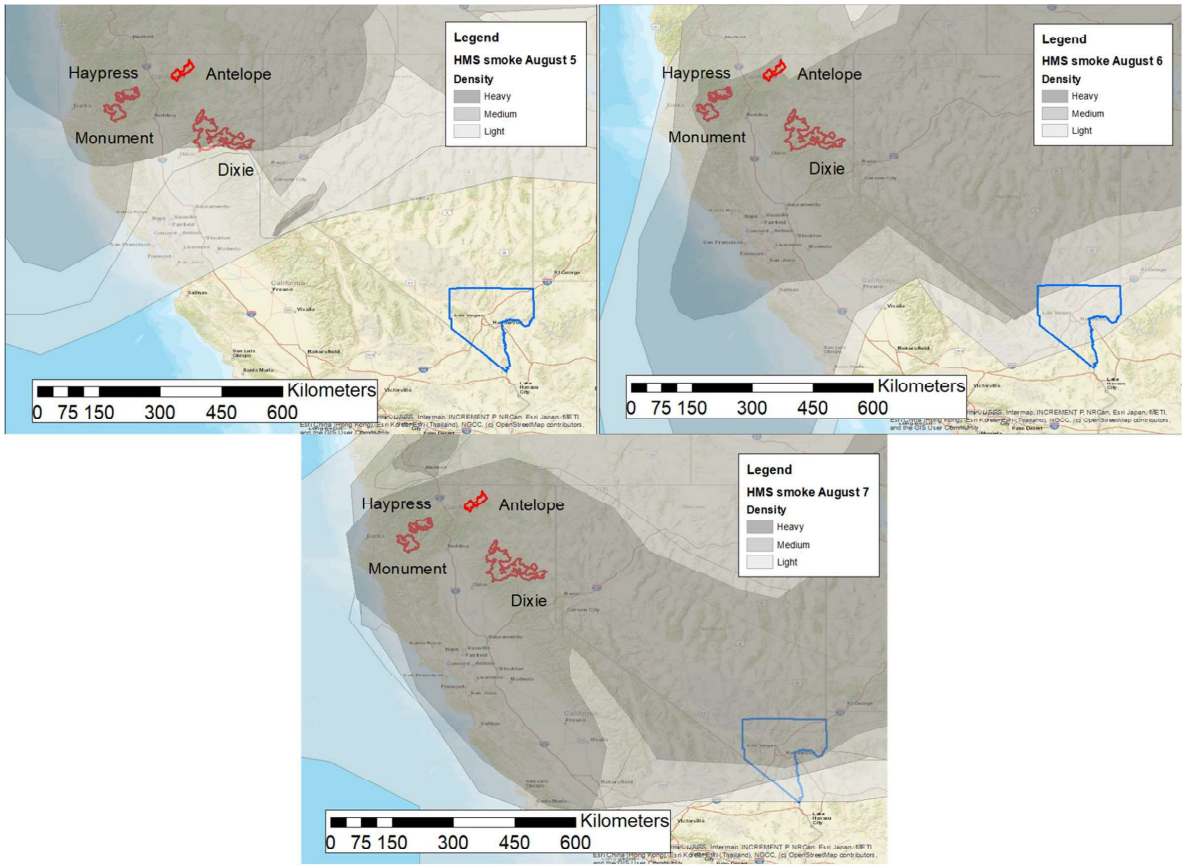

Figure 93. HMS smoke data for August 5-7, 2021, included with qualitative smoke density. Fire perimeters from the major fires contributing to the exclusion date are shown in red and the Clark County, NV, boundary is shown in blue.

Table 19. Wildfires affecting Clark County on the exclusion day.

Wildfire Name	State	Total Acres	Active Acres August 7	Start Date	Containment Date
Dixie	California	963,405	48,129	July 14	October 15
Monument	California	223,124	19,480	July 31	October 20
Haypress River Complex	California	199,343	12,103	July 31	October 25
Antelope	California	145,632	12,341	August 1	October 14

4.5.3 Dispersion Modeling and Regional Analysis

HYSPLIT dispersion modeling was performed for August 5-7, 2021. Dispersion was initiated at 16:00 PST from the four identified active fires that impacted the exclusion date. GDAS 1.0° data horizontal resolution was used for meteorological input. Output from the dispersion modeling was integrated over a 24-hr period, from August 6 at 16:00 PST through August 7 at 16:00 PST. 16:00 PST on August 6, the day before the exclusion date, was chosen to correspond with the initial increase of observed $PM_{2.5}$ concentrations in Clark County. The accumulation of smoke at 0-100 m for the 24-hr period is shown in Figure 94.

The results of the HYSPLIT dispersion modeling show that smoke from multiple California wildfires accumulated to produce a dense layer of widespread smoke that covered much of California and Nevada, including Clark County. The dispersion modeling results are consistent with the HMS smoke plume data (shown in gray in Figure 94); HMS is an independent smoke identification database. The dispersion modeling results show smoke from multiple California wildfires reached Clark County, Nevada, on August 7, 2021, and the smoke was present in the lower mixed layer, impacting the surface conditions.

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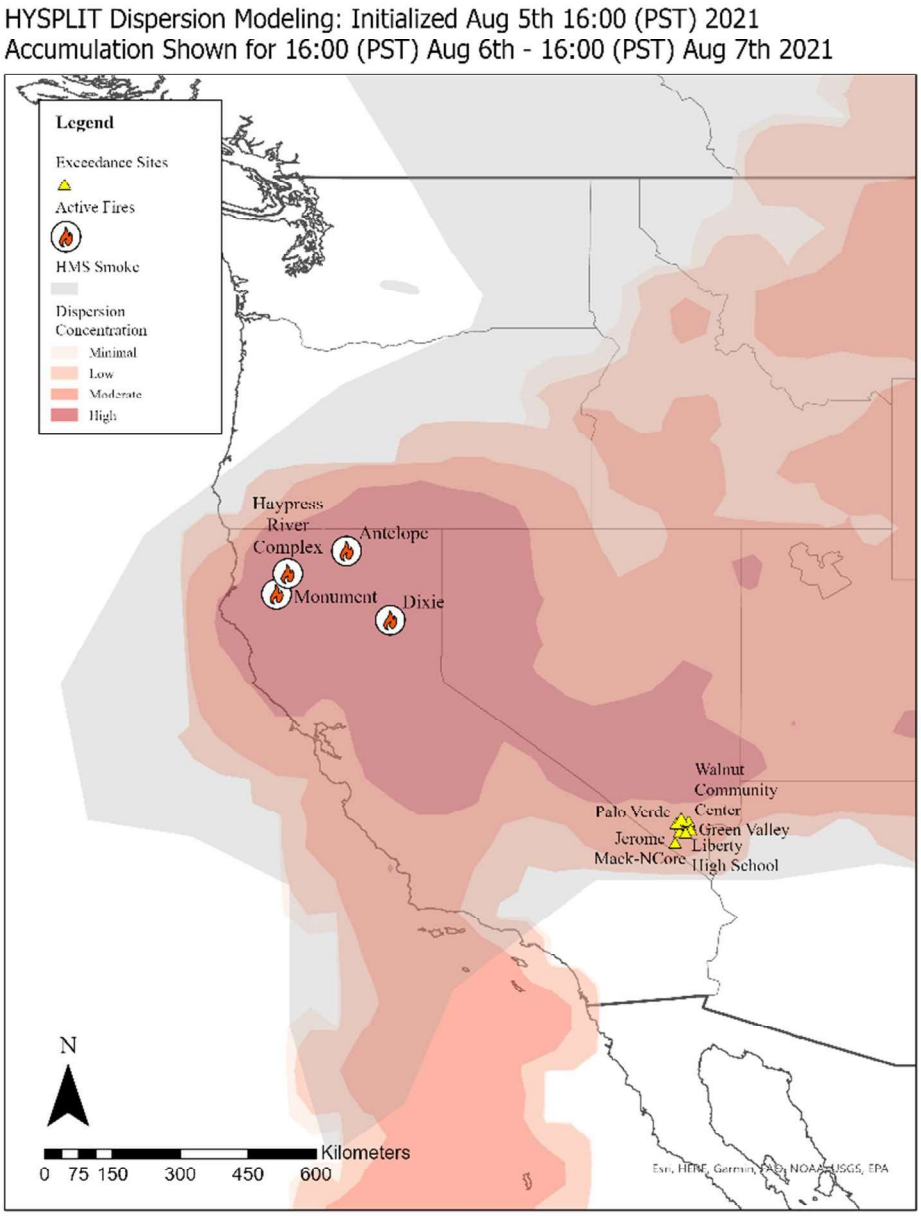

Figure 94. HYSPLIT dispersion modeling for four large fires (labeled as "Active Fires") throughout the western U.S. GDAS 1.0° meteorological data was used, and dispersion was initiated on August 5, 2021, at 16:00 PST to model the regional smoke observed in satellite and HMS products. HMS smoke is shown in gray and qualitative concentrations of particulate matter are shown in shades of red. Accumulation of particulate matter is shown at 0-100 m for 16:00 PST on August 6 through 16:00 PST on August 7, 2021.

Remote sensing data from MODIS Terra visible satellite imagery confirms the large extent of regional smoke from the California fires and is consistent with the dispersion modeling results for August 7. Figure 95 shows regional smoke from the California fires extending below the Central Valley in California into southern Nevada, and directly affecting Clark County, NV.

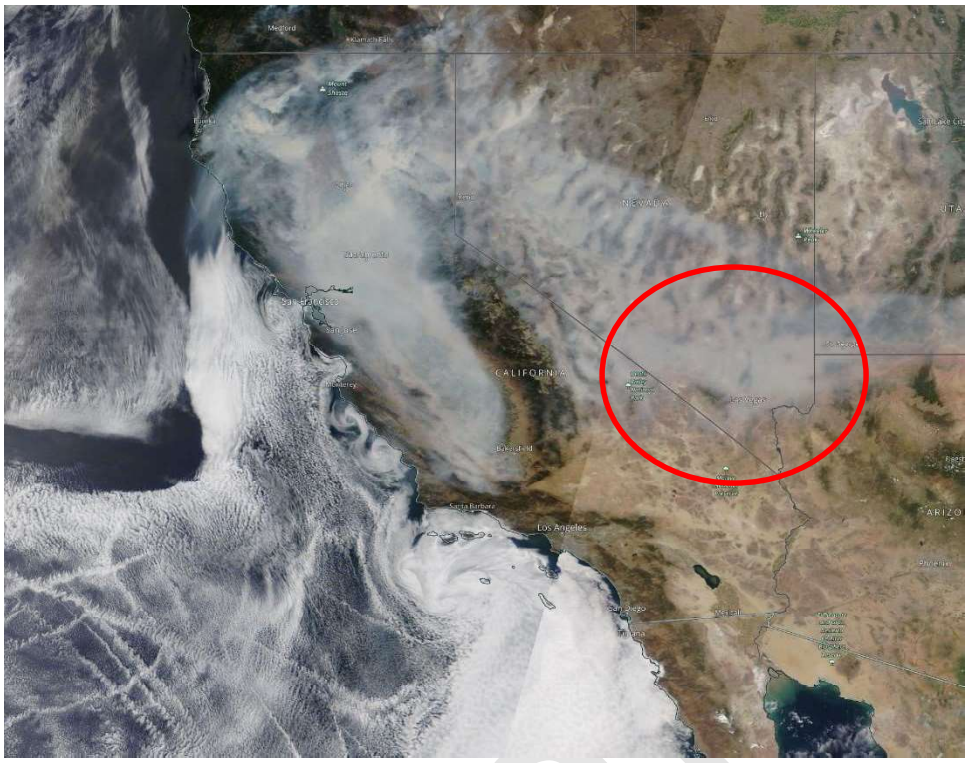

Figure 95. MODIS Terra satellite image valid on August 7, 2021. Smoke from California wildfires is visible across central and southern Nevada. This smoke contributed to poor air quality and reduced visibility in Clark County. The red circle shows the area of smoke over Clark County.

4.5.4 Surface Impacts

Figure 96 and Figure 97 compare visibility conditions in the Las Vegas Valley before and during the exclusion date. Figure 96 shows visibility conditions at 13:00 LST (13:00 PST) on August 6, the day before the event. Figure 97 shows visibility conditions at 13:00 LST on August 7, the exclusion date, and the presence of thick, regional wildfire smoke from the fires identified in Section 4.5.2. Regional smoke from wildfires strongly influenced air quality including ozone and ozone precursors in the Clark County area and caused atypical ozone concentrations on the exclusion date.

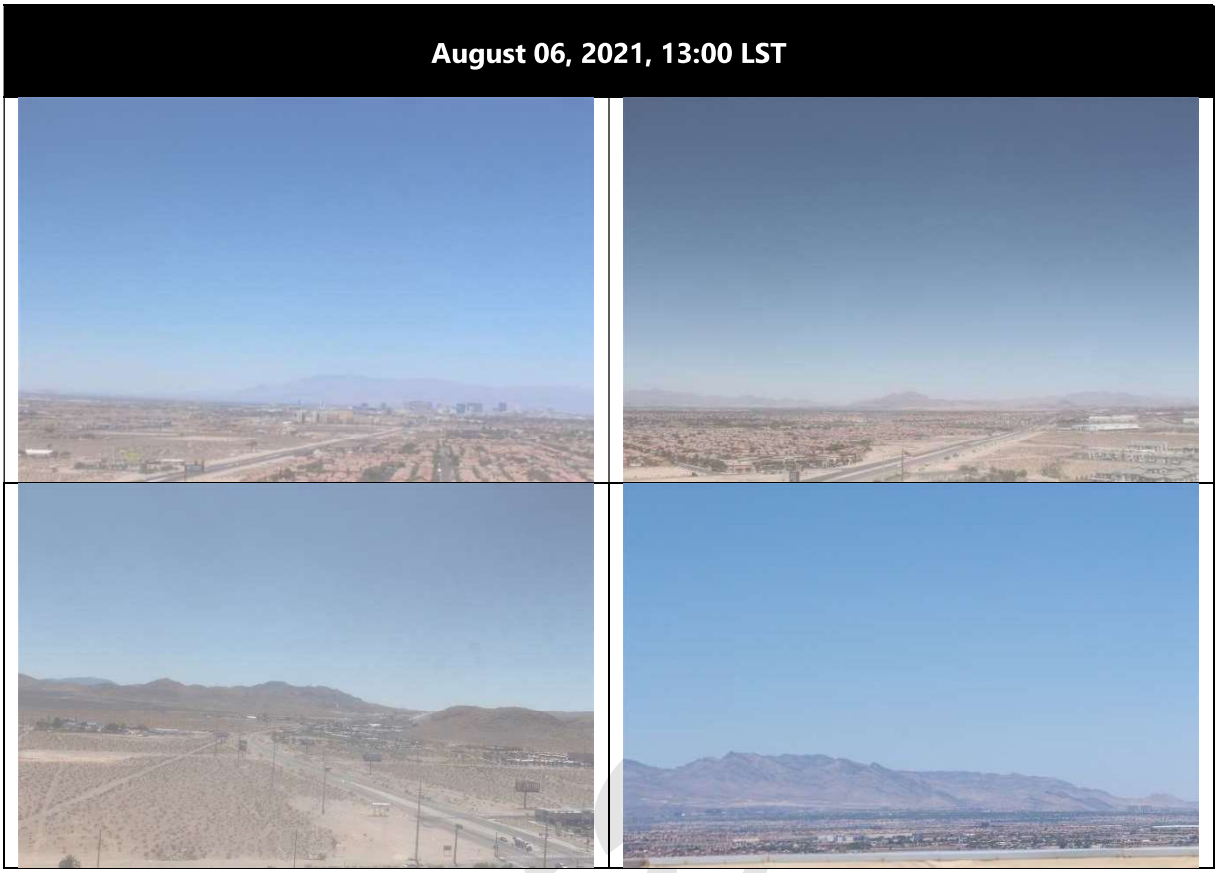

Figure 96. Camera images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions, taken from the M Resort Hotel in Clark County, NV, on August 6, 2021, at 13:00 LST.

Figure 97. Camera images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions taken from the M Resort Hotel in Clark County, NV, on August 7, 2021, at 13:00 LST.

The presence of surface level wildfire smoke on August 7 is strongly corroborated by enhanced ground-level $PM_{2.5}$, CO, and NO_2 concentrations during the same time period. Hourly $PM_{2.5}$ concentrations exceeded 200 µg/m^3 in Clark County on August 7, and far-exceeded the diurnal 90th percentile for $PM_{2.5}$ concentrations at all sites that exceeded the MDA8 ozone NAAQS threshold. $PM_{2.5}$ concentrations compared to the diurnal 10th-90th percentile $PM_{2.5}$ concentration, calculated from 2017-2021, shown in Figure 98.

Hourly CO concentrations are shown alongside the 10th-90th percentile diurnal concentration, calculated from 2017-2021 at affected sites (Figure 99). CO concentrations exceeded the 90th percentile concentration at each site during the late morning and afternoon of August 7. Concurrently, NO_2 concentrations in Clark County were elevated and above the 90th percentile diurnal concentration (Figure 100).

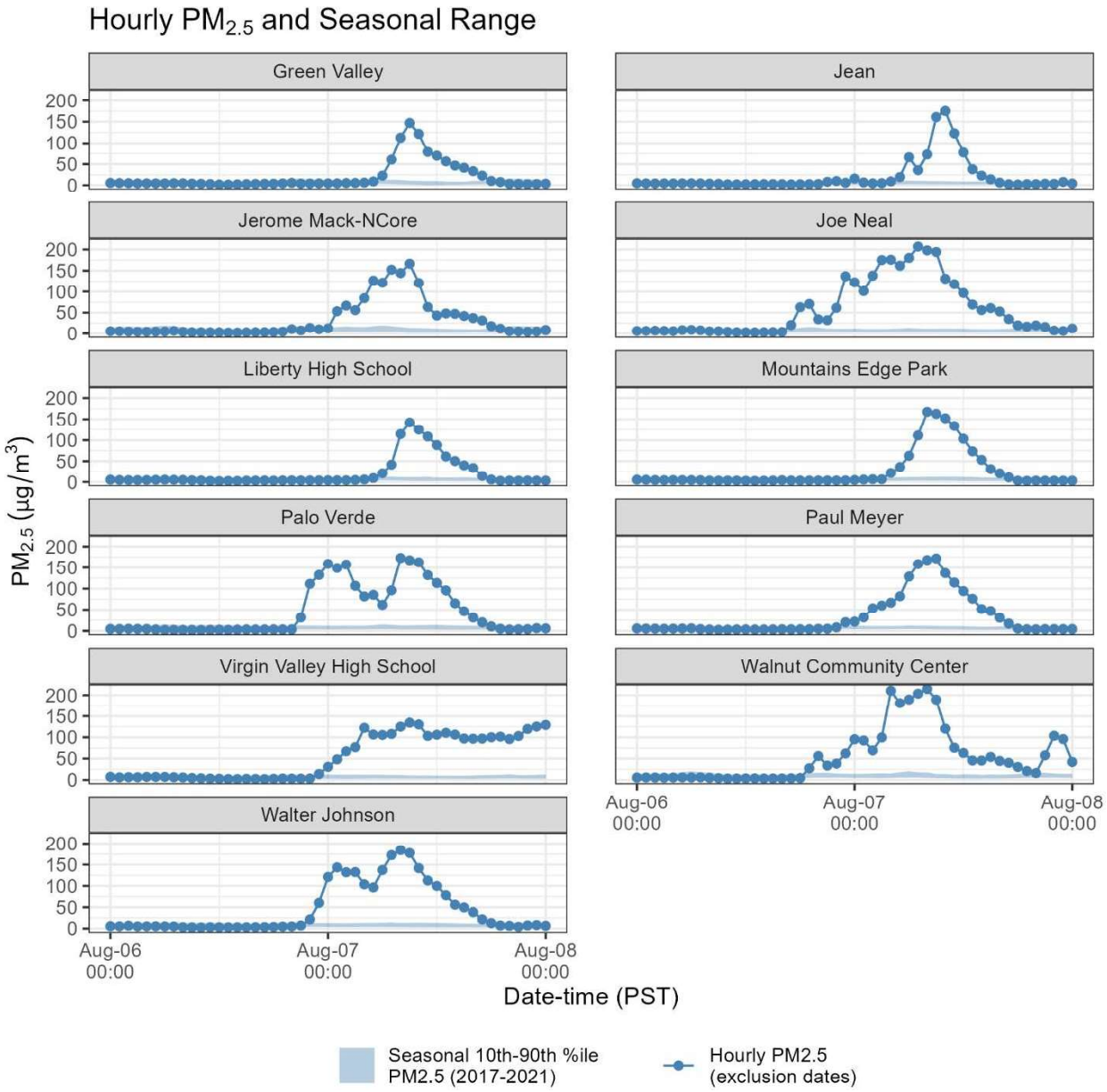

Figure 98. Hourly $PM_{2.5}$ measurements overlaid on the 10th-90th percentile diurnal concentration at affected sites that measure $PM_{2.5}$. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

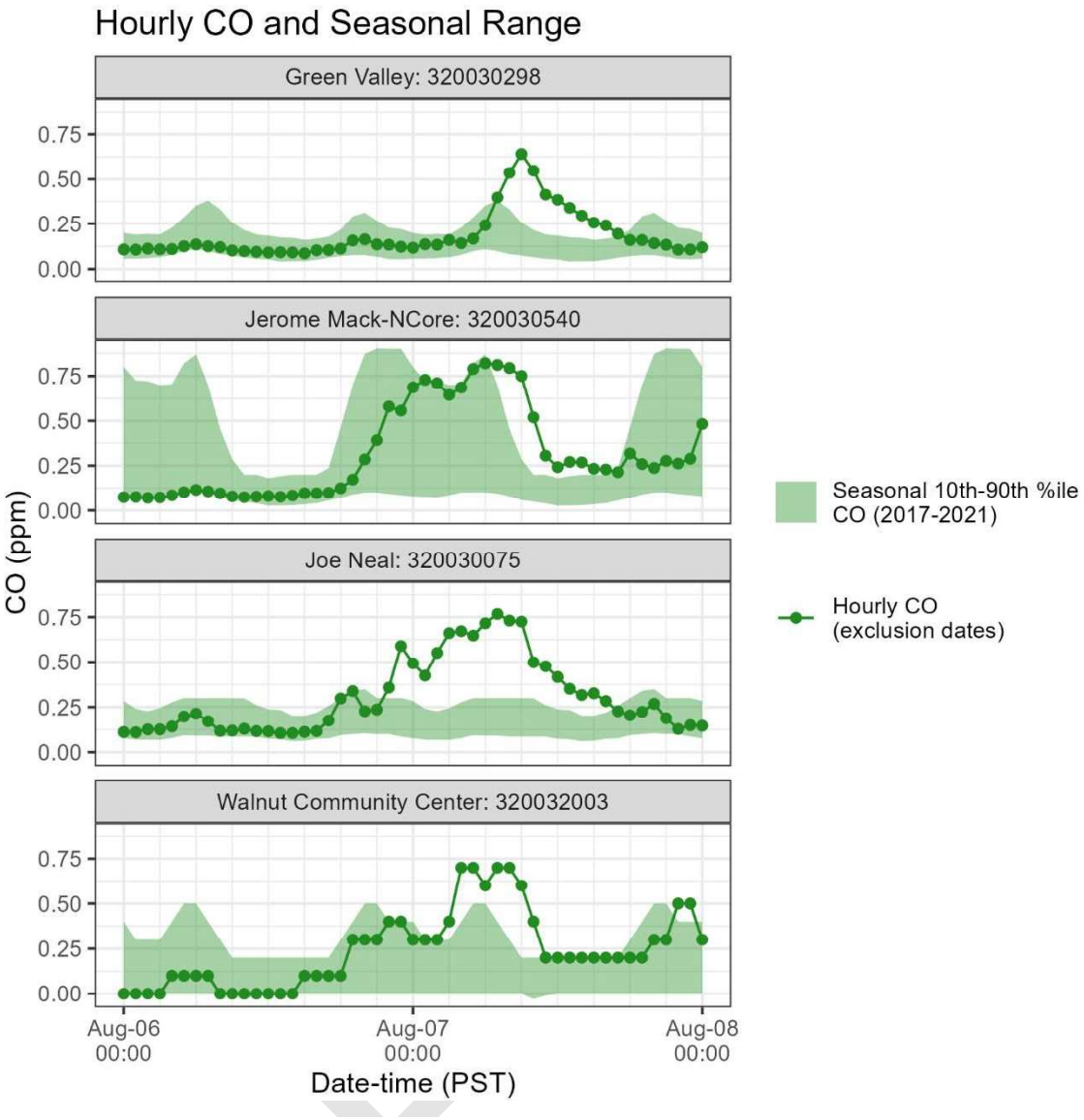

Figure 99. Hourly CO measurements overlaid on the 10th-90th percentile diurnal concentration at affected sites that measure CO. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

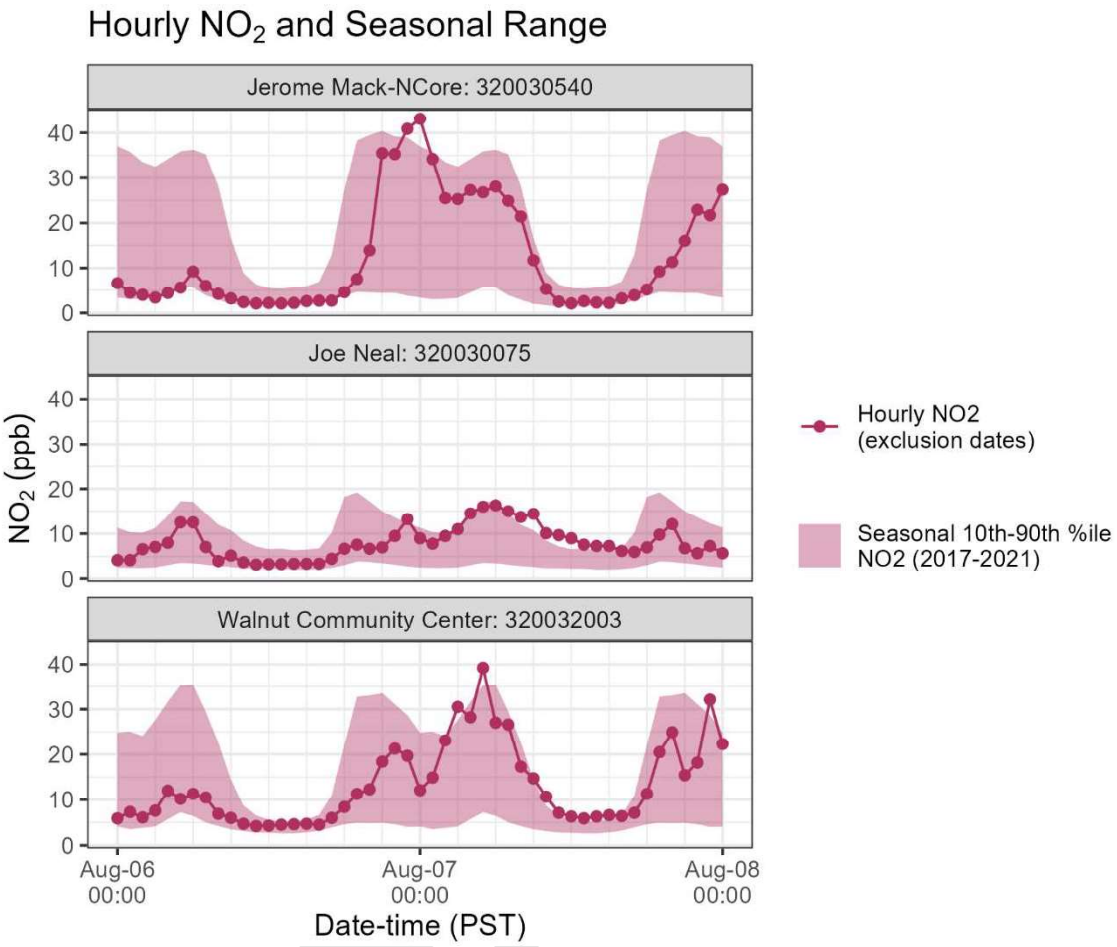

Figure 100. Hourly NO_2 measurements overlaid on the 10th-90th percentile diurnal concentration at affected sites that measure NO_2. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

The ratio of $PM_{2.5}$-to-PM_{10} concentrations was also examined to determine if wildfire smoke entered Clark County on or before the exclusion dates. Increases in this ratio are indicative of wildfire smoke. Figure 101 and Figure 102 show time series of the $PM_{2.5}$-to-PM_{10} ratio from August 6 through August 8, the 5-yr average ratio, compared to the ozone season mean and 5th-95th percentile range for available data between 2017-2021. $PM_{2.5}$-to-PM_{10} ratios at all affected (Figure 101) and non-affected sites (Figure 102) were generally below average on August 6, then reached or exceeded the 95th percentile during the morning and daytime on August 7. Ratios at all sites spiked to reach or exceed the 95th percentile again the following day (August 8). These observations provide evidence that wildfire smoke containing enhanced $PM_{2.5}$-to-PM_{10} ratios entered Clark County on August 7, immediately prior to and during the atypical ozone event on August 7.

Figure 101. Ratio of $PM_{2.5}$-to-PM_{10} concentrations at all affected sites during the August 7 event period. The 5-yr average $PM_{2.5}$-to-PM_{10} diurnal ratio is displayed as a dotted line, and the 5th-95th percentile range is shown as a shaded ribbon. The 5th-95th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

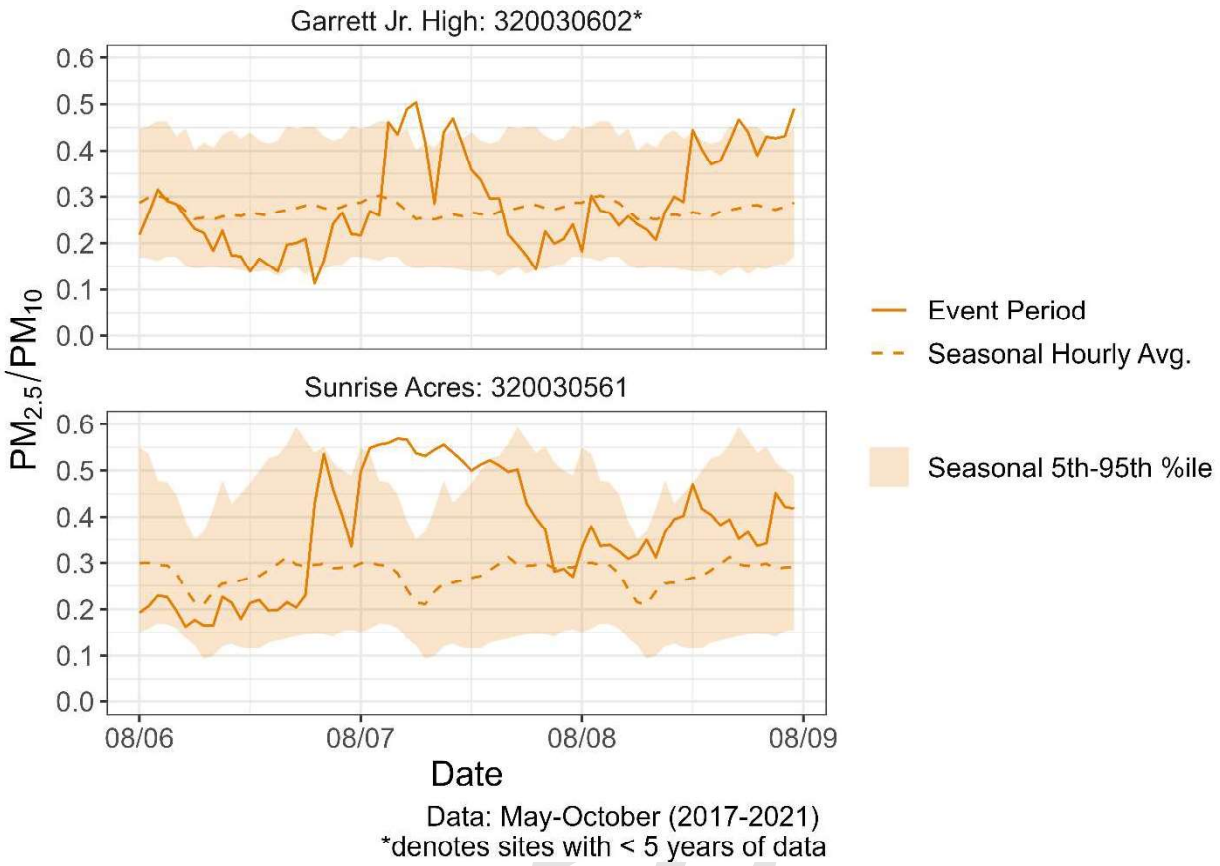

Figure 102. Ratio of $PM_{2.5}$-to-PM_{10} concentrations at all non-affected sites during the August 7 event period. The 5-yr average $PM_{2.5}$-to-PM_{10} diurnal ratio is displayed as a dotted line, and the 5th-95th percentile range is shown as a shaded ribbon. The 5th-95th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

The Las Vegas airport (KLAS) hourly METAR reports for August 7, 2021, also notes that smoke was present for 14 hours (Table 20). The METAR report additionally indicates that visibility was significantly impacted on this day due to smoke intrusion. Wind speeds were low (0-5 knots) at KLAS during this time, resulting in stagnant conditions favorable to smoke-influenced ozone production.

Table 20. Hourly METAR ASOS reports from KLAS for August 7, 2021. Smoke from denoted by the METAR code FU.

August 7 Time (UTC)	Wind Direction / Speed	Visibility (Sq. Miles)	Sky Condition
23:56	VRB / 05 KT	7	FU (SMOKE)
22:56	230 / 04 KT	6	FU (SMOKE)
21:56	200 / 03 KT	5	FU (SMOKE)
20:56	000 / 00 KT	4	FU (SMOKE)
19:56	000 / 00 KT	4	FU (SMOKE)
18:56	VRB / 06 KT	3	FU (SMOKE)
18:54	060 / 06 KT	3	FU (SMOKE)
17:56	010 / 07 KT	2	FU (SMOKE)
16:59	000 / 00 KT	2	FU (SMOKE)
16:56	070 / 03 KT	2	FU (SMOKE)
15:56	000 / 00 KT	2	FU (SMOKE)
15:03	000 / 00 KT	2 1/2	FU (SMOKE)
14:56	000 / 00 KT	3	FU (SMOKE)
13:56	000 / 00 KT	4	FU (SMOKE)

Additionally, data from the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO) over Clark County also shows a layer of smoke near the surface [1-4 km above ground level (AGL)] in the Las Vegas region (Figure 103).

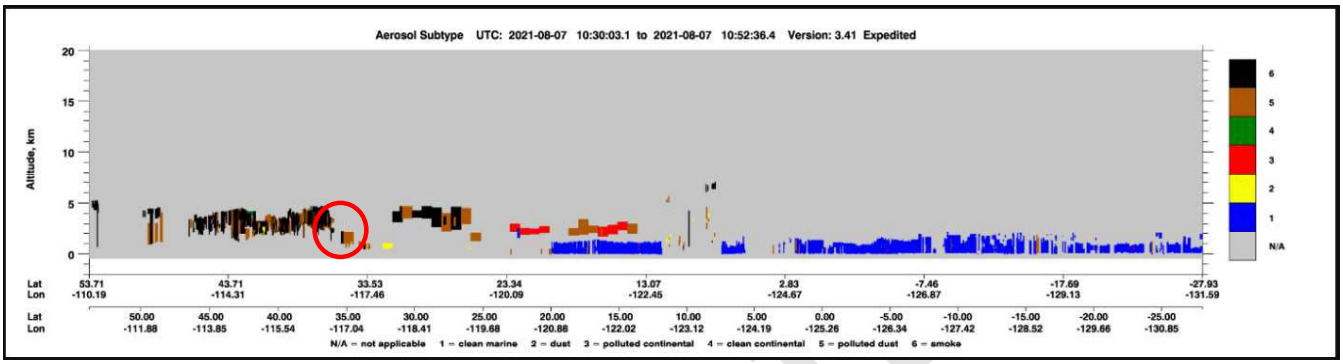

Figure 103. CALIPSO image on August 7, 2021. Black colors are defined as smoke and brown colors as polluted dust. The satellite detected a smoke layer near the Las Vegas region at an elevation of 1-4 km AGL. The red circle indicates Las Vegas (which is centered near 36.2, -115.2), with a smoke layer nearby.

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4.5.5 Event Statistics

Table 21 summarizes the daily measurements of ozone, $PM_{2.5}$, CO, and NO_2 concentrations on the exclusion day, as well as the percentile rank of the observation compared to the previous five years of data (2017-2021). On August 7, 2021, ozone MDA8 measurements were the highest recorded in the 5-yr period at eight out of 12 sites, and above the 99th percentile for the remaining four sites. 24-hr average $PM_{2.5}$ concentrations were similarly the highest recorded in the 5-yr period at nine out of 11 sites, and in the 99.9th percentile at the remaining two sites. CO 1-hr daily maximum concentrations ranged from the 74th-100th percentile. NO_2 1-hr daily maximum measurements were also enhanced, ranging from the 59th percentile at Joe Neal to ~85th percentile at the Jerome Mack-NCore and Walnut Community Center sites.

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Table 21. Percentile of pollutant measurements on the exclusion day compared with most recent five years* (2017-2021). The percentile rank is calculated across the ozone production season (May 1-October 31) of 2017-2021.

Date	Site Name	Site Code	Ozone		$PM_{2.5}$		CO		NO_2	
			Ozone MDA8 (ppb)	Percent Rank	$PM_{2.5}$ 24-hr Avg ($\mu g/m^3$)	Percent Rank	CO 1-hr Daily Max (ppb)	Percent Rank	NO_2 1-hr Daily Max (ppb)	Percent Rank
8/7/2021	Green Valley	320030298	84	100	36.6	99.9	641	99.3*	--	--
8/7/2021	Indian Springs	320037772	87	100	--	--	--	--	--	--
8/7/2021	Jean	320031019	73	99.2	36.6	99.9	--	--	--	--
8/7/2021	Jerome Mack-NCore	320030540	76	99.7	61.1	100	820	74.6	43.1	84.3
8/7/2021	Joe Neal	320030075	83	100	98.2	100*	768	100*	16.3	59
8/7/2021	Liberty High School	320030299	82	100*	37.2	100*	--	--	--	--
8/7/2021	Mountain's Edge	320030044	80	99.5*	49.2	100*	--	--	--	--
8/7/2021	Palo Verde	320030073	83	100	80.6	100*	--	--	--	--
8/7/2021	Paul Meyer	320030043	81	100	63.9	100	--	--	--	--
8/7/2021	Virgin Valley High School	320030024	73	100*	100.7	100*	--	--	--	--
8/7/2021	Walnut Comm. Center	320032003	79	100*	98.2	100*	700	88.2*	39.2	85.6*
8/7/2021	Walter Johnson	320030071	82	99.7	85.2	100*	--	--	--	--

*Sites that have less than five years of data available for a given parameter.

4.6 August 19, 2021

4.6.1 Event Summary

The unrepresentative ozone event took place on August 19, 2021, and affected five sites in Clark County, NV: Joe Neal, Palo Verde, Paul Meyer, Walnut Community Center, and Walter Johnson. Time series graphs showing hourly ozone concentrations exceeding the seasonal means (calculated using May 1 – October 31, 2017-2021) and 10th-90th percentiles at each site are shown in Figure 104.

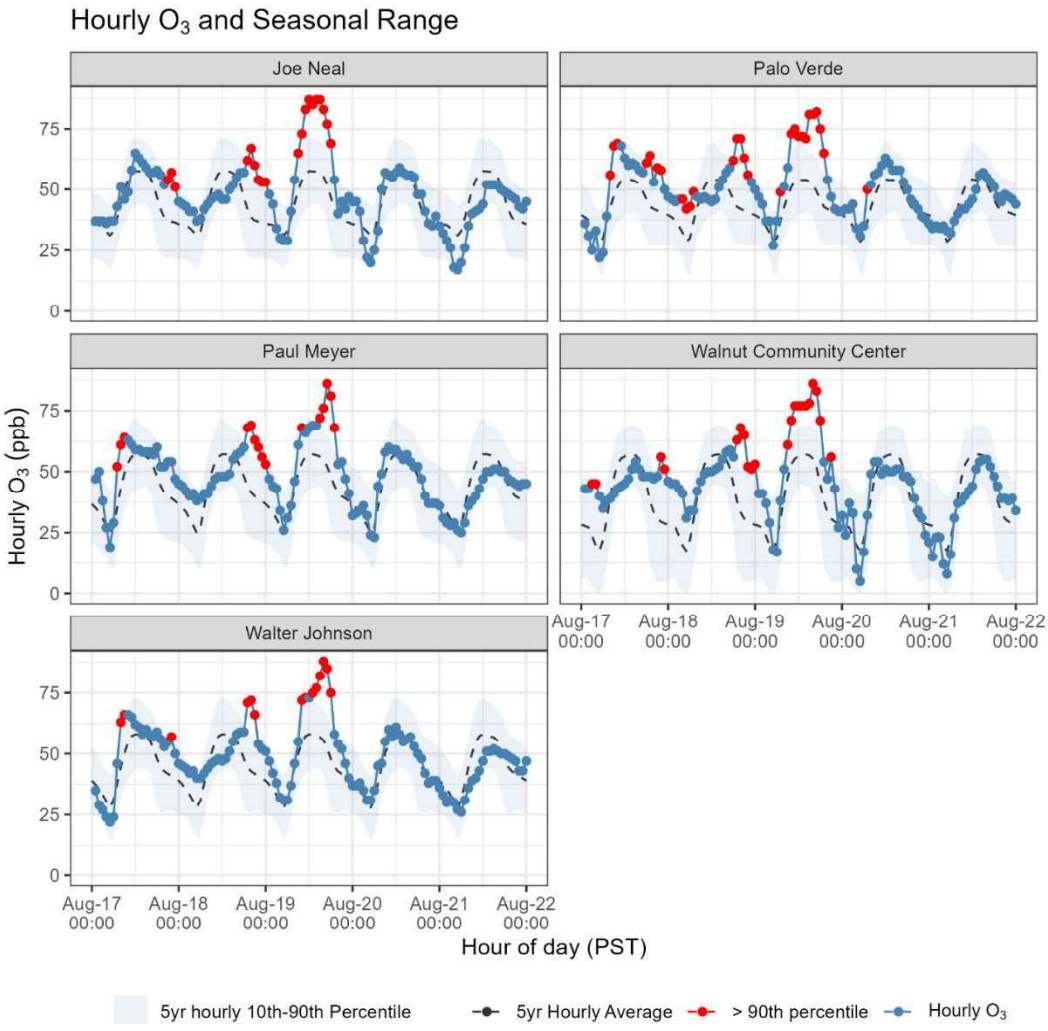

Figure 104. Hourly ozone concentrations (ppb) compared to 5-yr* ozone season (May 1-October 31) hourly means and 10th-90th percentiles. Note: data collected from the Walnut Community Center site is only available for June 1-October 31, 2021.

On August 18, hourly ozone concentrations exceeded the 90th percentile late in the day between 19:00-23:00 PST, and throughout August 19 from 09:00 to 19:00 PST. The MDA8 concentrations at affected sites ranged from 73-82 ppb: 82 ppb at the Joe Neal site, 78 ppb at the Walnut Community Center and Walter Johnson sites, 76 ppb at the Palo Verde site, and 73 ppb at the Paul Meyer site.

An abundance of regional, widespread smoke from at least 12 wildfires was identified as a major contributor to this event. Evidence includes (1) HYSPLIT dispersion modeling indicating the presence of smoke accumulation in Clark County, (2) remote sensing imagery and HMS smoke boundaries showing smoke over Clark County, (3) elevated concentrations of ground-level $PM_{2.5}$, CO, and NO_2, as well as enhanced $PM_{2.5}$-to-PM_{10} ratios that aligned with elevated ozone levels. Hourly $PM_{2.5}$ concentrations were three times higher than the 5-yr 90th percentile range, and smoke was visible in ground-based visibility camera and satellite imagery. The combination of this evidence and the results of dispersion modeling strongly indicate that this is an unrepresentative event for assessing base and future ozone design values.

4.6.2 Identification of Wildfires

Numerous wildfires throughout the western U.S. and Canada were actively burning on August 19, 2021, the exclusion day, and contributed to widespread regional smoke. Active wildfires were identified in California, Oregon, and Washington (Figure 105 and Figure 106). Regional smoke from these fires is present during mid-August 2021 throughout the western U.S., and this was verified for the days of August 17-19 based on smoke and wildfire detection geodata provided by the NOAA HMS (Figure 107). Table 22 lists the state location, total acres within the fire perimeter, actively burning acres on the exclusion day, and the start and containment dates for each fire based on data from the WFIGS Current Interagency Fire Perimeters, and the Satellite Fire Occurrence and Growth database.[14]

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[14] McClure et al. (2023) Consistent, high-accuracy mapping of daily and sub-daily wildfire growth with satellite observations. International Journal of Wildland Fire 32, 694-708. Available at https://www.publish.csiro.au/wf/ExportCitation/WF22048.

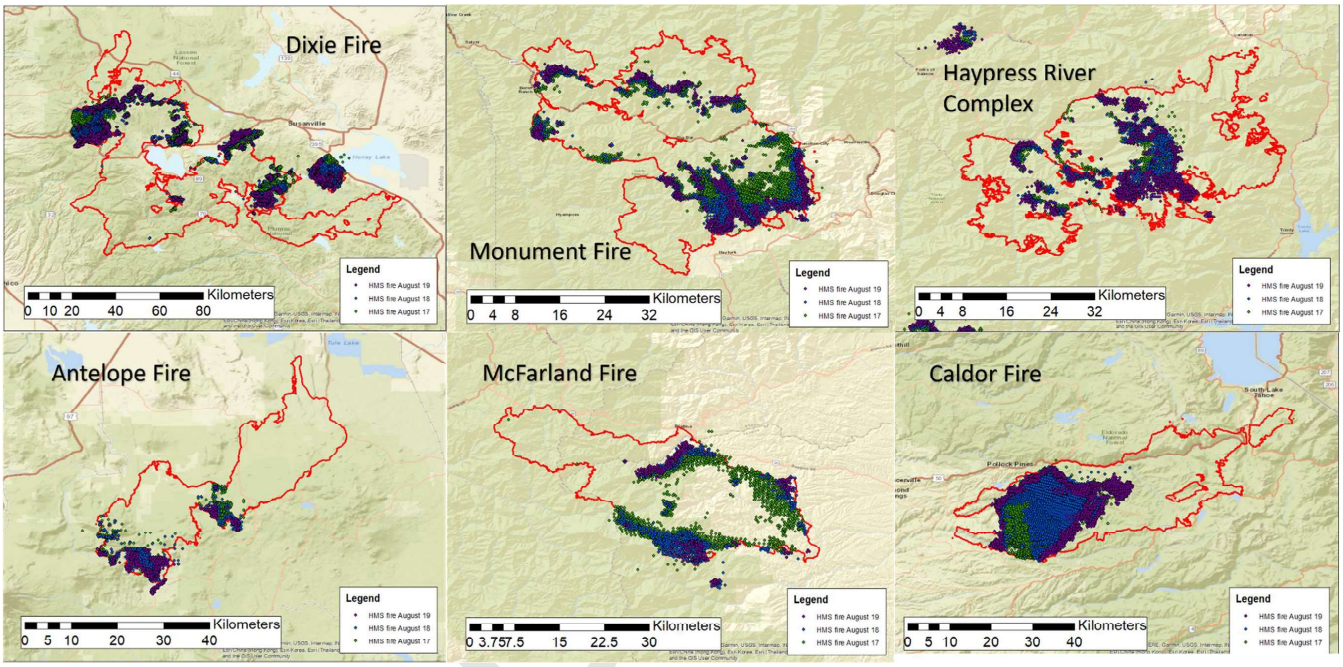

Figure 105. Final fire perimeters (red) and HMS fire detections for the Dixie, Monument, Haypress River Complex, Antelope, McFarland, and Caldor Fires during August 17-19, 2021.

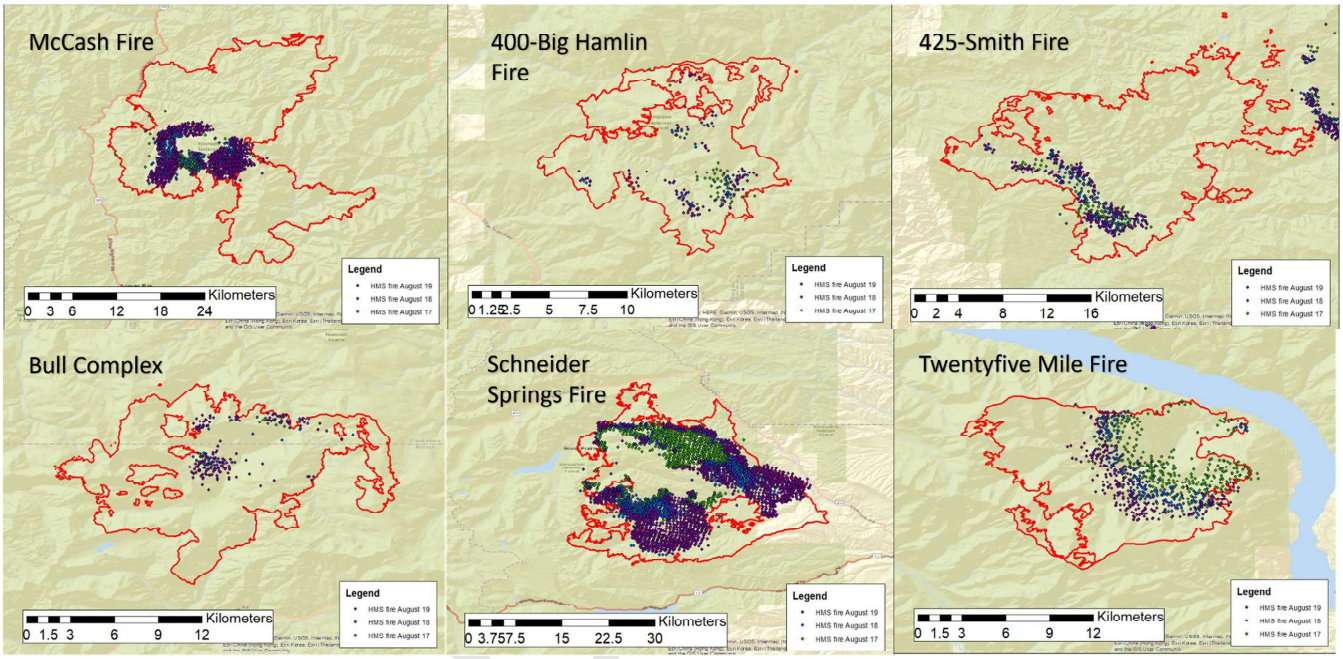

Figure 106. Final fire perimeters (red) and HMS fire detections for the McCash, Big Hamlin, Smith, Bull Complex, Schneider Springs, and Twentyfive Mile Fires during August 17-19, 2021.

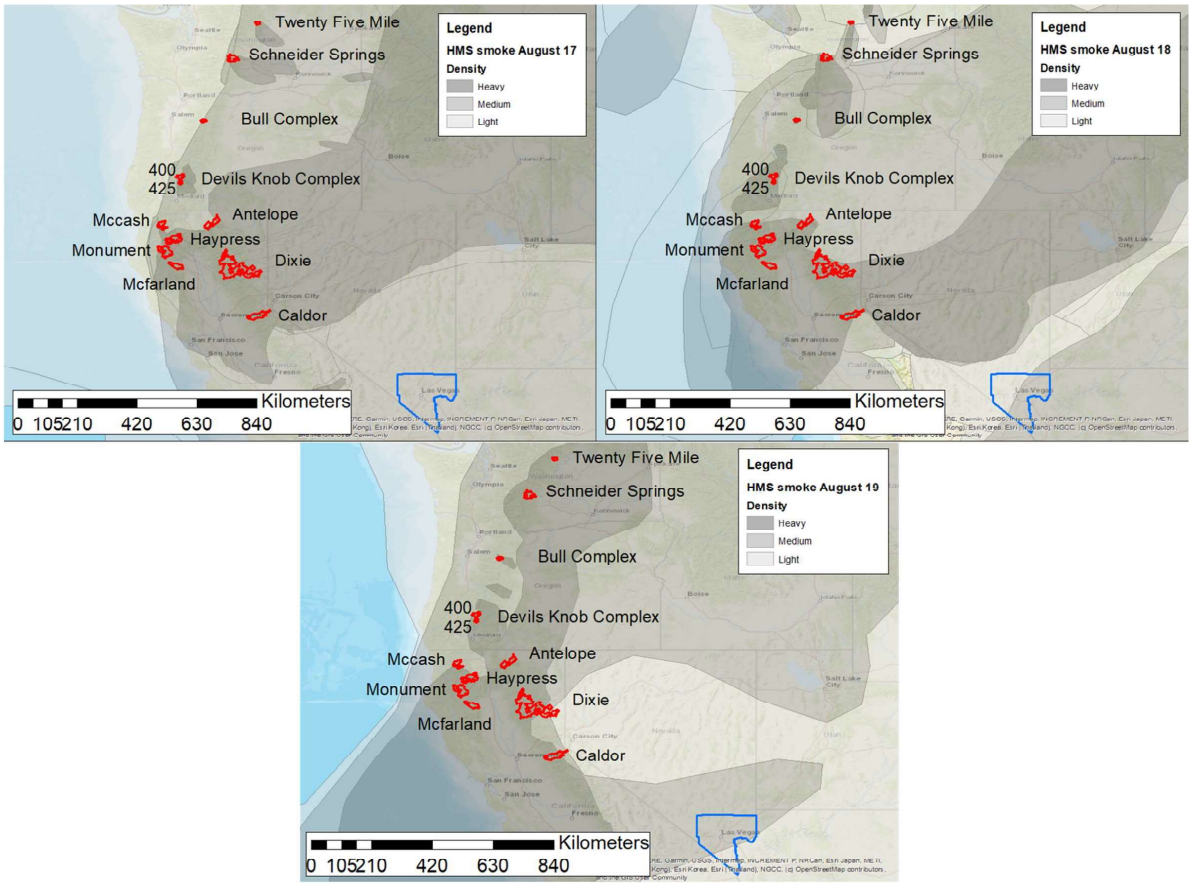

Figure 107. HMS smoke boundaries for August 17-19, 2021, is included with qualitative smoke density. Fire perimeters from the major fires contributing to the exclusion date are shown in red and the Clark County, NV, boundary is shown in blue.

Table 22. Wildfires affecting Clark County on the exclusion day. Where active areas are not available, cumulative acres burned are listed in italics.

Wildfire Name	State	Total Acres	Active Acres August 19	Start Date	Containment Date
Dixie	California	963,405	59,497	July 14	October 15
Monument	California	223,124	24,756	July 31	October 20
Haypress River Complex	California	199,343	25,279	July 31	October 25
Antelope	California	145,632	9,833	August 1	October 14
McFarland	California	122,653	6,331	July 30	September 16
Caldor	California	221,835	28,878	August 15	NA
McCash	California	94,962	10,264	August 1	October 27
400-Big Hamlin (Devils Knob Cpx)	Oregon	19,377	16,923[15]	August 7	NA
425-Smith (Devils Knob Cpx)	Oregon	49,238	4,037[15]	August 2	NA
Bull Complex	Oregon	24,894	5,761[16]	August 1	NA
Schneider Springs	Washington	107,353	56,422[17]	August 4	November 3
Twentyfive Mile	Washington	22,290	9,800[18]	August 15	October 19

4.6.3 Dispersion Modeling and Regional Analysis

HYSPLIT dispersion modelling was performed for August 16 through 19, 2021. Dispersion was initiated at 19:00 PST from each of the 12 actively burning fires impacting the exclusion date, August 19, 2021. GDAS 1.0° data horizontal resolution was used for meteorological input. Output from the dispersion modeling was integrated over a 24-hr period, from August 18 at 19:00 PST through August 19 at 19:00 PST. The accumulation of smoke at 0-100 m for the 24-hr period is shown in Figure 108.

The HYSPLIT dispersion modeling shows that smoke from multiple fires in California, Oregon, and Washington produced a dense layer of smoke that blanketed the western U.S. region, including Clark

[15] https://www.nrtoday.com/news/environment/wildfires/devils-knob-rough-patch-complexes-see-significant-growth-wednesday/article_27af1da7-405e-589e-a99c-53588b50ab70.html
[16] https://www.statesmanjournal.com/story/news/2021/08/18/oregon-wildfires-bull-complex-janus-butte-fire/8188419002/
[17] https://www.fox13seattle.com/news/level-3-evacuations-ordered-at-schneider-springs-fire
[18] https://lakechelannow.com/fire-update/

County, NV. The modeling results are consistent with the HMS smoke plume (shown in gray in Figure 108); HMS is an independent smoke identification database. The dispersion results indicate smoke from multiple fires reached Clark County, NV, on August 19, 2021, and that the smoke was present in the lower mixed layer, impacting surface conditions.

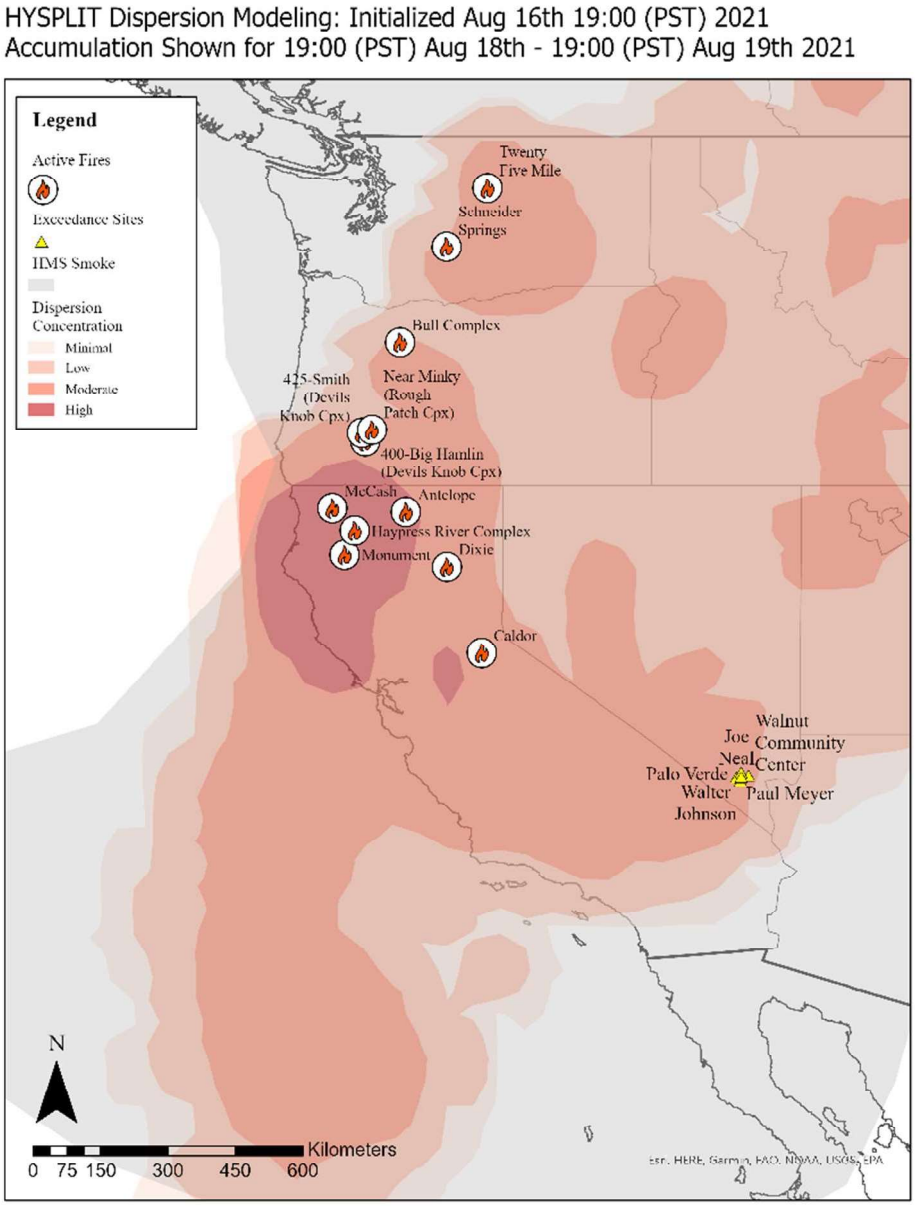

Figure 108. HYSPLIT dispersion modeling for 12 large fires (labeled as "Active Fires") throughout the western U.S. GDAS 1.0° meteorological data was used, and dispersion was initiated on August 16, 2021, at 19:00 PST to model the regional smoke observed in satellite and HMS products. HMS smoke is shown in gray and qualitative concentrations of particulate matter are shown in shades of red. Accumulation of particulate matter is shown at 0-100 m for 19:00 PST on August 18 through 19:00 PST on August 19, 2021.

MODIS Aqua visible satellite imagery confirms the extent of regional smoke shown in the dispersion modeling on August 19. Figure 109 shows regional smoke from the large California fires extending below the California Central Valley into southern Nevada, and directly affecting Clark County, NV.

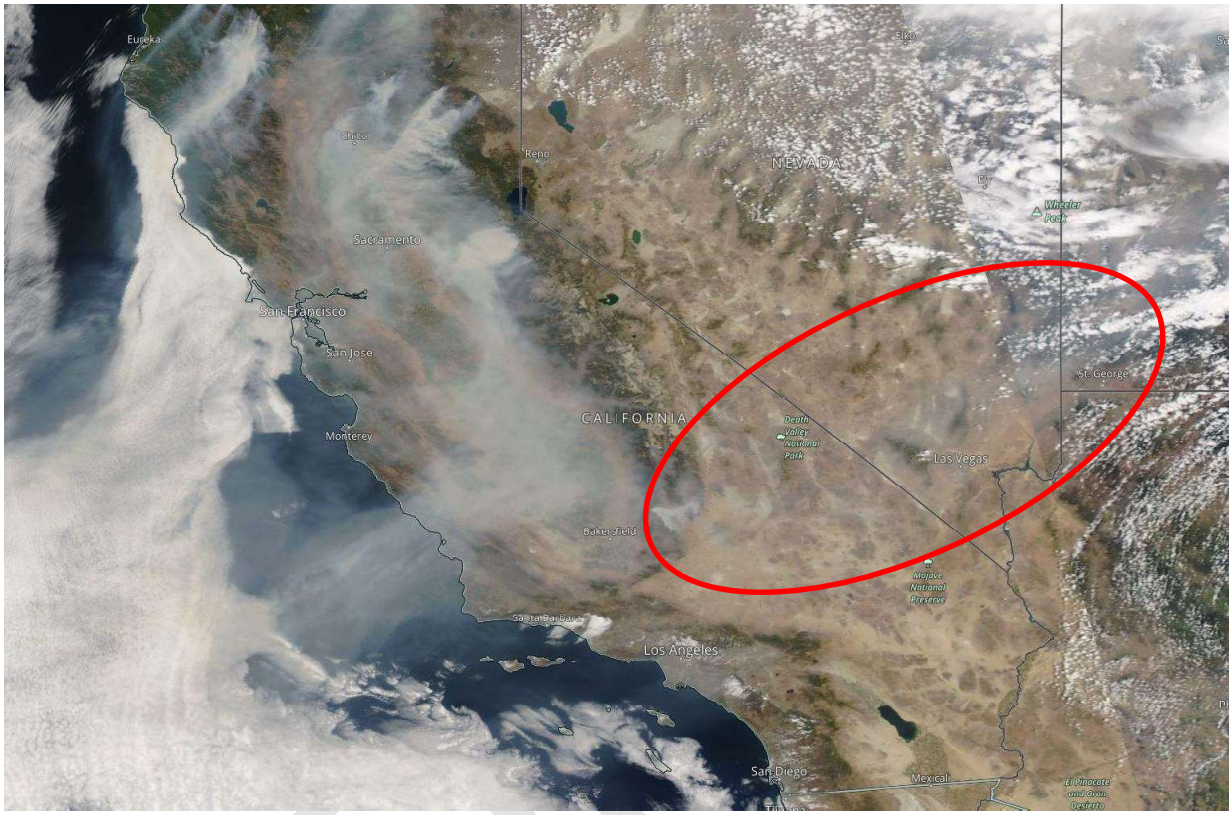

Figure 109. MODIS Aqua satellite image valid on August 19, 2021. Smoke from California wildfires is visible across central and southern Nevada. This smoke contributed to poor air quality and reduced visibility in Clark County. The red circle shows the area of smoke over Clark County.

4.6.4 Surface Impacts

The presence of wildfire smoke during the exclusion date is evident by comparing the morning time visibility conditions on August 18, 2021 (Figure 110), to the same time period on the exclusion date of August 19 (Figure 111). Local and regional smoke from the fires identified in Section 4.6.2 is visible in Clark County at 09:00 LST (09:00 PST) on August 19, when ozone photochemical production typically starts to accelerate. The local and regional smoke is an atypical influence on ozone and ozone precursors in the Clark County area and caused atypical ozone concentrations on the exclusion date. This is consistent with the Las Vegas (KLAS) hourly METAR reports for August 19 (Table 23), which noted smoke was present over several hours, as well as haze and reduced visibility as a result of smoke intrusion. The METAR also shows wind speeds were low at KLAS, which is favorable for ozone production with smoke intrusion.

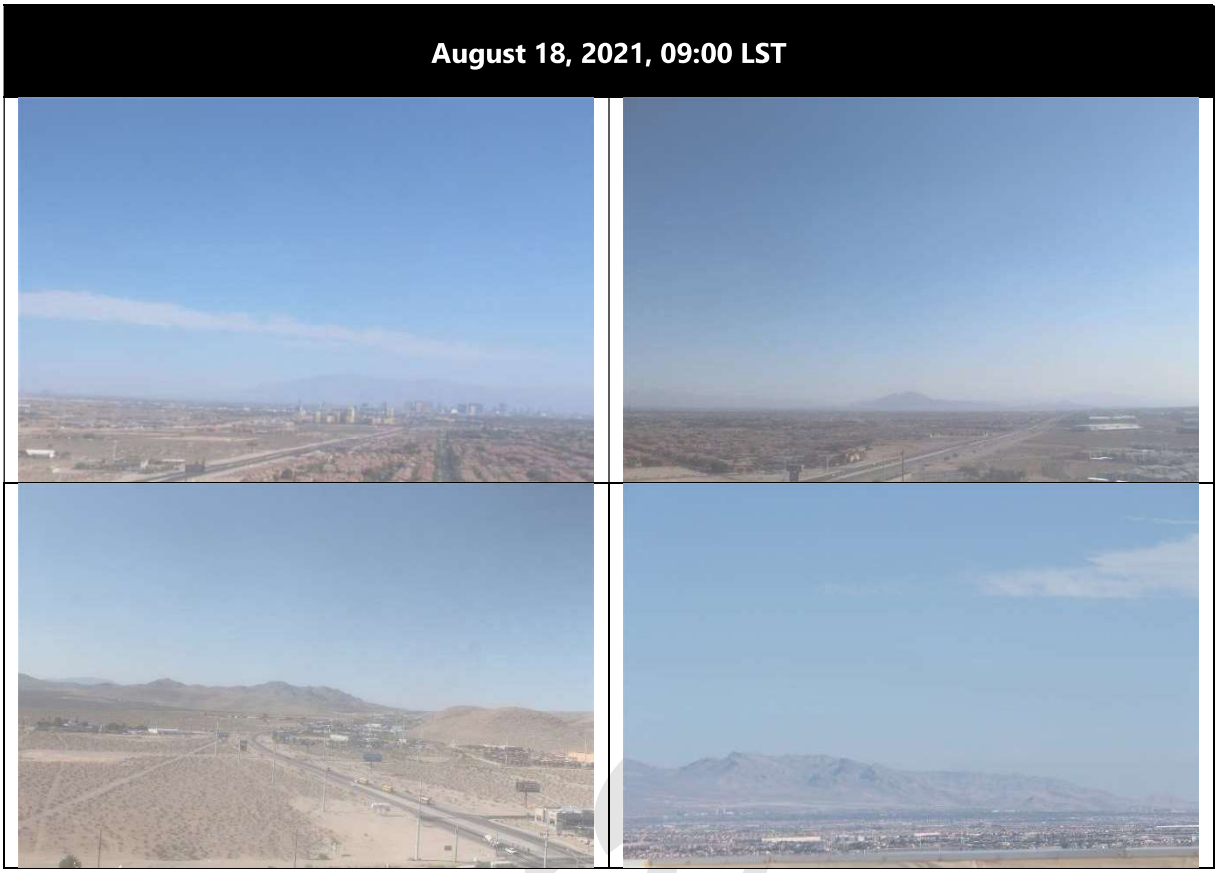

Figure 110. Camera images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions, taken from the M Resort Hotel in Clark County, NV, on August 18, 2021, at 09:00 LST.

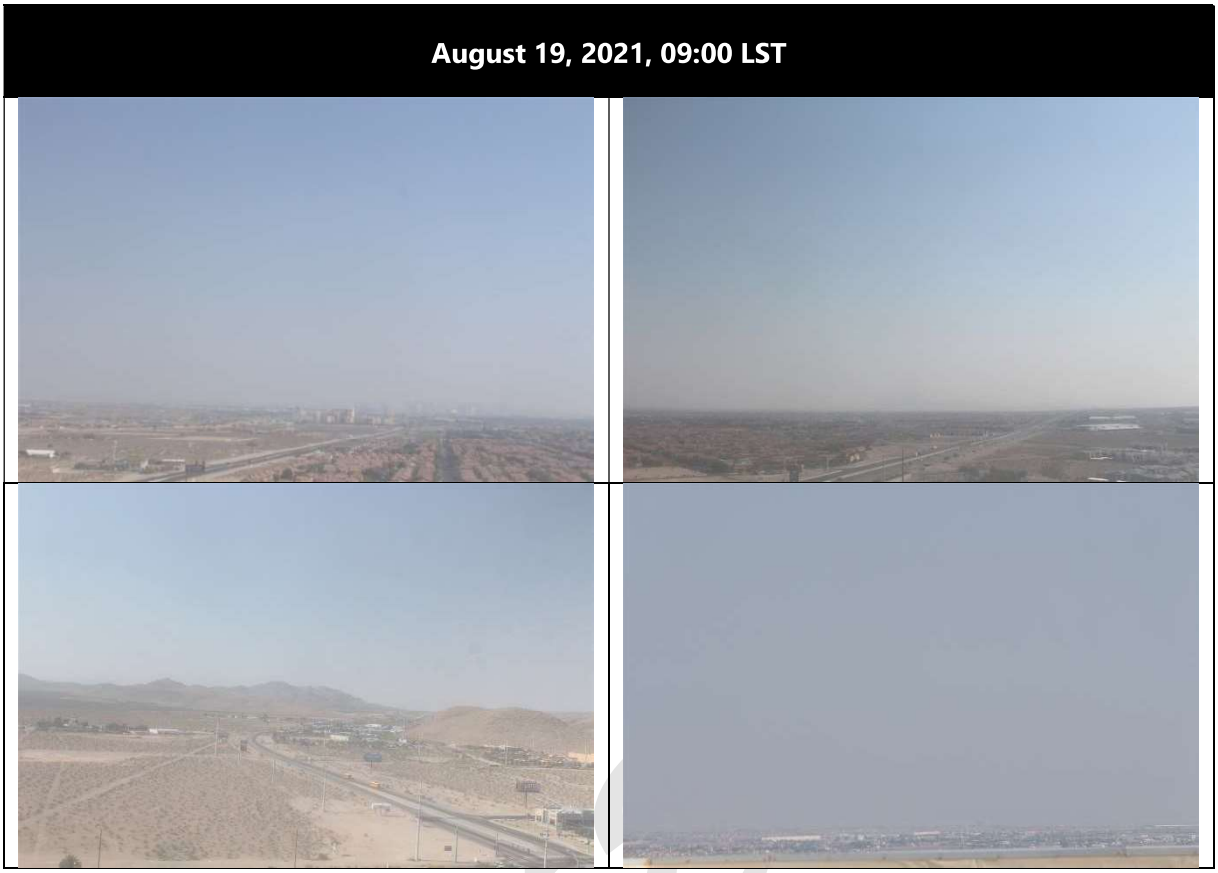

Figure 111. Camera images for north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions, taken from the M Resort Hotel in Clark County, NV, on August 19, 2021, at 09:00 LST.

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Table 23. KLAS hourly METAR reports for August 19, 2021, between 09:00-23:00 UTC. During this period, the METAR remarks noted "FU" (meaning Smoke) in the Sky observations field.

August 19 Time (UTC)	Wind Direction / Speed	Visibility (Sq. Miles)	Sky Conditions
08:56	030 / 07 KT	9 SM	FU (SMOKE)
09:56	060 / 05 KT	7 SM	FU (SMOKE)
10:56	100 / 03 KT	7 SM	FU (SMOKE)
11:56	000 / 00 KT	9 SM	FU (SMOKE)
12:56	280 / 05 KT	9 SM	FU (SMOKE)
13:56	210 / 03 KT	8 SM	FU (SMOKE)
14:56	190 / 03 KT	8 SM	FU (SMOKE)
15:56	000 / 00 KT	8 SM	FU (SMOKE)
16:56	VRB / 03 KT	9 SM	FU (SMOKE)
17:56	VRB / 04 KT	10 SM	
18:56	230 / 03 KT	10 SM	
19:56	190 / 06 KT	8 SM	FU (SMOKE)
20:56	240 / 05 KT	9 SM	FU (SMOKE)
21:56	240 / 05 KT	8 SM	FU (SMOKE)
22:56	VRB / 06 KT	8 SM	FU (SMOKE)
23:56	000 / 00 KT	7 SM	FU (SMOKE)

The presence of surface-level wildfire smoke on August 19 is also indicated by enhanced $PM_{2.5}$, CO, and NO_2 concentrations. $PM_{2.5}$ concentrations compared to the diurnal 10th-90th percentile $PM_{2.5}$ concentrations are shown for affected sites in Figure 112. Hourly $PM_{2.5}$ concentrations exceeded 65 µg/m^3 in Clark County on August 19, far exceeding the diurnal 90th percentile $PM_{2.5}$ concentrations at all sites that exceeded the Ozone NAAQS. The diurnal 10th-90th percentile range is calculated across five years (2017-2021) during the ozone season (May-October).

Concurrently, CO concentrations at the Joe Neal site exceeded the diurnal 90th percentile concentration throughout the day on August 19 (Figure 113). Figure 114 shows that morning time NO_2 concentrations also rose above the diurnal 90th percentile during the exclusion date.

Synchronous enhancement of $PM_{2.5}$, CO, and NO_2 concentrations on the exclusion date provides strong evidence that wildfire smoke was present in Clark County and acted as an atypical influence on ozone production.

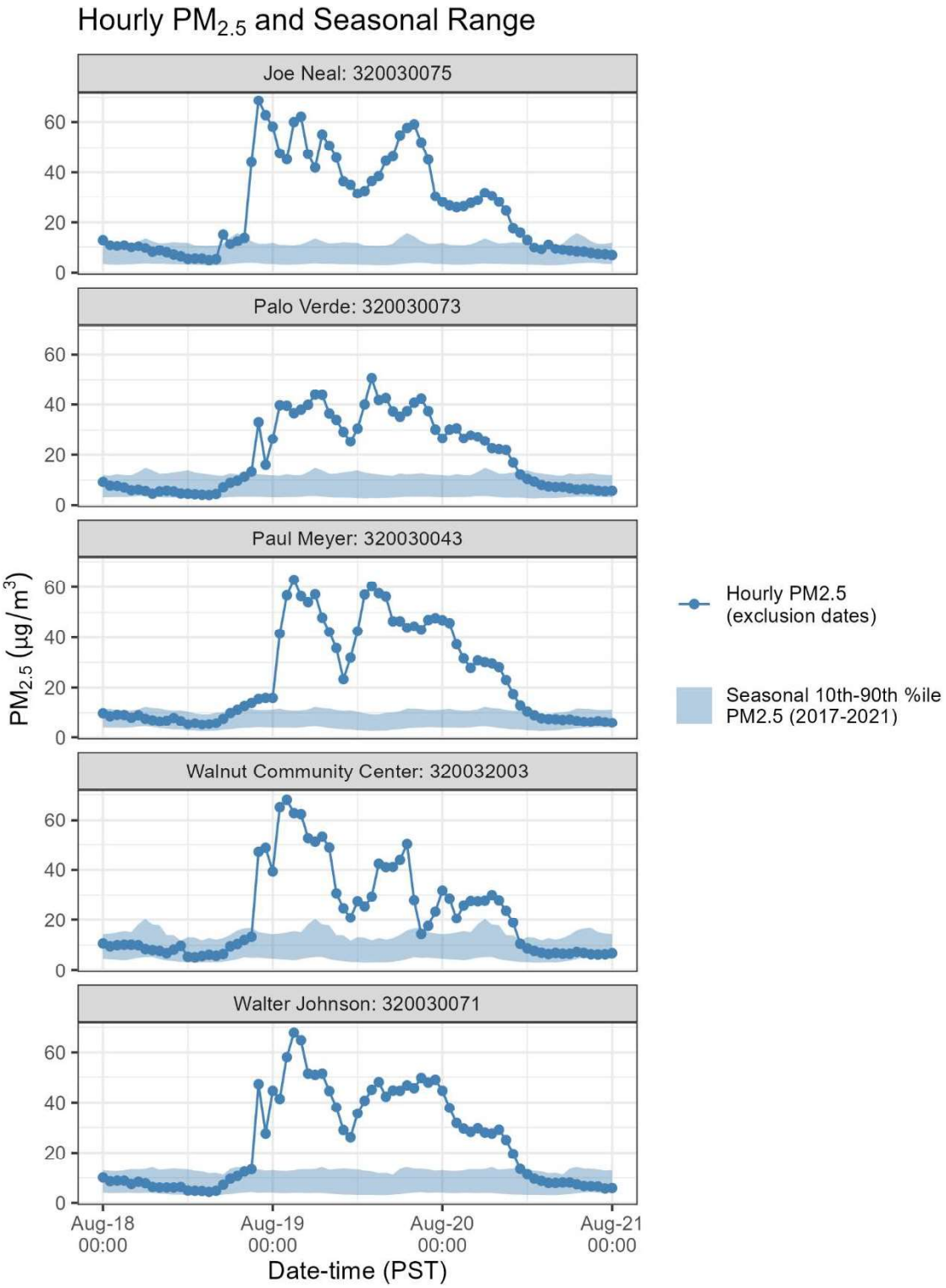

Figure 112. Hourly $PM_{2.5}$ measurements overlaid on the 10th-90th percentile diurnal concentration at affected sites that measure $PM_{2.5}$. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

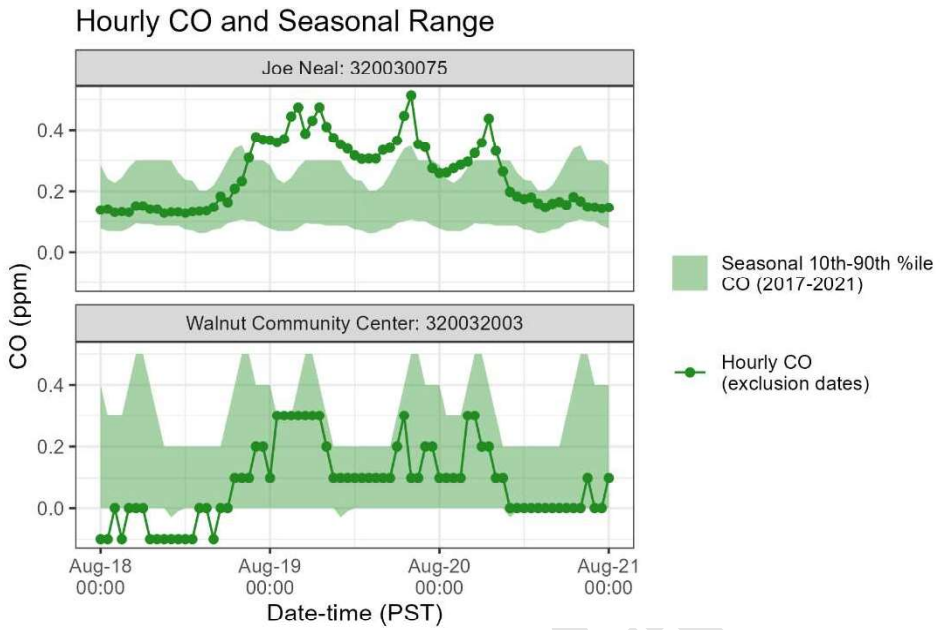

Figure 113. Hourly CO measurements overlaid on the 10th-90th percentile diurnal concentration at affected sites that measure CO. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

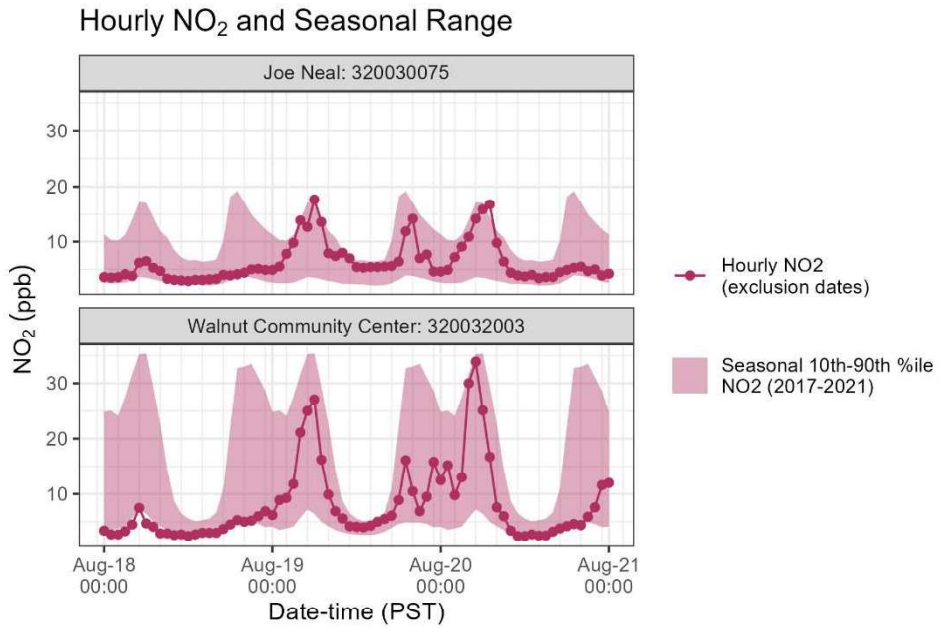

Figure 114. Hourly NO_2 measurements overlaid on the 10th-90th percentile diurnal concentration at affected sites that measure NO_2. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

The ratio of $PM_{2.5}$-to-PM_{10} concentrations was also examined to determine if wildfire smoke entered Clark County on or before the exclusion dates. Increases in this ratio are indicative of wildfire smoke.

Figure 115 and Figure 116 show time series of the $PM_{2.5}$-to-PM_{10} ratio from August 18 through August 20, compared to the ozone season mean and 5th-95th percentile range for available data between 2017-2021 at all affected sites (Figure 115) and non-affected regional sites (Figure 116). Ratios at all sites were generally at or below average during the day on August 18, then exceeded the 95th percentile during the late evening of August 18 and morning and day of August 19. Ratios at all sites exceeded 0.6 in the early morning of August 19, remained elevated throughout the day, and slowly declined over the following day (August 20). A similar pattern is present at other sites throughout Clark County (Figure 116). These observations provide evidence that wildfire smoke entered Clark County in the late evening of August 18 and early morning of August 19, containing enhanced $PM_{2.5}$-to-PM_{10} ratios immediately prior to and during the atypical ozone events that occurred on August 19.

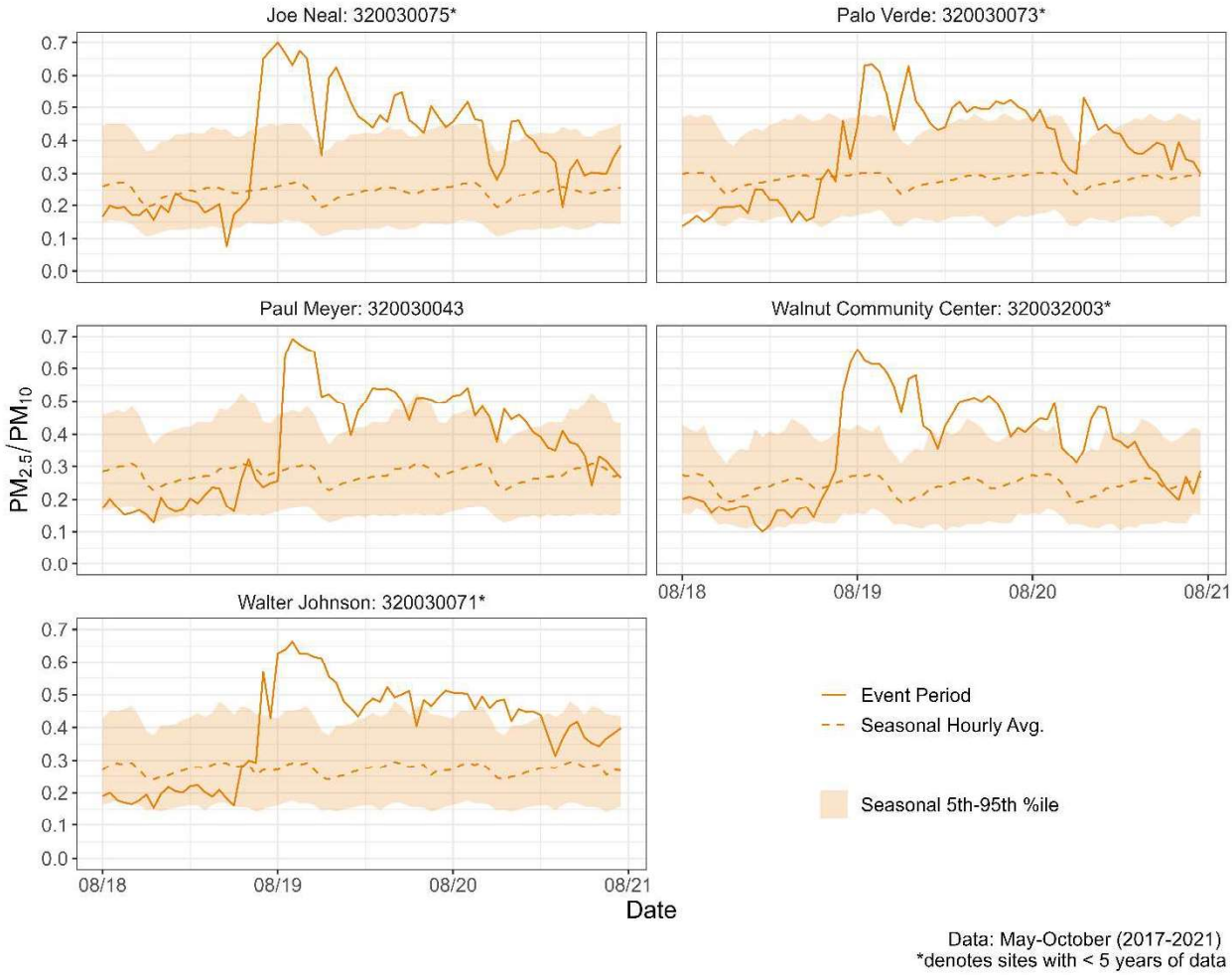

Figure 115. Ratio of $PM_{2.5}$-to-PM_{10} concentrations at the affected sites during the August 19 event period. The 5-yr average $PM_{2.5}$-to-PM_{10} diurnal ratio is displayed as a dotted line, and the 5th-95th percentile range is shown as a shaded ribbon. The 5th-95th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

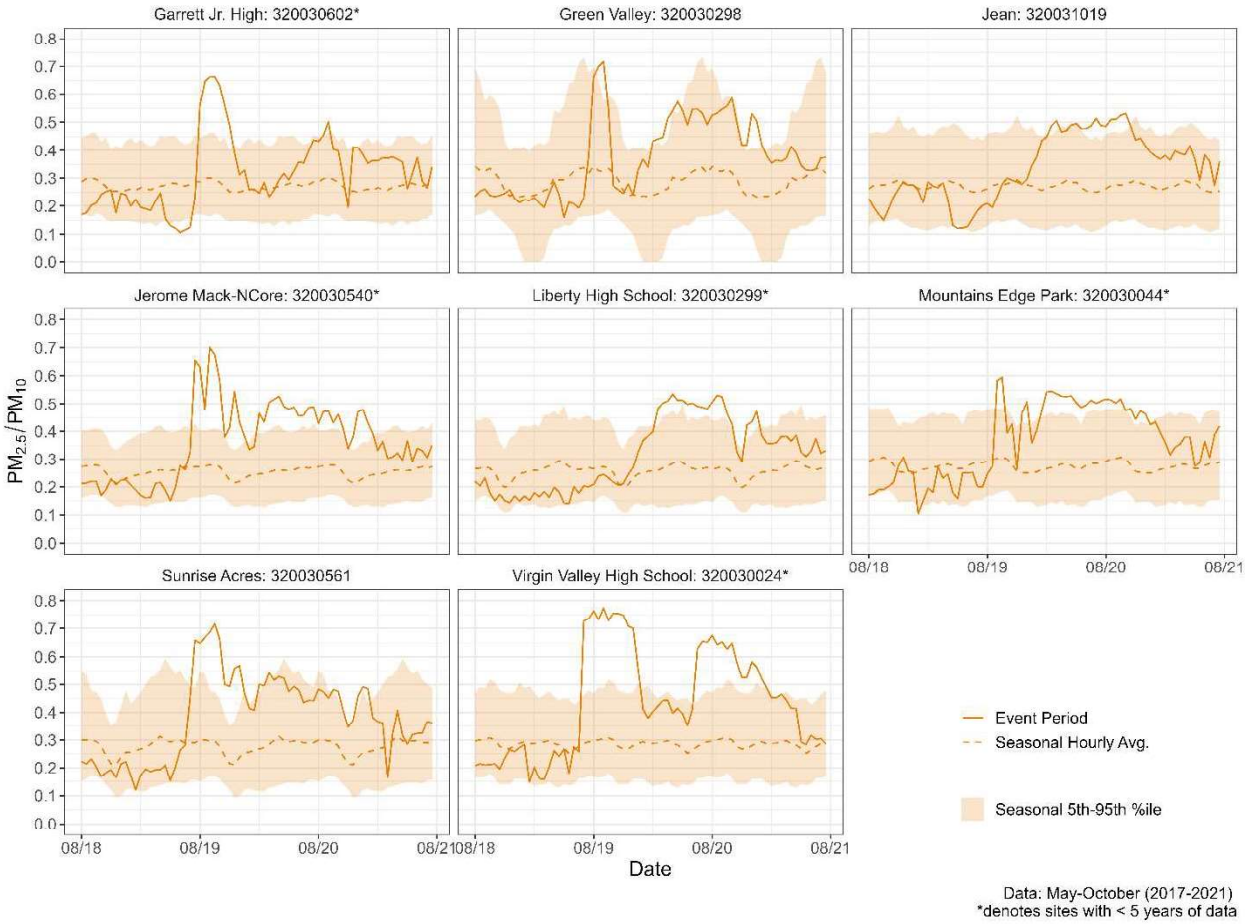

Figure 116. Ratio of $PM_{2.5}$-to-PM_{10} concentrations at the affected sites during the August 19 event period. The 5-yr average $PM_{2.5}$-to-PM_{10} diurnal ratio is displayed as a dotted line, and the 5th-95th percentile range is shown as a shaded ribbon. The 5th-95th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

4.6.5 Event Statistics

Table 24 summarizes the daily measurements of ozone, $PM_{2.5}$, CO, and NO_2 concentrations on the exclusion day, as well as the percentile rank of the observation compared to the previous five years of data (2017-2021). On August 19, 2021, ozone MDA8 measurements were above the 99th percentile for three out of the five sites, and above the 97th percentile for the remaining two sites. 24-hr average $PM_{2.5}$ measurements were above the 99th percentile at all sites, and 1-hr daily maximum measurements were elevated for CO (97th percentile) and NO_2 (67th percentile) at the Joe Neal site and lower at the Walnut Community Center site.

Table 24. Percentile of pollutant measurements on the exclusion day compared with most recent five years* (2017-2021). The percentile rank is calculated across the ozone production season (May 1-October 31) of 2017-2021.

Date	Site Name	Site Code	Ozone		$PM_{2.5}$		CO		NO_2	
			Ozone MDA8 (ppb)	Percent Rank	$PM_{2.5}$ 24-hr Avg ($\mu g/m^3$)	Percent Rank	CO 1-hr Daily Max (ppb)	Percent Rank	NO_2 1-hr Daily Max (ppb)	Percent Rank
8/19/2021	Paul Meyer	320030043	73	97.6	46.5	99.8	--	--	--	--
8/19/2021	Walter Johnson	320030071	78	99.2	46.1	99.7*	--	--	--	--
8/19/2021	Palo Verde	320030073	76	99.4	37.4	99.5*	--	--	--	--
8/19/2021	Joe Neal	320030075	82	99.9	46.4	99.9*	512	97.1*	17.7	66.9
8/19/2021	Walnut Comm. Center	320032003	78	98.7*	40.2	99.3*	300	32.7*	27.1	45.1*

*Sites that have less than five years of data available for a given parameter.

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4.7 September 8, 2021

4.7.1 Event Summary

The unrepresentative ozone event took place on September 8, 2021, and affected two sites in Clark County, Nevada: Palo Verde and Walter Johnson. The MDA8 concentrations were 71 ppb at Palo Verde and 73 ppb at Walter Johnson. Time series showing hourly ozone concentrations compared to the 5-yr seasonal means and 10th-90th percentiles (calculated using May 1-October 31, 2017-2021) at each site are shown in Figure 117.

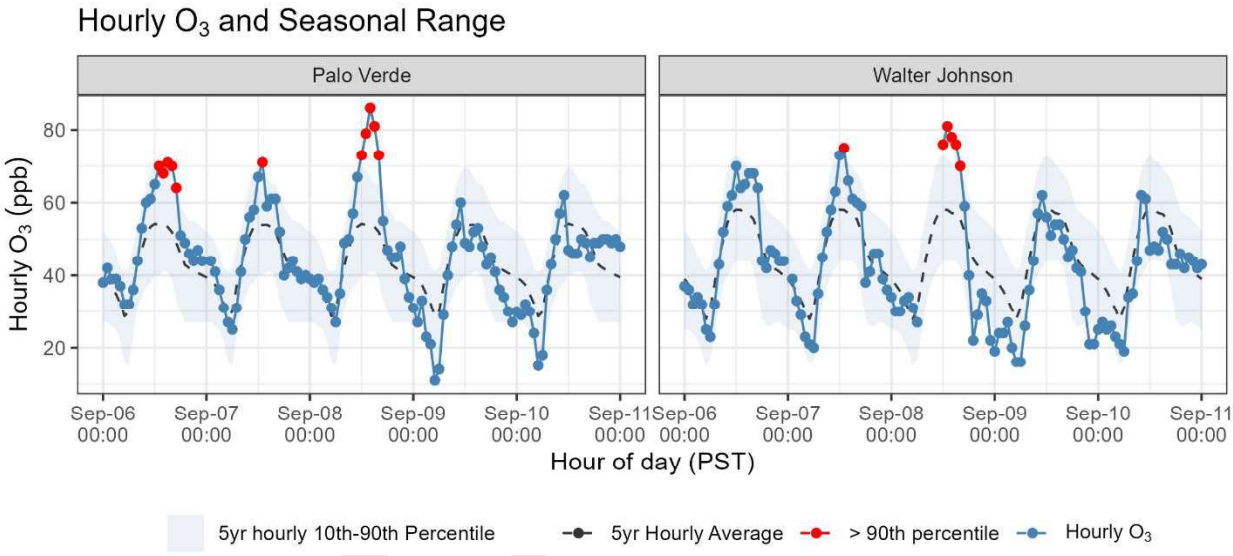

Figure 117. Hourly ozone concentrations (ppb) compared to 5-yr ozone season (May 1-October 31, 2017-2021) hourly means and 10th-90th percentiles.

Midday peaks began exceeding the 5-yr mean on September 5 and returned to normal values on September 9, 2021. On September 8, hourly ozone measurements exceeded the 5-yr 90th percentile at both sites from as early as 09:00 to 16:00 PST. Hourly ozone measurements were not available on September 8 from 07:00-11:00 PST at the Walter Johnson site.

Regional wildfire smoke likely influenced this event: in early September there were 13 active wildfires potentially contributing, with 150,000 acres actively burning in California alone. HYSPLIT back trajectories and dispersion modeling connect smoke plumes from these fires to surface conditions in Clark County. Additional evidence includes a reduction in visibility observed in ground-based images and elevated ground-based $PM_{2.5}$, CO, NO_2, and $PM_{2.5}$-to-PM_{10} ratio measurements. The combination of evidence indicates that this is an unrepresentative event for assessing base and future ozone design values.

4.7.2 Identification of Wildfires

Numerous active wildfires were identified throughout the western U.S. and Canada on September 8, 2021, the exclusion day (Figure 118 and Figure 119). Regional smoke from these fires was present during early September 2021 throughout the western U.S., and this was verified for the days of September 6-8 through visualization of smoke and wildfire detection geodata provided by the NOAA HMS (Figure 120). Table 25 lists the state location, total acres within the fire perimeter, actively burning acres on the exclusion day, and the start and containment dates for each fire based on data from the WFIGS Current Interagency Fire Perimeters and the Satellite Fire Occurrence and Growth database.[19]

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[19] McClure et al. (2023) Consistent, high-accuracy mapping of daily and sub-daily wildfire growth with satellite observations. International Journal of Wildland Fire 32, 694-708. Available at https://www.publish.csiro.au/wf/ExportCitation/WF22048.

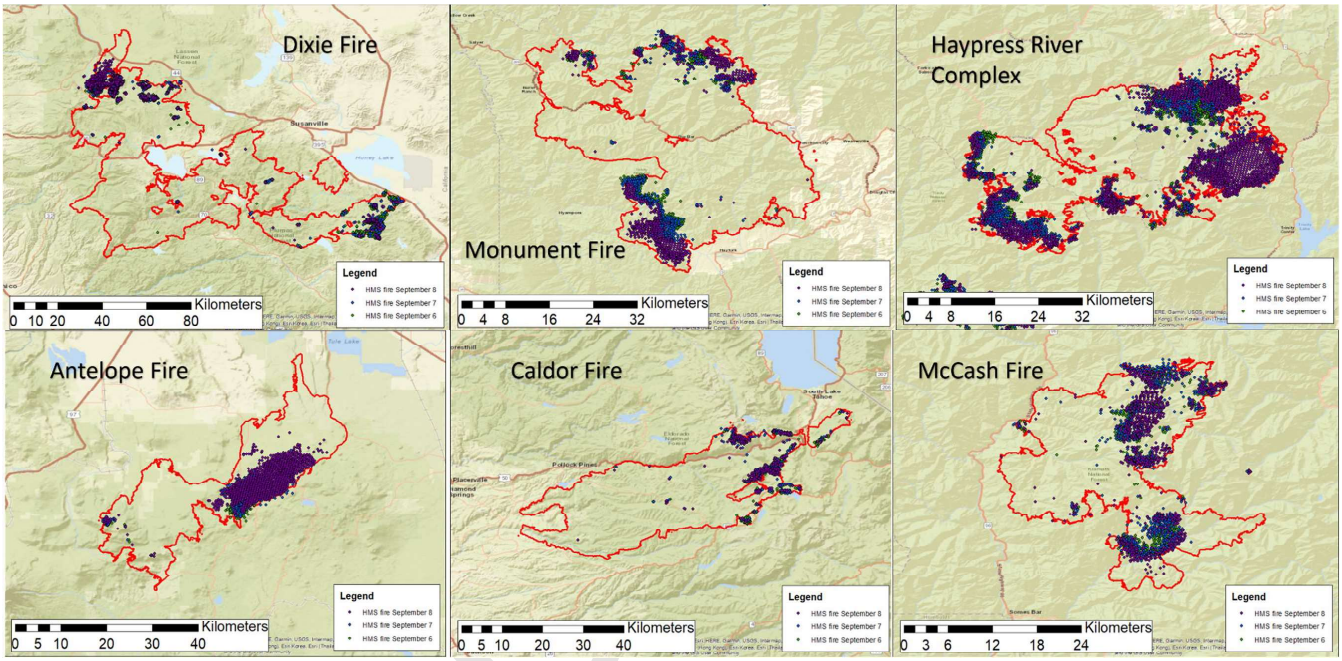

Figure 118. Final fire perimeters (red) and HMS fire detections for the Dixie, Monument, Haypress River Complex, Antelope, Caldor, and McCash Fires during September 6-8, 2021.

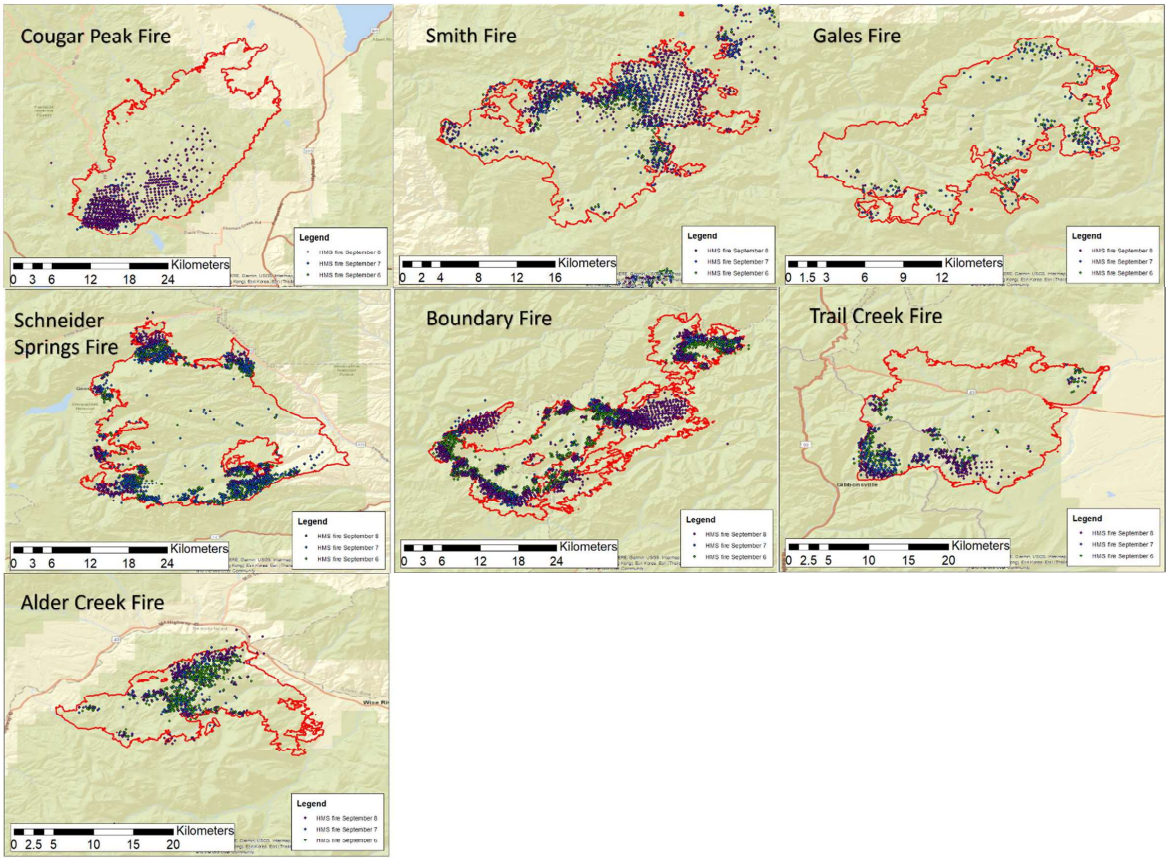

Figure 119. Final fire perimeters (red) and HMS fire detections for the Cougar Peak, Smith, Gales, Schneider Springs, Boundary, Trail Creek, and Alder Creek Fires during September 6-8, 2021.

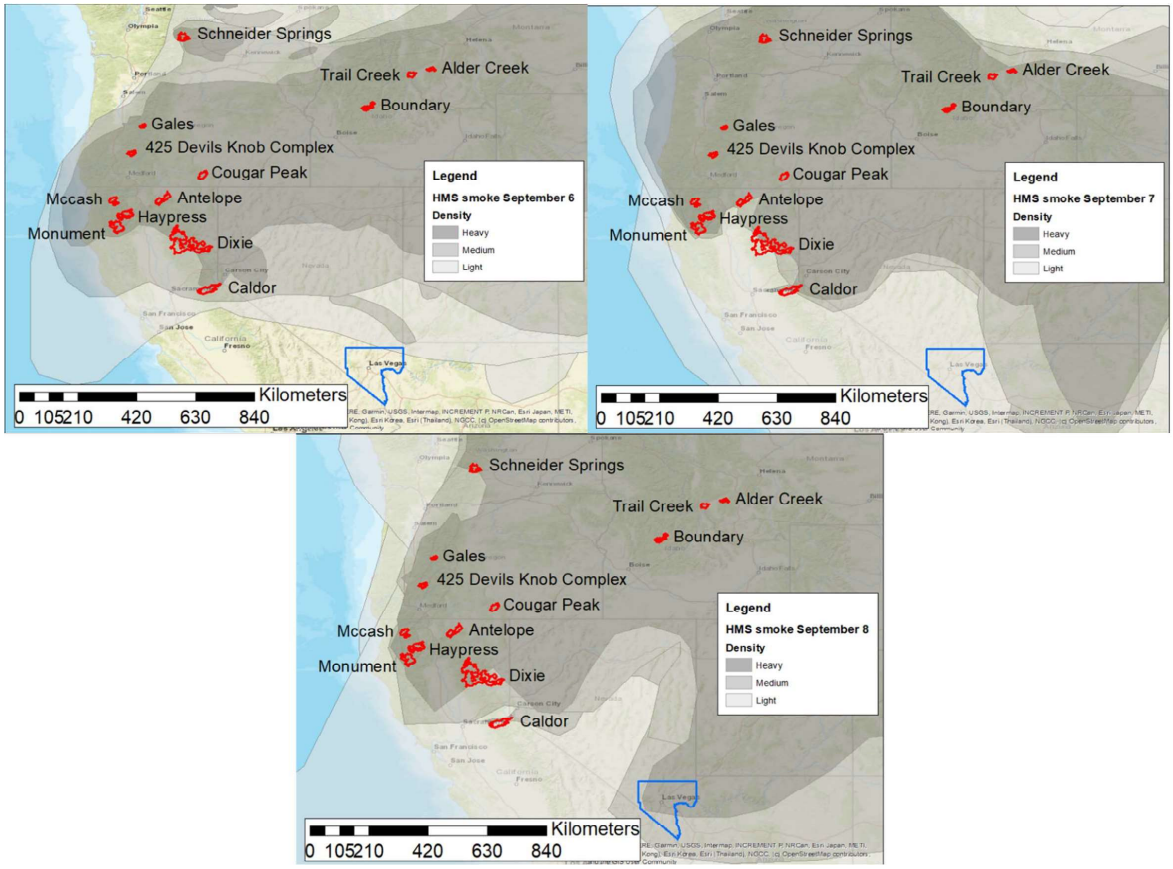

Figure 120. HMS smoke for September 6-8, 2021, is included with qualitative smoke density. Fire perimeters from the major fires contributing to the exclusion date are shown in red and the Clark County, NV, boundary is shown in blue.

Table 25. Wildfires affecting Clark County on the exclusion day. The fire name, state location, total acreage, active acreage burning on the exclusion day, and the start and containment date are included. Where active areas are not available, cumulative acres burned are listed in italics.

Wildfire Name	State	Total Acres	Active Acres as of September 8	Start Date	Containment Date
Dixie	California	963,405	20,988	July 14	October 15
Monument	California	223,124	19,710	July 31	October 20
Haypress River Complex	California	199,343	54,374	July 31	October 25
Antelope	California	145,632	27,608	August 1	October 14
Caldor	California	221,835	8,688	August 15	NA
McCash	California	94,962	17,519	August 1	October 27
Cougar Peak	Oregon	91,701	20,000[20]	September 7	October 21
425-Smith (Devils Knob Cpx)	Oregon	49,238	39,579[21]	August 2	N/A
Gales (Middle Fork Complex)	Oregon	24,894	*26,031[22] (whole complex)*	July 27	N/A
Schneider Springs	Washington	107,353	*97,288[23]*	August 4	November 3
Boundary	Idaho	79,721	*49,784[24] (September 10)*	August 10	November 23
Trail Creek	Idaho	61,992	*42,042[25] (as of September 7)*	July 8	November 4
Alder Creek	Idaho	36,968	*28,377[25] (as of September 7)*	July 8	November 3

[20] https://www.oregonlive.com/pacific-northwest-news/2021/09/cougar-peak-fire-in-lake-county-grows-to-1500-acres-prompts-evacuations.html
[21] https://www.nrtoday.com/news/environment/wildfires/level-3-go-evacuation-ordered-for-residents-near-smith-fire-on-devils-knob-complex/article_7e12117e-ce12-5266-a224-53db9fe790a7.html
[22] https://www.nwfirescience.org/aggregator/sources/21?page=49
[23] https://m.facebook.com/SchneiderSpringsFire/posts/169202121972001/
[24] https://localnews8.com/news/idaho/2021/09/10/boundary-fire-grows-to-49784-acres/
[25] https://opi.mt.gov/Portals/182/Superintendent-Docs-Images/SEPTEMBER%207%20DNRC%20WILDFIRE%20SITUATION%20REPORT.pdf

4.7.3 Dispersion Modeling and Regional Analysis

HYSPLIT dispersion modelling was performed for September 5 through 9, 2021. Dispersion was initiated at 06:00 PST to simulate regional smoke from the 13 identified active fires impacting the exclusion date. GDAS data at 1.0° horizontal resolution was used for meteorological input. Output from the dispersion modeling was integrated over a 24-hr period starting September 8 at 06:00 PST through September 9 at 06:00 PST. 06:00 PST was chosen to correspond with the initial increase of observed $PM_{2.5}$ concentrations in Clark County. The accumulation of smoke at 0-100 m for the 24-hr period is shown in **Figure 121**.

The HYSPLIT dispersion modeling results show that multiple fires produced a dense layer of smoke that blanketed the western U.S. region, including Clark County, NV. The modeling results are consistent with the HMS smoke plume (shown in gray in Figure 121); HMS is an independent smoke identification database. The dispersion results show smoke from multiple fires reached Clark County, Nevada, on September 8, 2021, and the smoke was present in the lower mixed layer of the atmosphere, impacting ground-level air quality conditions.

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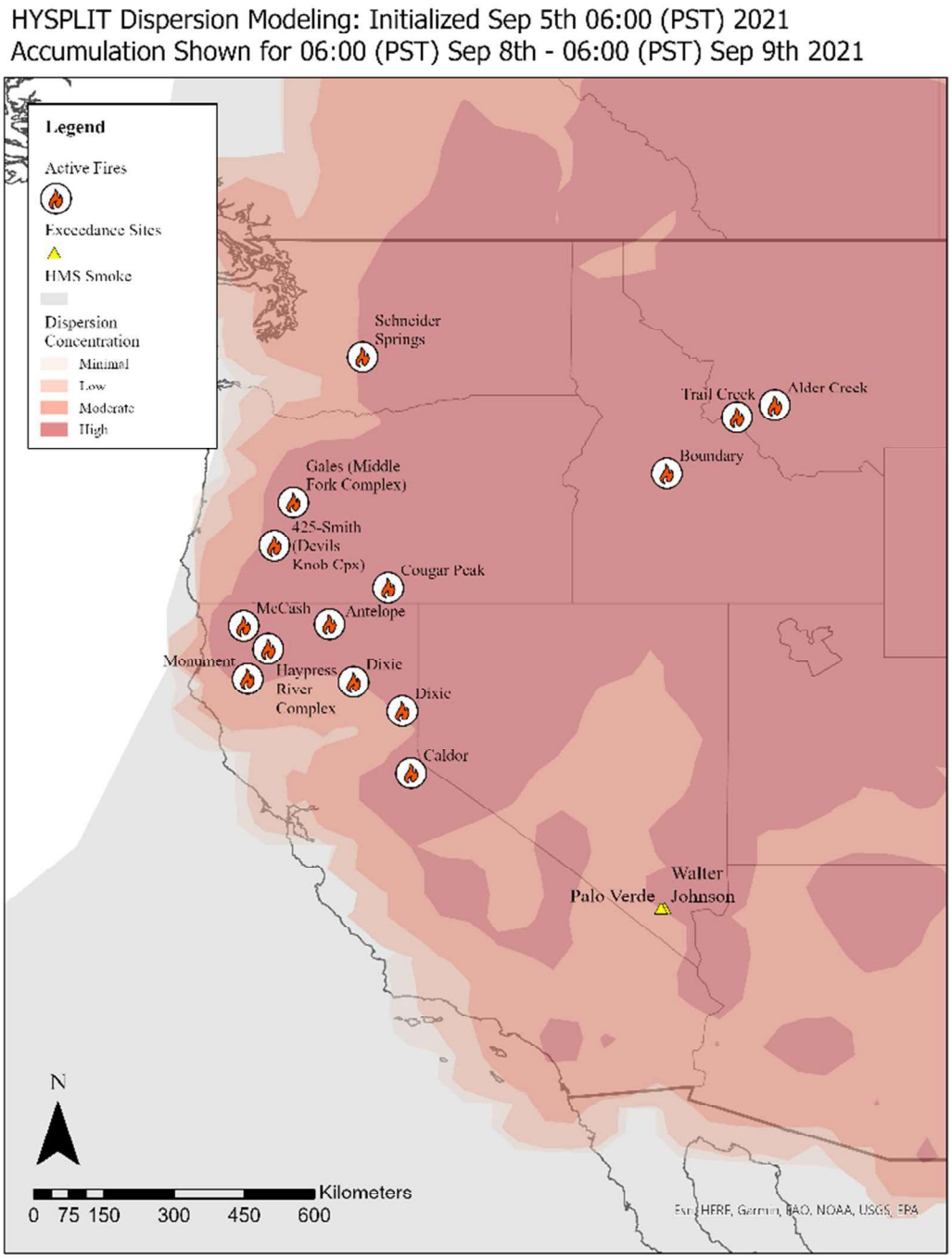

Figure 121. HYSPLIT dispersion modeling for 13 large fires (labeled as "Active Fires") throughout the western U.S. GDAS 1.0° meteorological data was used, and dispersion was initiated on September 5 at 06:00 PST to model the regional smoke observed in satellite and HMS products. HMS smoke is shown in gray and qualitative concentrations of particulate matter are shown in shades of red. Accumulation of particulate matter is shown at 0-100 m for 06:00 PST on September 8 through 06:00 PST on September 9, 2021. Note: the Dixie Fire is labeled twice because there was a significant distance between the active burning edges of the fire on these dates.

Back trajectories (Figure 122) were consistent with the results of the dispersion modeling and show transport from active fire areas and locations where dense smoke was observed by MODIS satellite imagery (Figure 123). Additionally, Figure 124 shows an upper-level high pressure system over central and eastern Nevada, which allowed wildfire smoke to be transported into Clark County and is consistent with the results of the dispersion modeling, back trajectories, and satellite imagery.

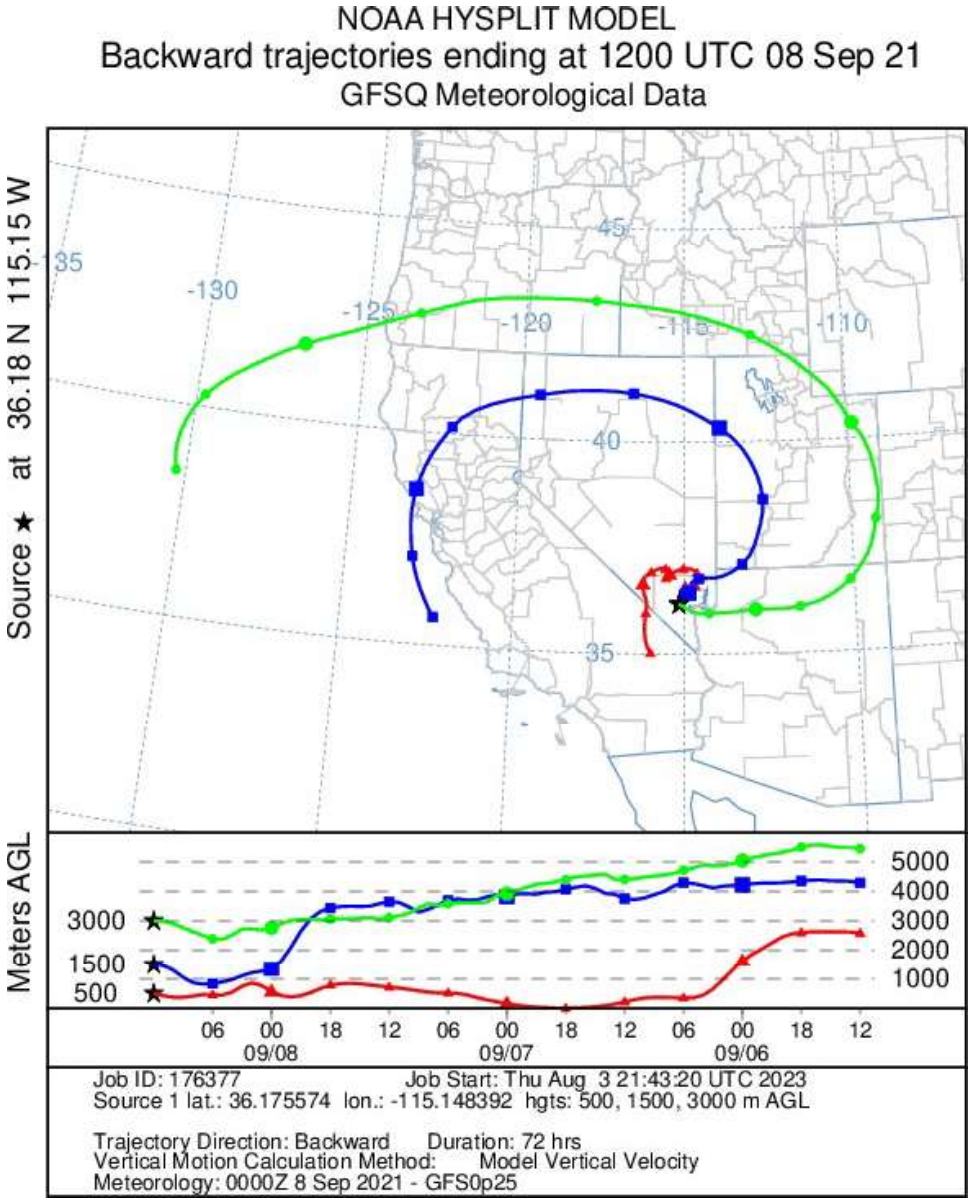

Figure 122. NOAA GFS HYSPLIT 72-hr back trajectory analysis ending at 12:00 UTC (04:00 PST) on September 8, 2021, shows smoke from fires in northern California and Oregon was likely transported into Clark County, NV, contributing to atypical ozone levels.

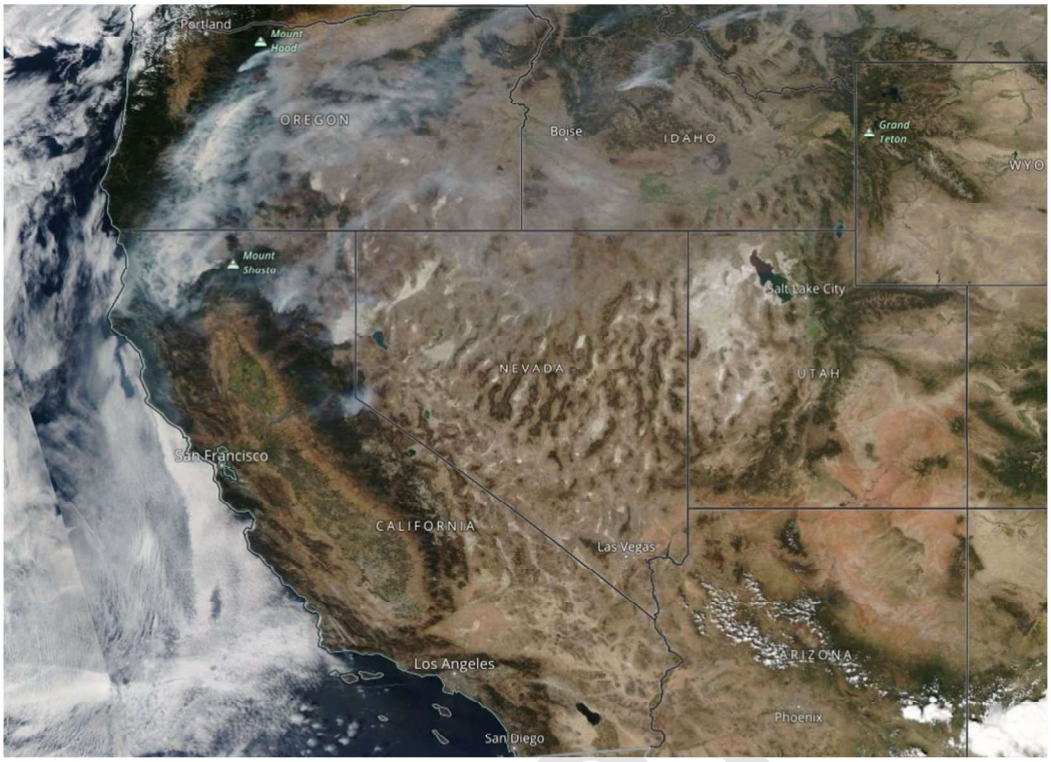

Figure 123. MODIS Aqua satellite image on September 5, 2021. Based on surface observations of haze and 72-hr back trajectory analysis on September 8, smoke from fires in northern California and Oregon impacted air quality in Clark County, NV.

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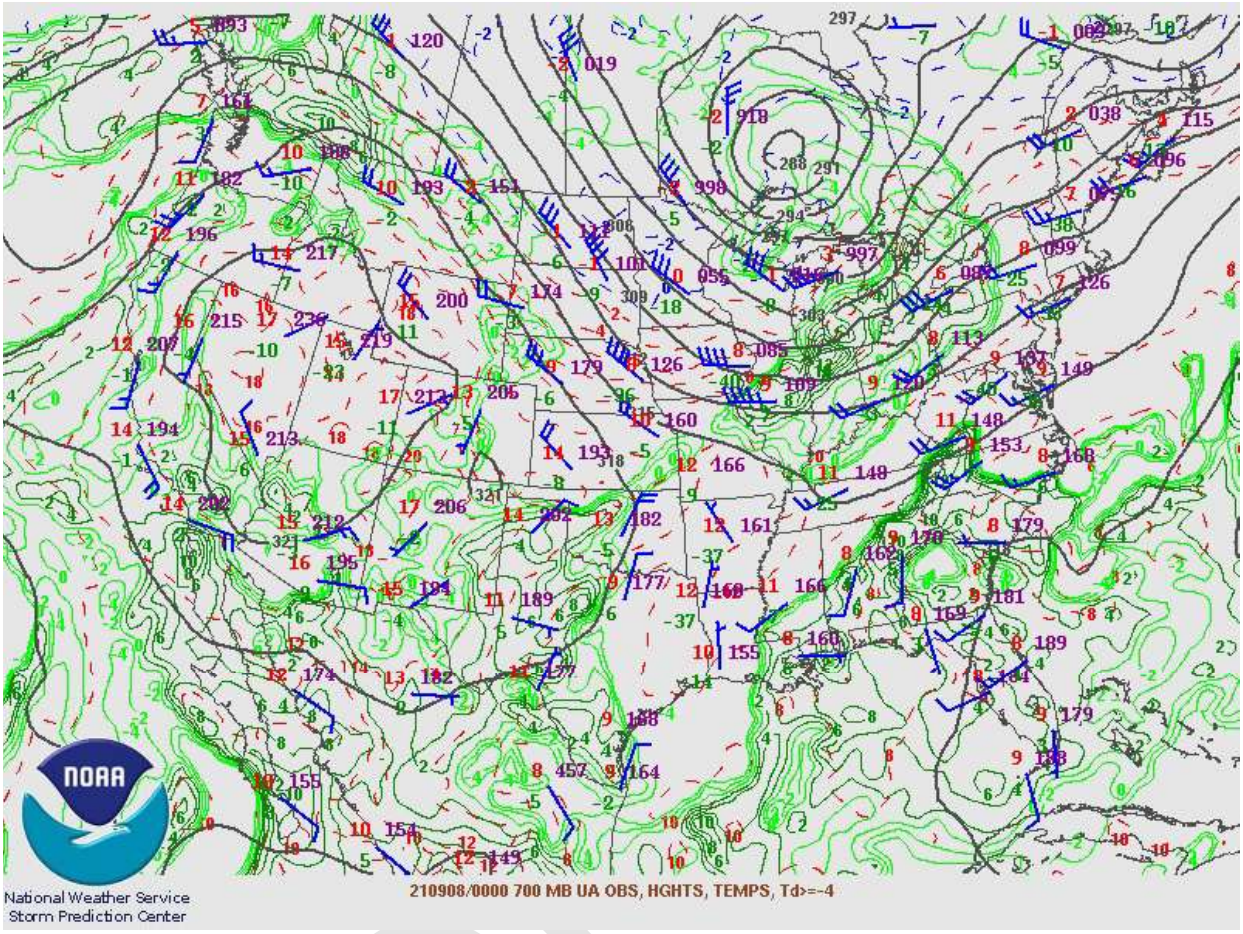

Figure 124. 700-mb map valid at 00:00 UTC on September 8, 2021 (16:00 PST on September 7, 2021). High pressure aloft over central and eastern Nevada allowed wildfire smoke to be transported into Clark County, NV.

4.7.4 Surface Impacts

The presence of surface-level wildfire smoke during the exclusion date is supported by the visibility-reduction observed when comparing the visibility conditions on September 7 (Figure 125) to the conditions on the exclusion date of September 8 (Figure 126). Local and regional smoke from the actively burning fires was visible in Clark County on September 8 at 09:00 LST (09:00 PST), when ozone photochemical production typically starts to accelerate. This is consistent with the KLAS hourly METAR reports for September 8, 2021, (Table 26) which note conditions were 'HAZY' due in part to wildfire smoke impacting Clark County. The METAR reports also show that wind speeds were low at KLAS,[26] resulting in stagnant conditions favorable to smoke-induced ozone production.

[26] Available from Iowa Environmental Mesonet, accessed Sept 7, 2023. https://mesonet.agron.iastate.edu/request/download.phtml?network=NV_ASOS.

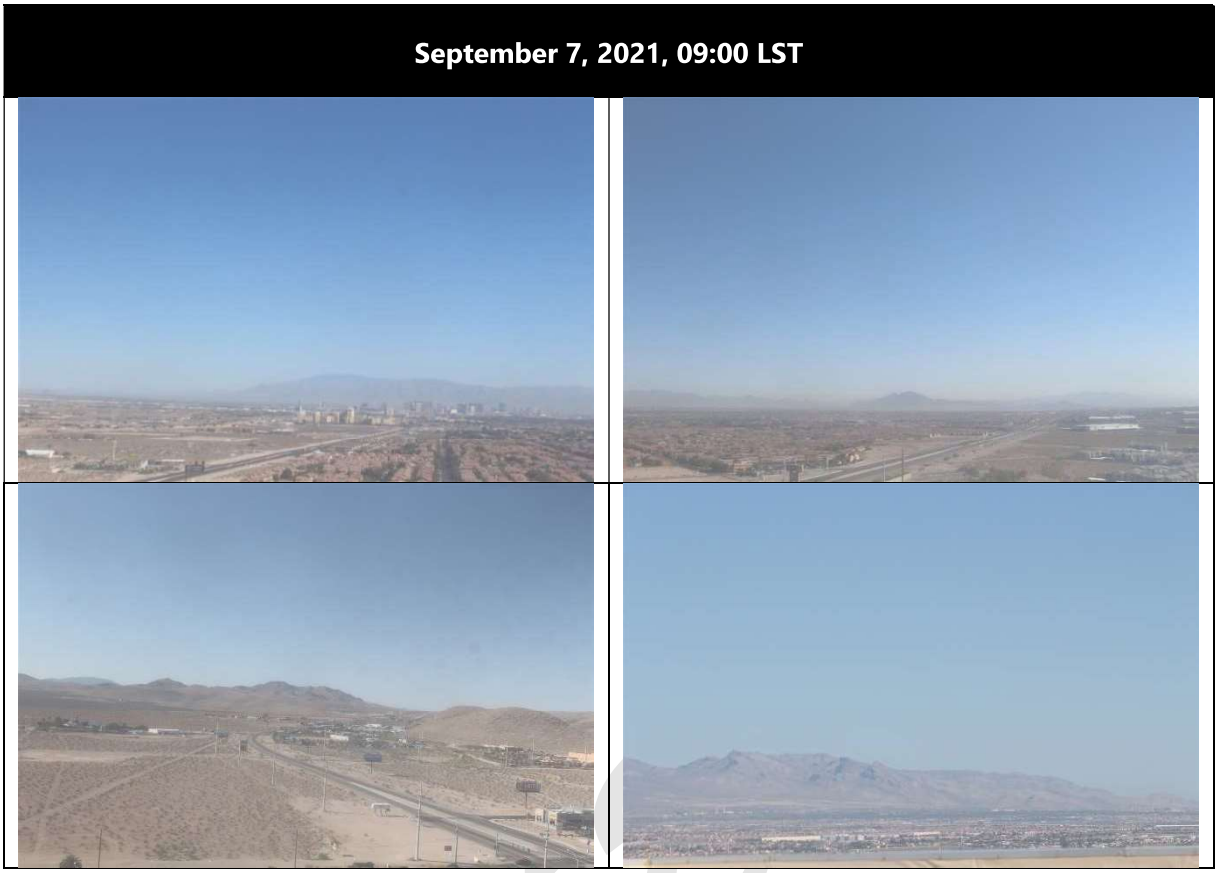

Figure 125. Camera images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions taken from the M Resort Hotel in Clark County, NV, on September 7, 2021, at 09:00 LST.

Figure 126. Camera images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions taken from the M Resort Hotel in Clark County, NV, on September 8, 2021, at 09:00 LST.

Table 26. KLAS hourly METAR reports for September 8, 2021, between approximately 21:00-23:00 UTC (13:00-15:00). During this period, the METAR remarks noted "HAZY" sky conditions.

September 8 Time (UTC)	September 8 Time (PST)	Wind Direction / Speed	Temp / Dew Point (C)	Sea Level Pressure (hPa)	Sky Conditions
20:56	12:56	VRB / 03 KT	41 / 06	1009.4	HAZY
21:56	13:56	VRB / 05 KT	41 / 06	1008.7	HAZY
22:56	14:56	000 / 00 KT	41 / 06	1008.1	HAZY

The presence of surface level wildfire smoke on September 8 is also indicated by enhanced ground-level $PM_{2.5}$, CO, and NO_2 concentrations. $PM_{2.5}$ concentrations compared to the diurnal 10th-90th percentile $PM_{2.5}$ concentration (Figure 127) shows hourly $PM_{2.5}$ concentrations exceeded the diurnal 90th percentile $PM_{2.5}$ concentrations at both sites on September 8.

Hourly CO concentrations are shown in Figure 128 with the 10th-90th percentile diurnal concentration, calculated from 2017-2021, at two nearby sites (Palo Verde and Walter Johnson sites do not have CO or NO_2 monitors). CO concentrations exceeded the 90th percentile concentration on September 7, the evening prior to the exclusion date and on the morning of September 8. Concurrently, NO_2 concentrations in Clark County were enhanced above the 90th percentile diurnal concentration on the night prior and morning of the exclusion date (Figure 129).

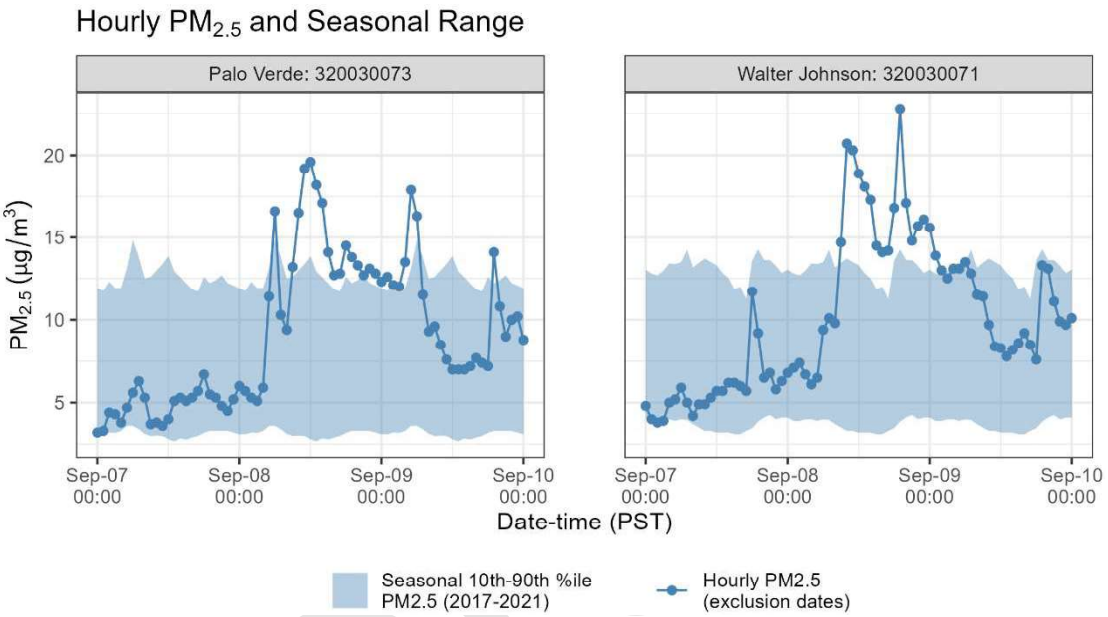

Figure 127. Hourly $PM_{2.5}$ measurements overlaid on the 10th-90th percentile diurnal concentration at a subset of event-affected measurement sites that measure $PM_{2.5}$ concentrations. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

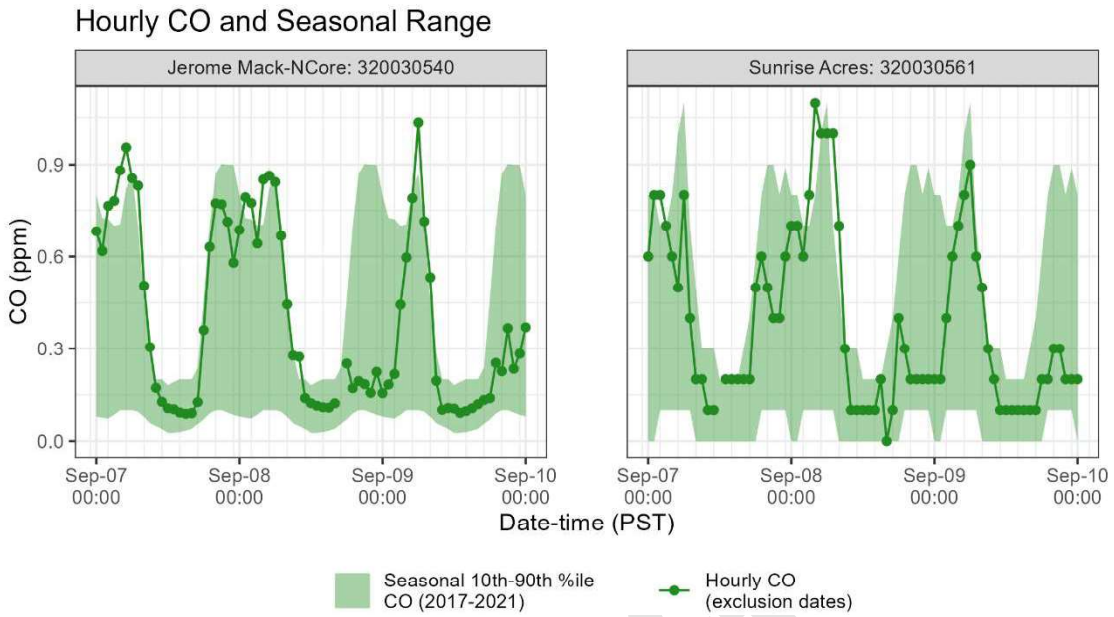

Figure 128. Hourly CO measurements overlaid on the 10th-90th percentile diurnal concentration at Clark County sites that measure CO. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

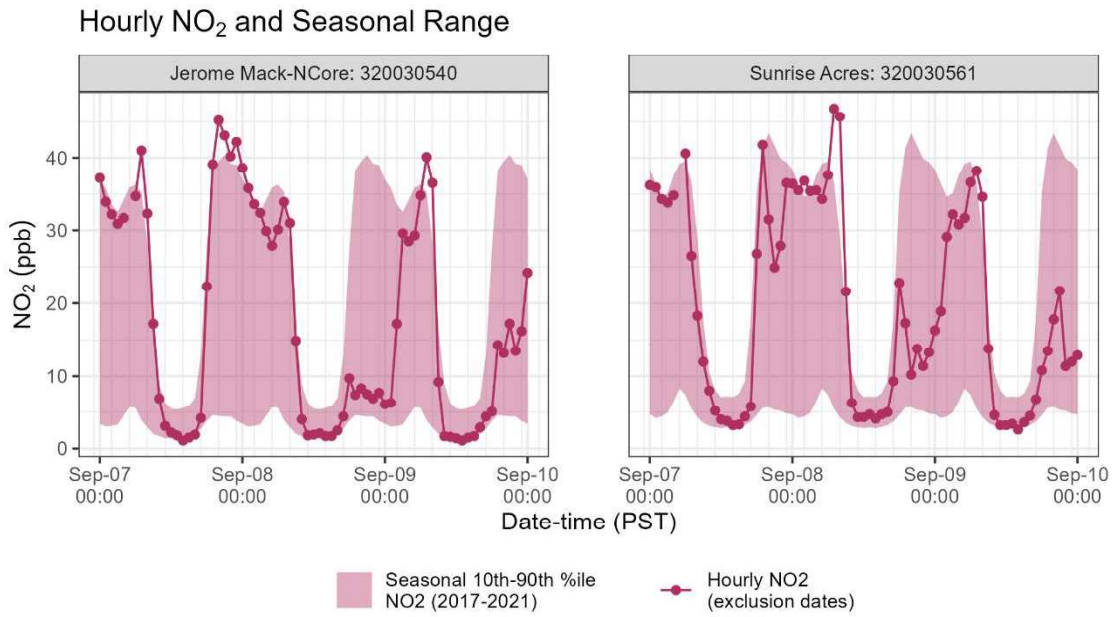

Figure 129. Hourly NO_2 measurements overlaid on the 10th-90th percentile diurnal concentration at Clark County sites that measure NO_2. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

The ratio of $PM_{2.5}$-to-PM_{10} concentrations was also examined to determine if wildfire smoke entered Clark County on or before the exclusion dates. Increases in this ratio are indicative of wildfire smoke.

Figure 130 shows a time series of the ratio of $PM_{2.5}$-to-PM_{10} concentrations from September 7 through September 10, compared to the ozone season mean and 5th-95th percentile range for available data between 2017-2021 at the Palo Verde and Walter Johnson monitoring sites. The ratios show a sharp increase to above the 95th percentile during the late morning and early afternoon of September 8. A similar pattern is present at many of the non-affected sites (Figure 131), indicating that $PM_{2.5}$ was enhanced throughout the Las Vegas Valley. These observations are consistent with the $PM_{2.5}$, CO, and NO_2 enhancements that occurred on September 7 and 8, again suggesting that wildfire smoke entered the Clark County area on September 7 and lingered through September 8, influencing the atypical ozone event that occurred on September 8.

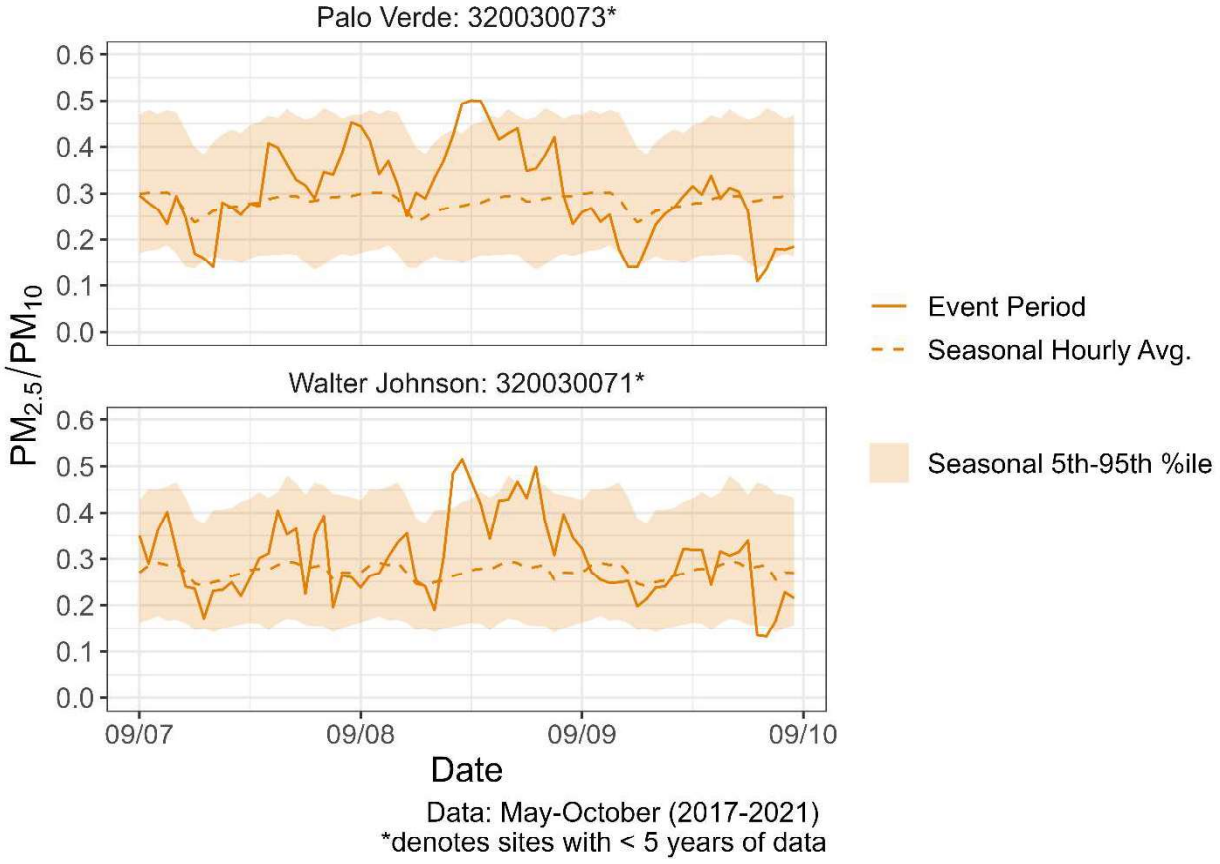

Figure 130. Ratio of $PM_{2.5}$-to-PM_{10} concentrations at the Palo Verde (top) and Walter Johnson (bottom) sites before and during the September 9 event period. The 5-yr average $PM_{2.5}$-to-PM_{10} diurnal ratio is displayed as a dotted line, and the 5th-95th percentile range is shown as a shaded ribbon. The 5th-95th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

Figure 131. Ratio of $PM_{2.5}$-to-PM_{10} concentrations at the non-affected sites before and during the September 9 event period. The 5-yr average $PM_{2.5}$-to-PM_{10} diurnal ratio is displayed as a dotted line, and the 5th-95th percentile range is shown as a shaded ribbon. The 5th-95th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

4.7.5 Event Statistics

Table 27 summarizes the daily measurements of ozone, $PM_{2.5}$, CO, and NO_2 concentrations on the exclusion day, as well as the percentile rank of the observation compared to the previous five years of data (2017-2021). On September 8, 2021, ozone MDA8 measurements were above the 96th percentile, and 24-hr average $PM_{2.5}$ measurements were above the 90th percentile.

The 1-hr daily maximum CO and NO_2 concentrations measured at nearby sites show that both pollutants were somewhat higher than the typical ozone season values in Clark County, Nevada. CO 1-hr daily maximum measurements ranged from 864-1,100 ppb, or the 76th-83rd percentile. NO_2 1-hr daily maximum observations ranged from 38.6 to 46.8 ppb, or the 70th-87th percentile.

Table 27. Percentile of pollutant measurements on the exclusion day compared with most recent five years (2017-2021). The percentile rank is calculated across the ozone production season (May 1-October 31) of 2017-2021. Data from nearby sites that were not identified for the exclusion event are shown in italics.

Date	Site Name	Site Code	Ozone		$PM_{2.5}$		CO		NO_2	
			Ozone MDA8 (ppb)	Percent Rank	$PM_{2.5}$ 24-hr Avg ($\mu g/m^3$)	Percent Rank	CO 1-hr Daily Max (ppb)	Percent Rank	NO_2 1-hr Daily Max (ppb)	Percent Rank
9/8/2021	Walter Johnson	320030071	73	96	13.5	91.5*	--	--	--	--
9/8/2021	Palo Verde	320030073	71	97.3	12.4	90*	--	--	--	--
9/8/2021	*Jerome Mack-NCore*	*320030540*	--	--	--	--	*864*	*76.4*	*38.6*	*70.5*
9/8/2021	*Sunrise Acres*	*320030561*	--	--	--	--	*1100*	*83.6*	*46.8*	*87.1*

*Sites that have less than five years of data available for a given parameter: $PM_{2.5}$ measurements at the Walter Johnson and Palo Verde sites began in January 2020.

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4.8 Request for Exclusion

The wildfire smoke events resulted in ozone measurements that are atypical, extreme, and nonrepresentative of past and future days for Clark County, NV. Appendix W to Part 51 states "control agencies have long expressed a need for consistency in the application of air quality models for regulatory purposes…the expanded requirements for models to cover even more complex problems have emphasized the need for period review and update of guidance on these techniques." Wildfire smoke events are one such complex problem, as wildfire season has extended and encompasses the summer months, which are also considered to be the ozone production season. Wildfire occurrence is wildly considered to be a stochastic natural phenomenon and is therefore inconsistent year-to-year. Downstream smoke impacts, including ozone formation, are not typical nor representative of the ambient conditions of Clark County, NV. The seven wildfire smoke events identified in this report are inconsistent with previous records and determined to be extreme, as indicated by:

- All site exceedances are above the 93rd percentile of historical ozone measurements.
- Multiple sites were affected during each event, including those that did not exceed regulatory standards.
- Significant smoke was identified from local or regional wildfire incidents.

Table 28 provides the evidence and exclusion narrative for each date.

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Table 28. Evidence provided for each exclusion date.

Exclusion Date(s)	Event Summary
June 11-12, 2021	Local transport from the Sandy Valley Fire provided enhanced $PM_{2.5}$ concentrations during the flaming portion of the fire and enhanced gaseous pollutants during the smoldering portion of the fire. Transport is confirmed through dispersion modeling, meteorological analysis, and the timing of pollutant enhancements. Statistics show pollutant concentrations, including ozone, were atypical due to this event.
June 16-17, 2021	Regional transport of smoke from large wildfires in Arizona and New Mexico significantly enhanced $PM_{2.5}$ concentrations overnight prior to the exclusion days. Enhancements of co-emitted pollutants, camera images, and meteorological reports confirm the presence of smoke from these fires at the surface in Las Vegas. Dispersion modeling provides additional evidence that smoke was at the surface on the exclusion days. Statistics show pollutant concentrations, including ozone, were atypical due to this event.

Exclusion Date(s)	Event Summary
July 20, 2021	Regional transport of smoke from large wildfires in northern California and Oregon entered the Las Vegas area overnight on July 18 and 19 and coincided with an enhancement in $PM_{2.5}$ concentrations. Winds were calm-to-light and variable through July 20, allowing a build-up of pollutants and, therefore, atypical ozone production. Statistics show ozone concentrations were atypical and dispersion modeling confirms transport.
August 2-3, 2021	Regional transport of smoke from large fires in northern California was carried along a high-pressure system and caused increasingly hazy and smoky conditions over the course of the exclusion days. $PM_{2.5}$ concentrations increased above the 90th percentile, along with co-emitted pollutants and the $PM_{2.5}$-to-PM_{10} ratio, all of which are indicative of smoke impacts. Surface observations and camera images confirm the dispersion modeling showing smoke reaching the surface. Statistics show pollutant concentrations, including ozone, were atypical due to this event.
August 7, 2021	Regional transport of smoke from large wildfires in northern California showed an extreme enhancement in $PM_{2.5}$ concentrations on the exclusion day. Dispersion modeling confirms transport and enhancement in surface pollutants, and camera images and satellite imagery provide additional evidence that smoke was transported into the Clark County area. Statistics show pollutant concentrations, including ozone, were atypical due to this event.
August 19, 2021	Regional transport of smoke from multiple large wildfires across the western U.S. showed an extreme enhancement in $PM_{2.5}$ concentrations overnight on August 18-19. Dispersion modeling confirms transport, and meteorological data plus enhanced coincident pollutant concentrations confirm smoke in the Clark County area. Statistics show pollutant concentrations, including ozone, were atypical due to this event.
September 8, 2021	Regional transport of smoke from multiple large wildfires across the western U.S. coincides with enhanced $PM_{2.5}$ concentrations above the 90th percentile on the exclusion day, along with CO concentrations. Camera images confirm smoke at the surface, and dispersion modeling confirms transport of smoke from wildfires throughout the western U.S. Statistics show pollutant concentrations, including ozone, were atypical due to this event.

Based on the evidence provided, we formally request exclusion of the following dates in the base and projected ozone design values

5. 2022 Ozone Technical Supporting Documents

The U.S. Environmental Protection Agency (EPA) published the memo "Clarification Memo on Additional Methods, Determinations, and Analyses to Modify Air Quality Data Beyond Exceptional Events," which illustrates cases where air quality data may be modified for certain regulatory determinations, actions, and analysis. The document defines cases where a request to exclude data can be made through the Exceptional Events Rule, such as when a National Ambient Air Quality Standard (NAAQS) design value is recalculated in EPA's Air Quality System (AQS) using modified data to determine attainment. The document also defines additional analyses that are not covered in the Exceptional Events Rule, where submitting modified data may be appropriate. These additional cases are defined as conditions where ambient air quality data may have been "influenced by an atypical, extreme or unrepresentative event." The Clark County Department of Environment & Sustainability (DES) is submitting a request to exclude data on this basis for the following case explicitly defined in the document: "Estimating base and future-year design values ozone SIP attainment demonstrations," as a part of DES' State Implementation Plan (SIP).

The EPA document states that monitoring data could qualify for exclusion if "[A]mbient data are not representative to characterize background or base period concentrations in accordance with the *Guideline,*" in reference to *Guideline on Air Quality Models* (40 CFR Part 51, Appendix W). Extreme wildfire events are increasingly prevalent in the western U.S., resulting in increased smoke impacts. Clark County, Nevada, was impacted by smoke from regional wildfires in the western U.S. in the summer of 2022 (Table 29). Following atypical smoke intrusions, high ozone concentrations were measured as a result of direct transport and secondary photochemical processes.

As stated in the memo, EPA or the appropriate reviewing authority will determine whether the air agency—in this case, Clark County DES—has appropriately documented and justified the data exclusion and/or adjustment when it acts on a SIP submission. The following documentation is provided to demonstrate that four local and regional wildfire smoke events in the period of June-September 2022 meet the criteria as defined in the document and guidance. This evidence is included as part of Clark County's request to exclude these data from base and future-year design values as a part of their SIP.

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Table 29. Summary of events requested for exclusion from ozone SIP base and future-year design values.

Event Date	Event Ozone Concentration Percentile	Sites Exceeded During Event	Type of Event
June 16, 2022	95th – 97th	*(3)* Joe Neal, Paul Meyer, and Mountain's Edge	Smoke Transport from Mexico
July 17, 2022	98th – 99.7th	*(5)* Green Valley, Garrett Jr. High, Jerome Mack, and Liberty High School	Regional Smoke
July 28-29, 2022	98th – 99.9th	*(6)* Joe Neal, Liberty High School, Mountain's Edge, Palo Verde, Paul Meyer, and Walter Johnson	Regional Smoke
September 1-2, 2022	94th – 98th	*(2)* Paul Meyer and Walter Johnson	Regional Smoke

For each requested exclusion date(s), we present evidence that the ozone exceedance at each affected site in Clark County was impacted by regional wildfire smoke. Each subsequent section for the 2022 requested exclusion date(s) includes the following details:

- Ozone concentrations on, before, and after the exceedance date;
- A list of all wildfires that produced substantial smoke and impacted Clark County;
- Descriptions of transport of that smoke into Clark County, via meteorological analysis, dispersion modeling, and satellite data;
- Other air quality observations and associated statistics that coincide with the high ozone events.

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5.1 June 16, 2022

5.1.1 Event Summary

An ozone exceedance event took place on June 16, 2022, in Clark County, Nevada, where the MDA8 ozone concentration exceeded the National Ambient Air Quality Standards (NAAQS) at two monitoring site locations: 72 ppb at the Joe Neal site, and 71 ppb at the Paul Meyer site. The Spring Mountain (SM) Youth Camp monitoring site also experienced a NAAQS exceedance on this day. However, SM Youth Camp is outside of the Las Vegas Valley and not significant for the design value assessments. The Mountain's Edge monitoring site also experienced high ozone concentrations on this day, with a MDA8 concentration of 70 ppb. Regional wildfire smoke from Baja California, Mexico is suspected to have contributed to the NAAQS exceedances on this day. Major evidence includes ozone enhancement at background measurement sites such as SM Youth Camp, National Oceanic and Atmospheric Administration (NOAA) Hazard Mapping System (HMS) fire and smoke analysis, enhanced ground-level acetaldehyde concentrations, and Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) modeling. This combination of evidence suggests that this is an unrepresentative event for base and future design value ozone assessments.

Figure 132 shows the time series graphs of hourly ozone concentrations on June 15-19, the points that exceeded the seasonal means (calculated using data from May 1-October 31, 2017-2021), and the 10th-90th percentiles at each affected site. Hourly ozone concentrations exceeded the 90th percentile between 14:00 to 20:00 PST and generally remained high into the evening hours. The MDA8 value for each exceedance site was between 11:00 to 18:00 PST. The increase in ozone concentrations also shows a significant uptick in production around midday. This enhancement of ozone production is atypical compared with the usual ozone diurnal profile shown by the median and 10th-90th percentile bands. This atypical production points to an outside source of ozone precursors impacting the area.

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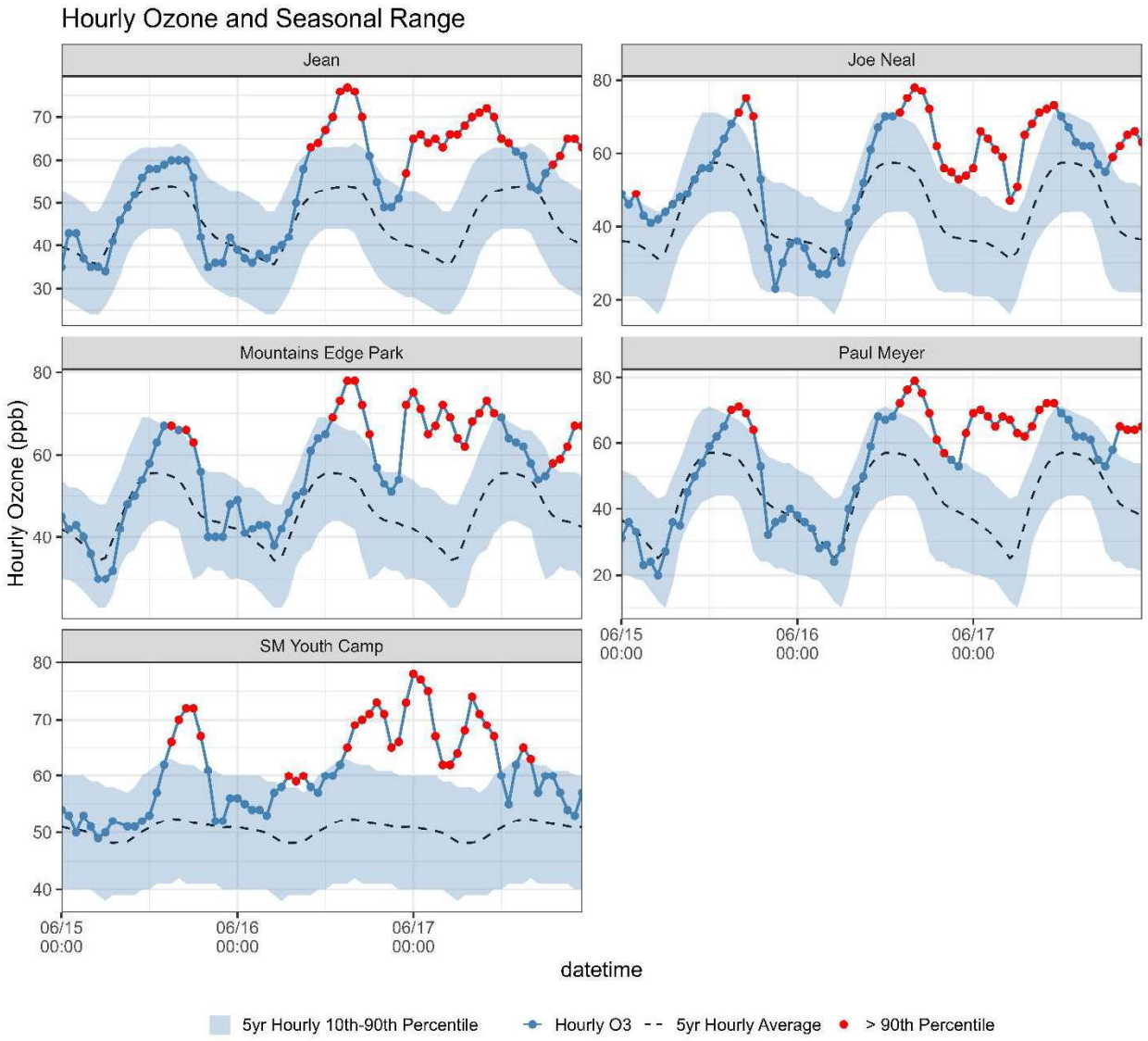

Figure 132. Hourly ozone concentrations (ppb) across June 15-19, 2022, compared to 5-yr ozone season (May 1-October 31) hourly means and 10th-90th percentiles. Note: data collection at the SM Youth Camp and Mountain's Edge sites did not begin until 2019 and 2020, respectively.

The Joe Neal and Paul Meyer sites are located near the Las Vegas city center, with Joe Neal to the northwest and Paul Meyer to the southwest. The SM Youth Camp, Mountain's Edge, and Jean sites, also included in Figure 132, are located far from the city center and provide insight into regional background levels. The SM Youth Camp site is far northwest of the city center in the Spring Mountain range at a high elevation; the Mountain's Edge site is located on the southwest border of the Las Vegas Valley; and the Jean site is far southwest of the city at a low elevation near the Mojave Desert and California border. The similarities in the trends between the city sites (Joe Neal and Paul Meyer) compared to the background sites (SM Youth Camp, Mountain's Edge, and Jean) provide evidence

that this event was more likely due to regional influences such as wildfire smoke, rather than only from locally generated emissions.

5.1.2 Identification of Wildfires

Figure 133 shows NOAA HMS smoke analysis and satellite fire detection maps across the southwestern United States and Mexico between June 15 and June 17, 2022. On June 15, satellites detected fires and smoke in northern Baja California, Mexico. By June 16, smoke is analyzed south of Clark County, Nevada, with satellites detecting fires in northern Baja California. The following day, June 17, smoke is analyzed over Clark County, with the fires in northern Baja California still being detected by satellites.

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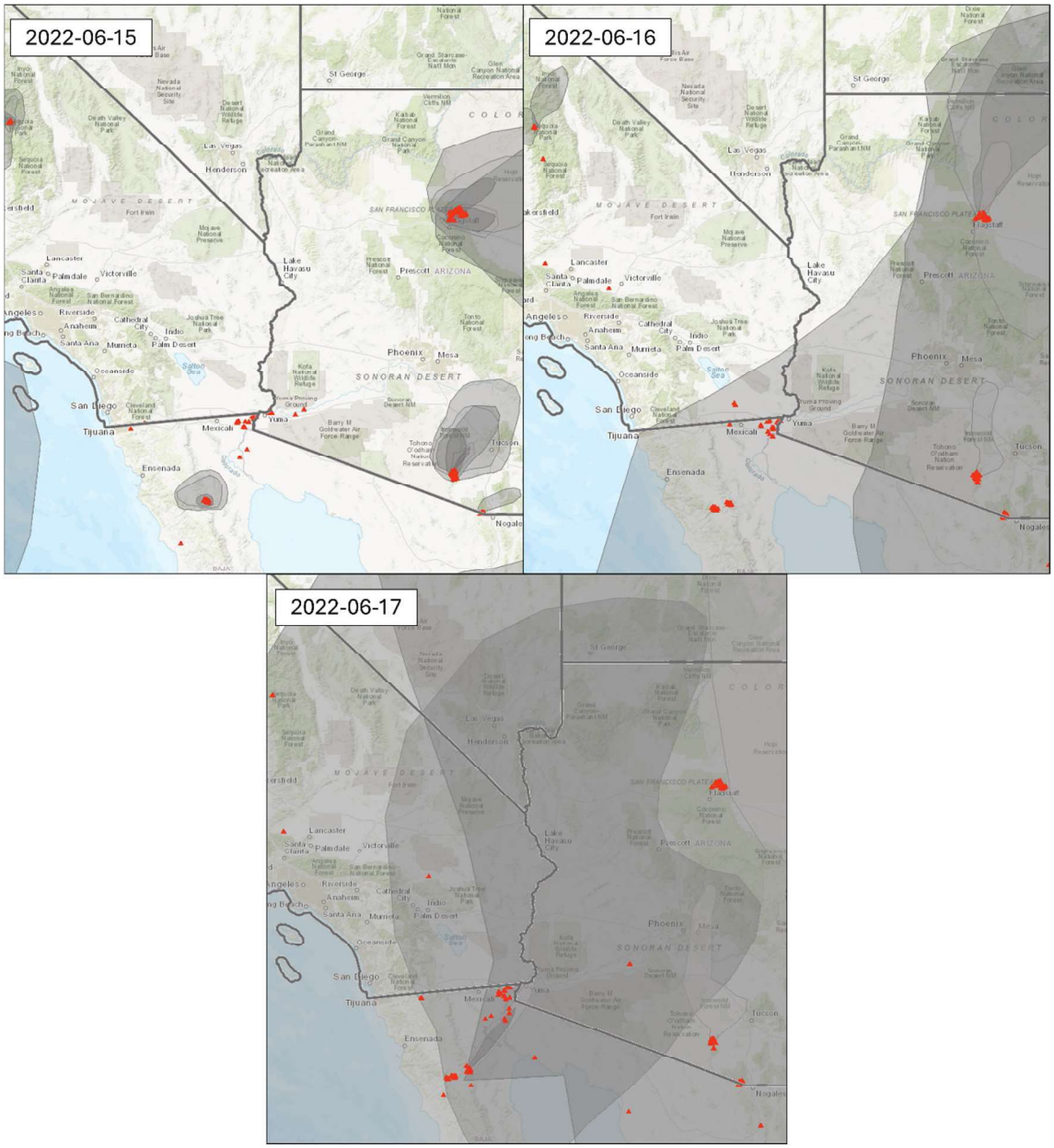

Figure 133. HMS smoke maps for June 15-17, 2022, showing fire and smoke detections in southern CA, NV, AZ, and Baja Mexico. Smoke is shown as gray shades on top of the map with darker gray indicating denser smoke plumes. Fire detections are shown as red triangles.

Wildfires in Baja California were active on and before June 16, 2022, the exclusion day, which contributed to regional smoke as shown in the HMS images from Figure 133. The fires in northern Baja California were identified as a likely contributor of wildfire smoke to Clark County on the exclusion day based on the HYSPLIT back-trajectories shown in Figure 134. Table 30 presents the estimated the start and containment dates for one of the fires in Baja California, Mexico, as well as the estimated size (details were unavailable, but general information based on HMS smoke and fire records are included). For the fire detections near Mexicali, even less information is available because

fires in that area near the border are frequent. However, there are significantly fewer fire detections near Mexicali in early June before the number of active fire detections increased significantly starting on June 9. Fire detections in this area remained high until June 29. No information is available on fire size or containment for these fires.

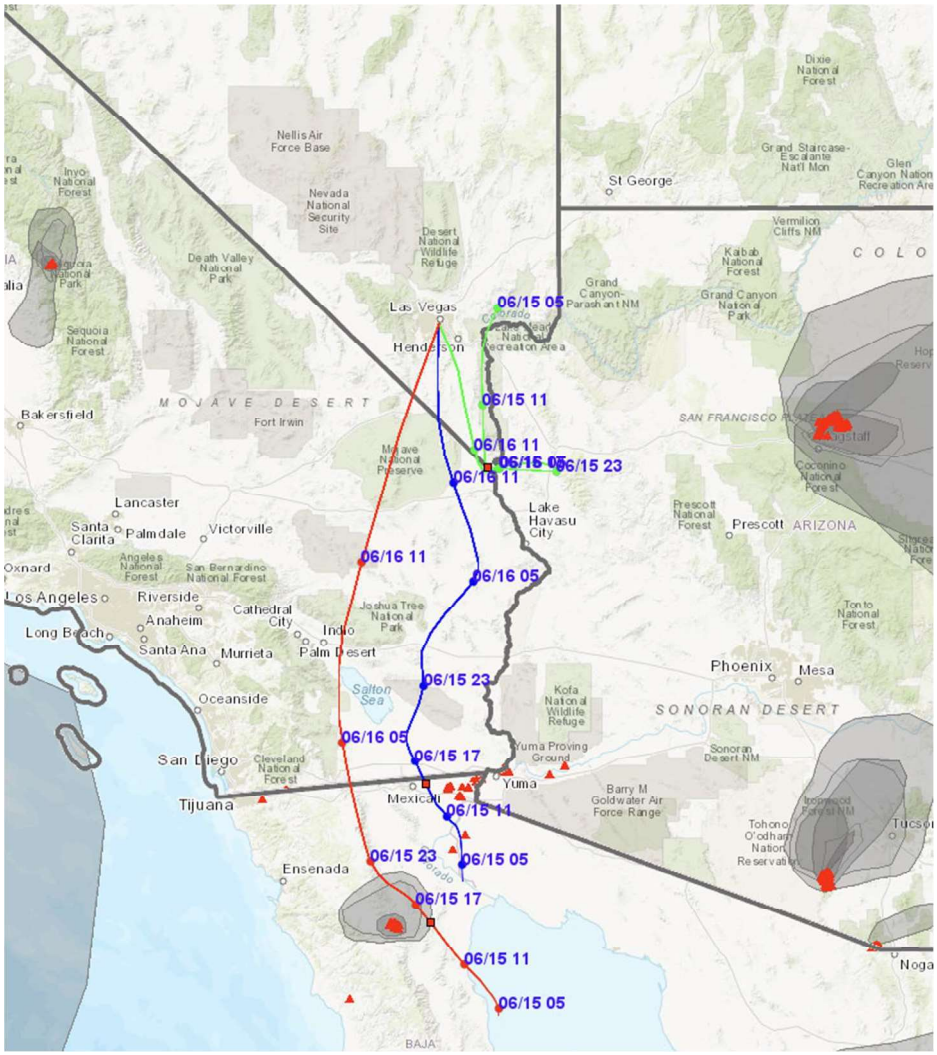

Figure 134. 36-hour HYSPLIT backward trajectory analysis starting on June 16, 2022, at 14:00 PST and NOAA HMS smoke analysis (grey shading) and satellite fire detections (red triangles) on June 15. HYSPLIT shows air advection from Baja Mexico fires into Clark County by June 16, 2022, using NAM 12 km meteorological data. Forward trajectory heights were modeled at 100 m (green), 1,850 m (blue), and 3,600 m (red) AGL to show near-surface and synoptic flow.

Table 30. Wildfire affecting Clark County on June 16, 2022. Italicized data for the Baja fire in Mexico are estimated using HMS fire and smoke data.

Wildfire Name	State	Total Acres	Acres Burned on or Before June 16	Start Date	Containment Date
Baja Fire	*Baja, MX*	*8,500*	*7,000 (June 17)*	*June 11*	*June 21*

5.1.3 Boundary Layer and HYSPLIT Analysis

To determine the impact of wildfire smoke on ozone development in Clark County, we analyzed the meteorological conditions on and before the June 16 event. We specifically focused on boundary layer dynamics to determine the depth of mixing and possibility of aloft smoke vertically transferring down to the surface. We then used this information to model transport via HYSPLIT and integrated NOAA HMS data to confirm smoke transport into southern Nevada on the exclusion date.

The PBL denotes the atmospheric layer closest to the surface, and the height of the PBL describes the vertical extent of air that could reach ground level. Atmospheric soundings and PBL maps provide visualizations of the extent of vertical mixing in the lower troposphere. The two skew-T diagrams in Figure 135 show the vertical profile of the atmosphere from the Las Vegas upper-air weather station (KVEF) on June 16 at 12:00 UTC (04:00 PST) and on June 17 at 00:00 UTC (June 16 at 16:00 PST). The two skew-T diagrams are characterized primarily by the near-surface temperature inversion on the 04:00 PST sounding being mixed out by the 16:00 PST sounding. While the early morning surface temperature inversion at 04:00 PST prevented air aloft from mixing down into the lower troposphere, the well-defined mixed layer shown on the 16:00 PST sounding would allow aloft air to be mixed down through the lower troposphere toward the surface. This mixed layer is indicated on the skew-T diagram by the solid temperature line at the far right following the dry adiabatic lapse rate. Based on the temperature line following a dry adiabatic lapse rate, the PBL was mixed to approximately 3,700 m AGL, at the same time ozone concentrations were remaining high and smoke was likely being transported into the area. The estimated PBL of 3,700 m AGL on June 16 was slightly lower, but similar, to the 5-year climatological average PBL height for June 16 at 16:00 PST, which is 4,100 m AGL.

The North American Mesoscale Forecast System (NAM)-modeled PBL heights over Clark County on June 16 at 16:00 PST (00:00 UTC June 17) roughly corresponds to the PBL height from the KVEF sounding of the same time (Figure 136), providing independent verification. The NAM-modeled data map in Figure 136 shows the altitude of PBL heights in 1,000 m increments, with color contour analysis starting at 1,000 m AGL. Based on the NAM model, PBL heights over Clark County were around 3,000 m AGL.

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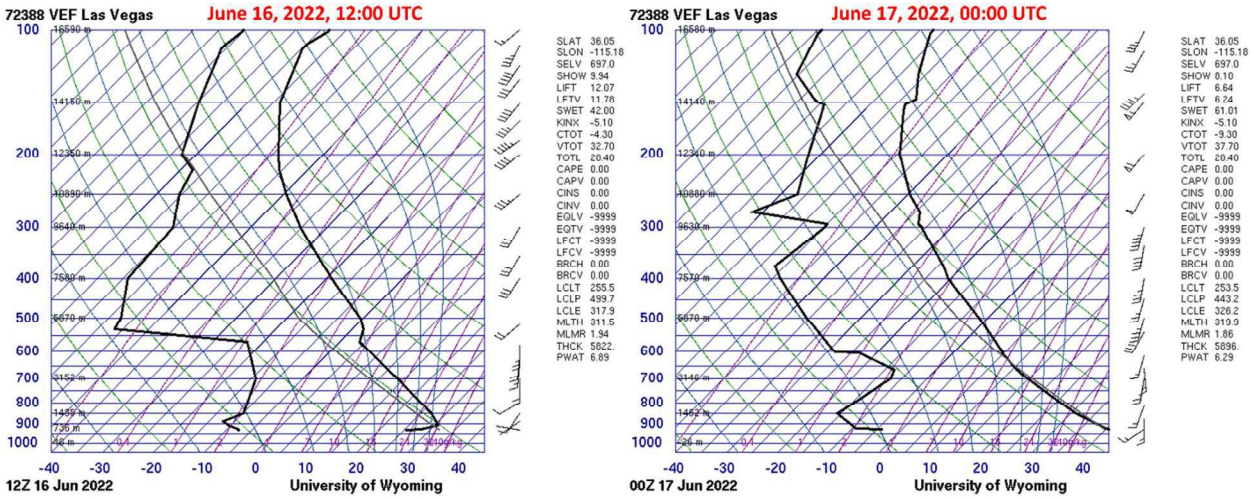

Figure 135. Skew-T soundings launched from KVEF on June 16, 2022, at 12:00 UTC (04:00 PST) (left), and June 17 at 00:00 UTC (June 16 at 16:00 PST) (right).

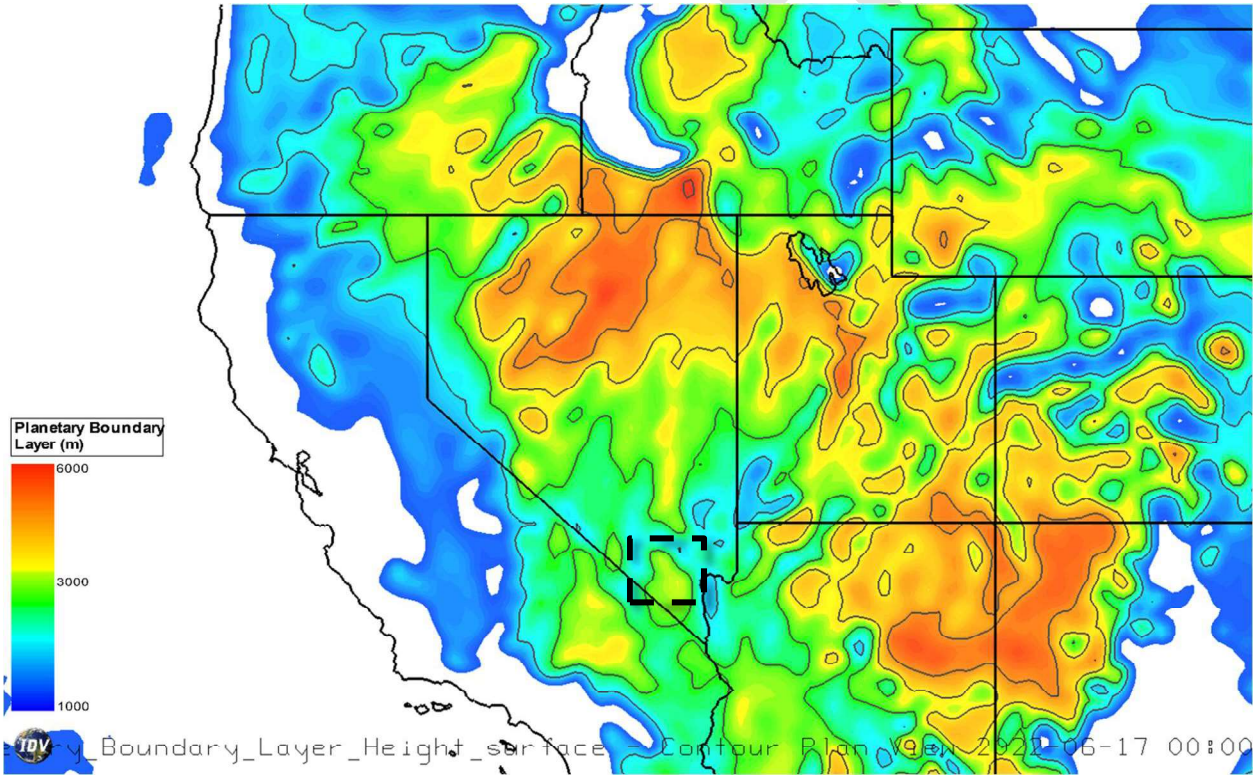

Figure 136. PBL height contour map based on the NAM model for June 17, 2022, at 00:00 UTC (June 16 at 16:00 PST). The gray lines denote PBL heights above 2,000 m in altitude in 1,000 m increments. Color contours begin at 1,000 m AGL. Clark County, NV, is enclosed by a dashed, black box.

The depth of the PBL was driven by a broad area of high pressure at 500 mb (5,500 m AGL), which stretched from Arizona to Georgia. This feature led to the development of sunny skies across southern Nevada, which allowed surface high temperatures at Harry Reid International Airport (KLAS) to reach 106°F on the exceedance day. Ample sunshine, combined with very hot surface temperatures, is conducive for ozone production. Furthermore, strong daytime heating can yield deep mixing and high PBL heights, which promotes the vertical transfer of aloft air to ground level. Surface winds for June 16 averaged less than 10 MPH at KLAS, with a noted wind shift to southerly to southeasterly from mid-afternoon to the late evening hours. These winds would be capable of carrying surface-based pollutants regionally into Clark County on the exceedance day.

While NOAA HMS did not analyze smoke over southern Nevada on June 16, forward trajectories shown in Figure 137 indicate that source air entering Clark County originated from regional fires in Baja California. HYSPLIT forward trajectories were initialized on June 15 at 9:00 PST (17:00 UTC). Also shown in Figure 137 are NOAA HMS satellite fire detections and smoke analysis from June 15. The lower level (100 m) forward trajectory shows surface level transport from the direction of the fires in far northeastern Baja California reaching Clark County between 8:00-14:00 PST on June 16. The upper level (3,600 m) forward trajectory also indicates potential smoke transport from a fire in north-central Baja California, which likely reached Clark County around 14:00 PST on June 16. Both the lower-level and upper-level trajectories are within the well-mixed boundary layer in Clark County according to PBL height estimate of 3,700 m AGL.

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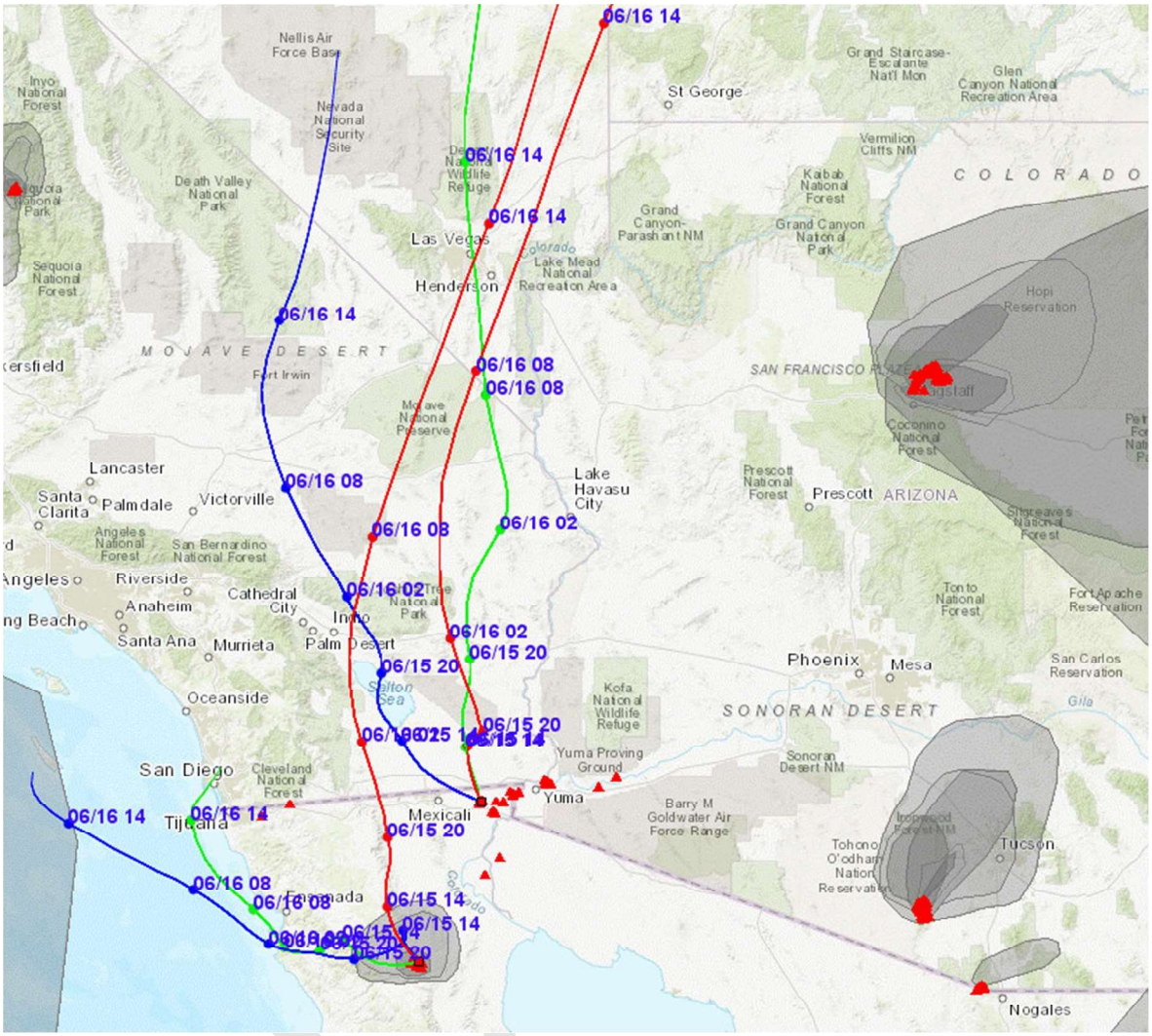

Figure 137. 34-hour HYSPLIT forward trajectory analysis starting on June 15, 2022, at 9:00 PST (17:00 UTC) and NOAA HMS smoke analysis (grey shading) and satellite fire detections (red triangles) on June 15. HYSPLIT shows air advection from Mexico fires into Clark County by June 16 using NAM 12 km meteorological data. Forward trajectory heights were modeled at 100 m (green), 1,850 m (blue), and 3,600 m (red) AGL to show near-surface and synoptic flow.

Although a large plume of smoke was analyzed by HMS to the south and east of Clark County on June 16, smoke was likely advected into southern Nevada from the Baja California fires. **Figure 138** contains the NOAA smoke discussion valid 8:00 PST (16:00 UTC) from June 16. In the discussion, NOAA meteorologists highlight seasonal fires and wildfires in Mexico, with smoke from these fires likely being carried into the southwestern United States. The NOAA smoke discussion from June 16, along with the HYSPLIT analysis in Figure 137, are evidence of smoke-enhanced ozone concentrations in Clark County. Additionally, based on the estimated PBL depth of 3,700 m AGL, aloft smoke entering Clark County would have been well-mixed down to the surface during peak daytime heating.

Thursday, June 16, 2022

DESCRIPTIVE TEXT NARRATIVE FOR SMOKE/DUST OBSERVED IN SATELLITE IMAGERY
THROUGH 1600Z June 16, 2022

SMOKE:
Alaska/Northwestern Canada...
Numerous large wildfires burning in southwestern and central Alaska
were responsible for large areas of varying density smoke which affected
virtually all of Alaska, coastal Alaska, northwestern Canada and extending
southeast into the Northern Plains of the United States. The thickest
smoke was present around some of the larger fires in Alaska as well as
over most of the Yukon.

Eastern and Central U.S, Southeastern Canada...
A swath of varying density smoke from several larger wildfires burning in
Arizona and New Mexico with contributions from seasonal burning extended
from portions of Arizona and New Mexico to the northeast across the
central and eastern U.S. to as far as the coastal Atlantic Ocean and
southeastern Canada.

SMOKE/AEROSOL:
Northern Mexico/Tropical Eastern Pacific Ocean/Southwestern U.S…
Generally thin density smoke from seasonal fire activity and possibly a
few wildfires in Mexico combined with aerosols from industry was visible
this morning over western and northern Mexico, the Baja and off the
western coast of Mexico over the eastern Pacific. The smoke also likely
extended into portions of the southwestern U.S where it eventually mixed
with smoke from the wildfires burning in Arizona and New Mexico.
DUST:

Tropical Atlantic Ocean, Caribbean Sea and Gulf of Mexico...
Saharan Dust was seen over the Central Tropical Atlantic Ocean and
extending through the eastern Caribbean Islands and into the eastern
Caribbean Sea.

Hanna

Figure 138. NOAA smoke discussion valid 8:00 PST (16:00 UTC) on June 16, 2022. Thin-density smoke from fires in Mexico likely extended into the southwestern United States, which impacted ozone production in Clark County, Nevada. Source: NOAA

5.1.4 Surface Impacts

Figure 139 and Figure 140 compare visibility conditions in the Las Vegas Valley before and during the exclusion date. Figure 139 shows visibility conditions at 15:00 PST on June 15, 2022, the day before the event. While the images captured on June 15 do show some reduction in visibility, the images captured at 15:00 PST on June 16 (Figure 140) do show more brown-tinted skies compared with June 15. This is consistent with a well-mixed boundary layer with smoke. Both Figure 139 and Figure 140 show the Sheep Mountain Range in the top left image and the La Madre Mountain in the bottom right image; both mountain ranges are less visible on June 16 than on June 15. The brown-tinted haze throughout the column, shown in the afternoon June 16 images compared to the afternoon June 15 images, is consistent with the narrative that smoke entered the Las Vegas area in the afternoon on June 16 and was well mixed in the column.

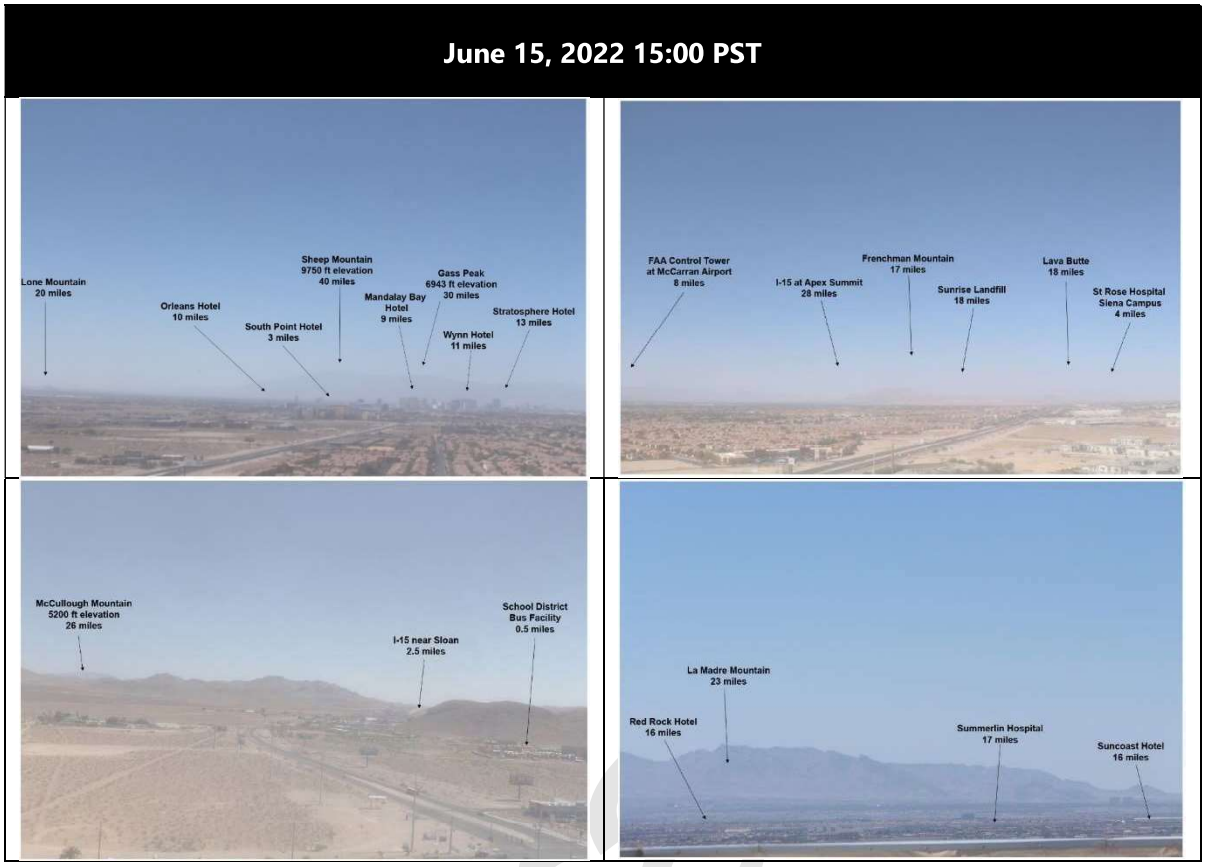

Figure 139. Camera images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions, taken from the M Resort Hotel in Clark County, NV, on June 15, 2022, at 15:00 PST.

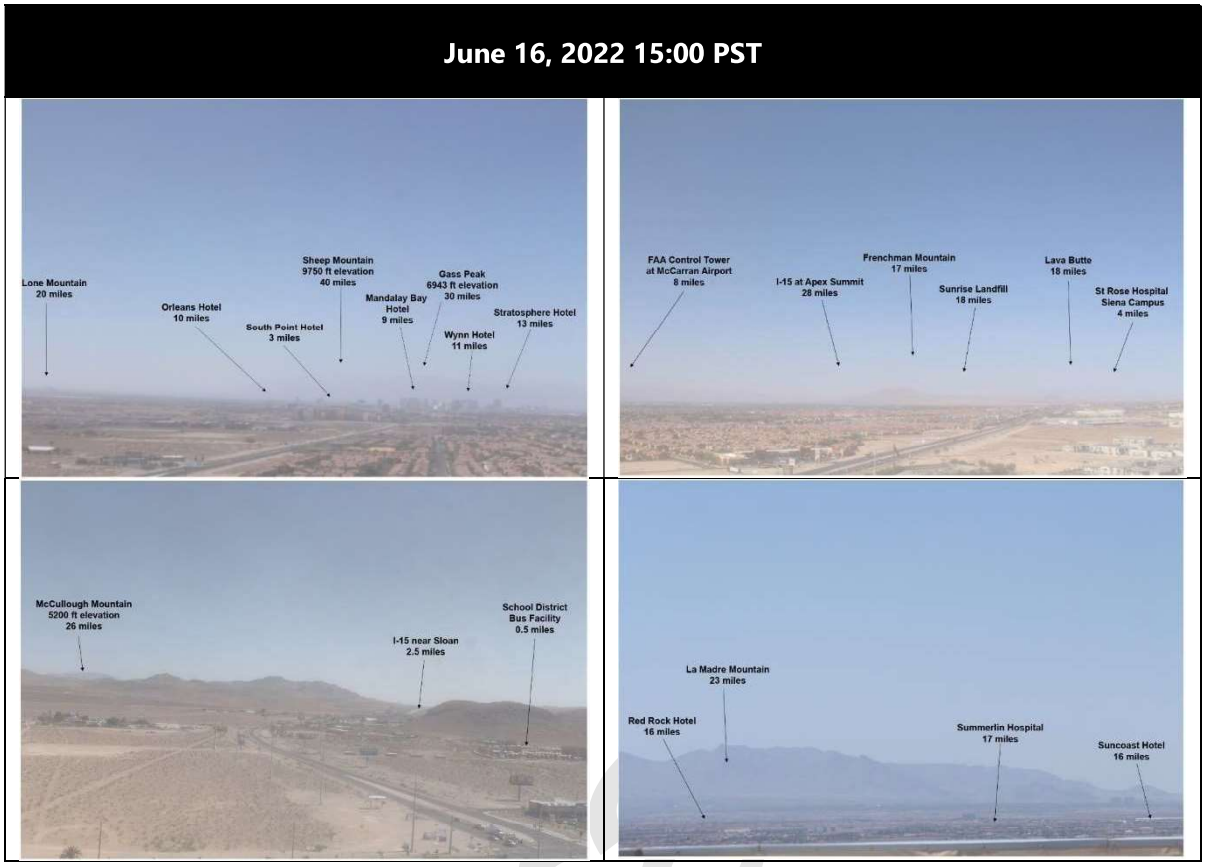

Figure 140. Camera images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions, taken from the M Resort Hotel in Clark County, NV, on June 16, 2022, at 15:00 LST.

Figure 141 through Figure 143 show the hourly $PM_{2.5}$, CO, and NO_2 concentrations for June 16, 2022. Figure 141 shows $PM_{2.5}$ concentrations compared to the diurnal 10th-90th percentile $PM_{2.5}$ concentration, calculated from 2017-2022, for each event-affected site and supporting sites in Clark County. On June 16, hourly $PM_{2.5}$ concentrations are not enhanced above the diurnal 90th percentile for most hours and monitoring sites. By June 17, the smoke plume was over Clark County, shown via HMS, meaning smoke was transported into the area between June 16 and 17. The bulk of smoke likely was transported into the area late in the day on June 16, as shown by the quick rate of change in $PM_{2.5}$ concentrations at all sites. $PM_{2.5}$ concentrations were not high during the June 16 MDA8 period because the fires from Baja were smaller than the smoke plumes from the fires to the east, which reached Clark County by June 17. While the main plume of smoke from the east reached Clark County after the MDA8 ozone period on June 16, the forward trajectories shown in Figure 137 indicate transport from the fires in Baja, Mexico into Clark County. Despite low $PM_{2.5}$ concentrations, the Las Vegas Valley tends to be volatile organic compound (VOC)-limited, meaning that VOCs transported at height and injected into the boundary layer are much more efficient at creating ozone (as seen by the abrupt increase in ozone concentrations around 14:00 PST on June 16 at all sites [Figure 132]).

Hourly CO and NO_2 concentrations are shown in Figure 142 and Figure 143, alongside the 10th-90th percentile diurnal concentrations, calculated from 2017-2022, at each of the event-affected and supporting sites that measure CO and NO_2. There was not significant evidence for smoke impacts for either pollutant, but clearly another air mass influenced the area by the afternoon on June 16 when both typical diurnal cycles for CO and NO_2 are completely suppressed. Concentrations for both pollutants stayed nearly flat at most sites through June 17.

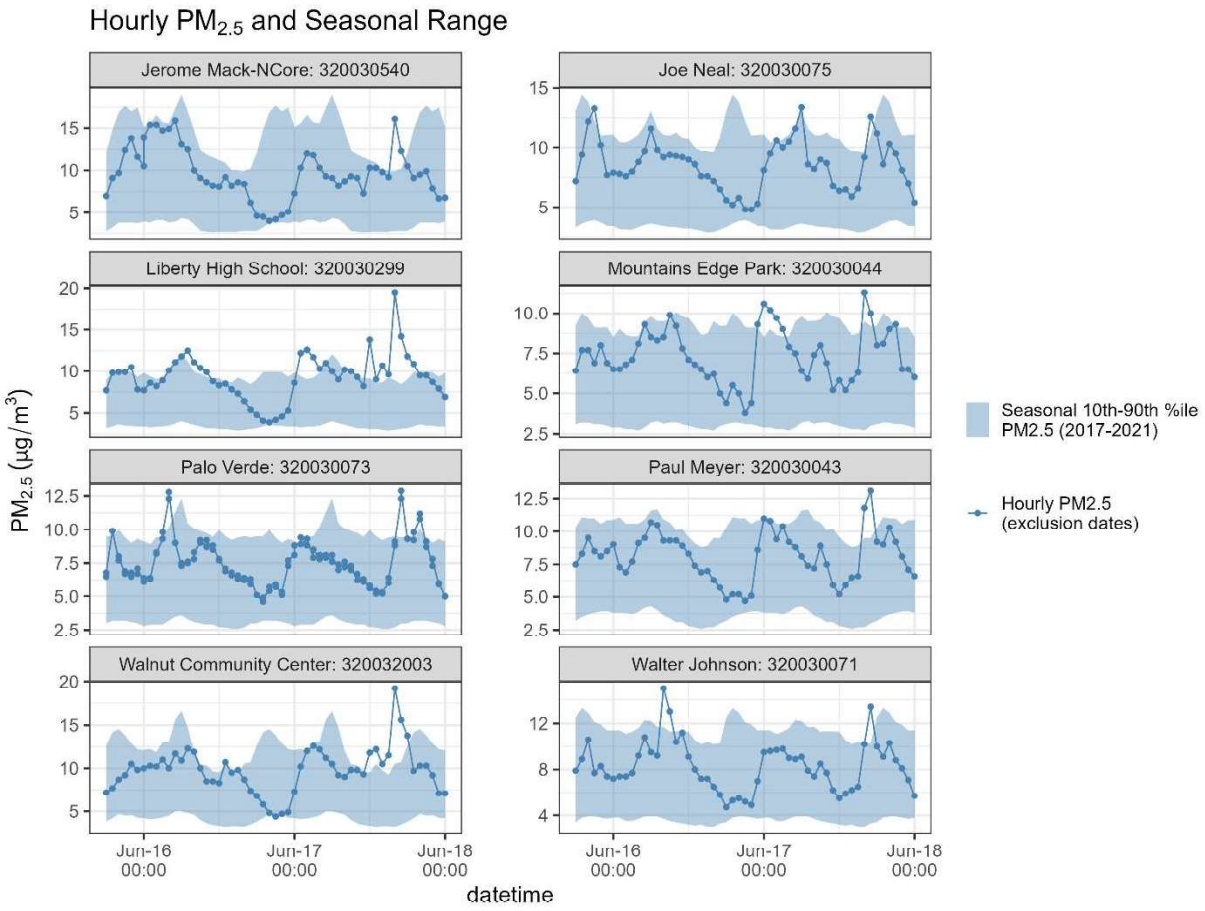

Figure 141. Hourly $PM_{2.5}$ measurements overlaid on the 10th-90th percentile diurnal concentration at the event-affected measurement sites and supporting sites that measure $PM_{2.5}$ concentrations. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2022.

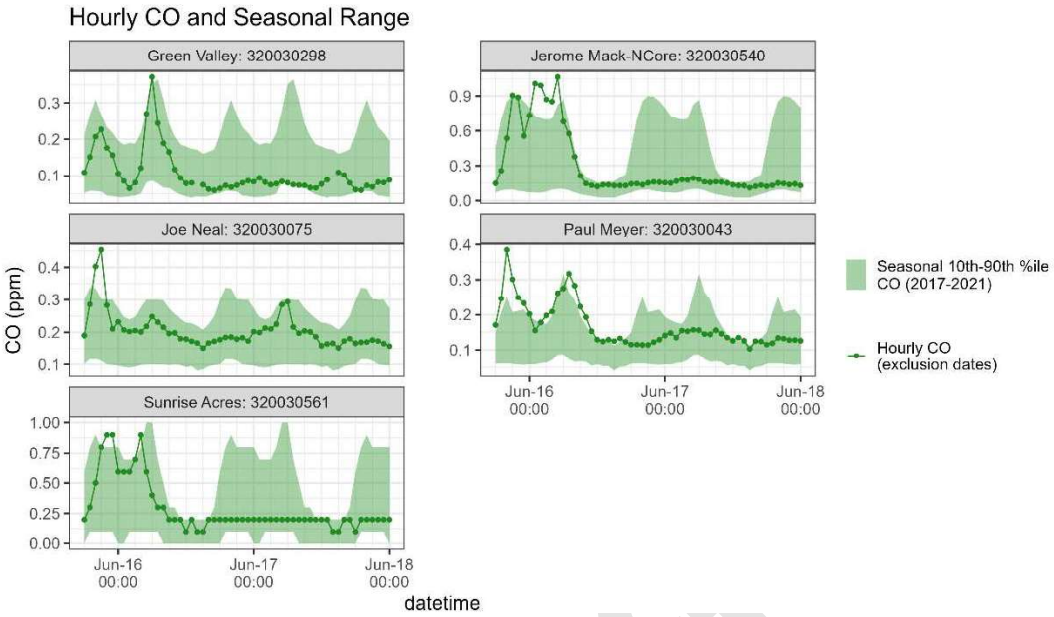

Figure 142. Hourly CO measurements overlaid on the 10th-90th percentile diurnal concentration at the event-affected sites and supporting sites that measure CO. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2022.

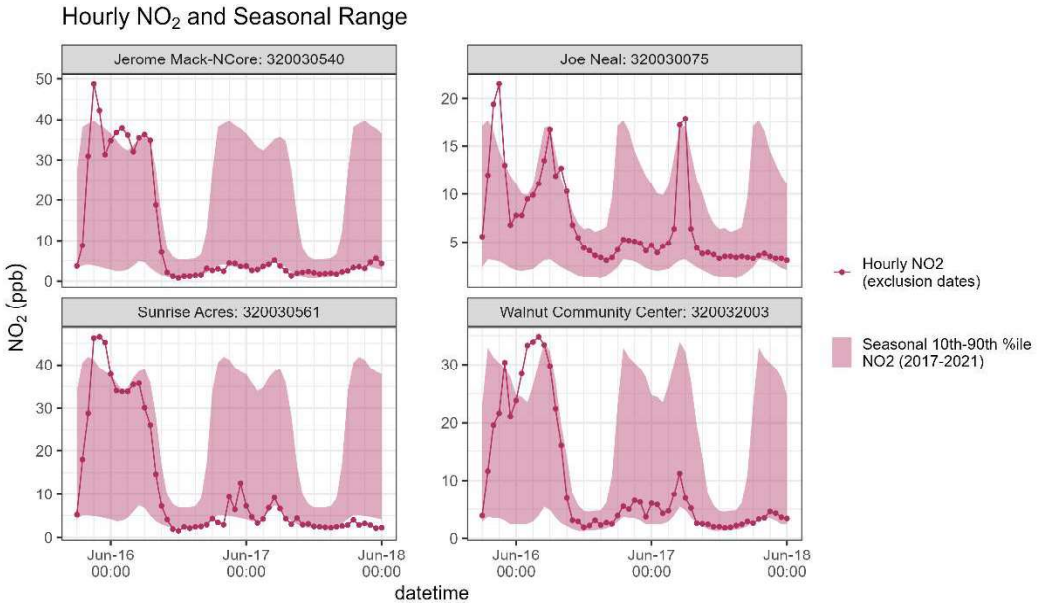

Figure 143. Hourly NO_2 measurements overlaid on the 10th-90th percentile diurnal concentration at the event-affected sites and supporting sites that measure NO_2. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2022.

Three 8-hr acetaldehyde cannister measurements are taken every three days at the Jerome Mack-NCore site each year from June 1 through August 30. The resulting acetaldehyde data for before, after, and on the exclusion date are in Figure 144. Enhanced acetaldehyde concentrations may be an indication of the presence of wildfire smoke, although this can also be due to other photochemical reactions and anthropogenic sources.[27,28,29] The measurement on June 16, 2022, from 04:00 – 12:00 PST was well above the 2022 90th percentile and was the second highest measurement of acetaldehyde during 2022. The measurement on June 16 at 12:00-20:00 PST was also at the 90th percentile of data for 2022, indicating an unusual amount of acetaldehyde, coinciding with the transport of smoke into the area. Again, this indicates the presence of additional VOCs in the Las Vegas Valley, which would support enhanced ozone production.

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[27] Wentworth et al. (2018) Impacts of a large boreal wildfire on ground level atmospheric concentrations of PAHs, VOCs and ozone. Atmospheric Environment. https://www.sciencedirect.com/science/article/pii/S1352231018300190.
[28] Liang et al. (2022) Aging of Volatile Organic Compounds in October 2017 Northern California Wildfire Plumes. Environmental Science & Technology. https://pubs.acs.org/doi/full/10.1021/acs.est.1c05684.
[29] Vicente et al. (2011) Measurement of trace gases and organic compounds in the smoke plume from a wildfire in Penedono (central Portugal). Atmospheric Environment. https://www.sciencedirect.com/science/article/pii/S1352231011006145.

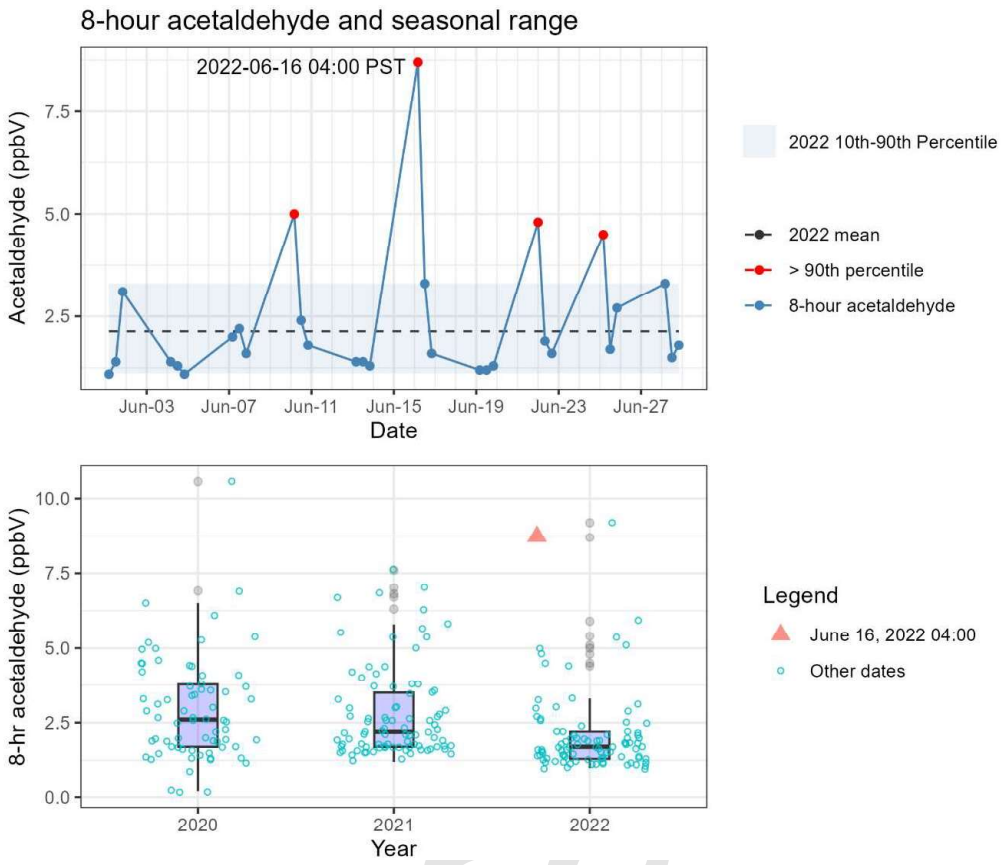

Figure 144. (Top) 8-hr acetaldehyde measurements before, on, and after the exclusion date overlaid on the 10th-90th percentile concentration in 2022. (Bottom) 8-hr acetaldehyde measurements grouped by year of measurement, where the box indicates the 25th-75th percentile of data, and the median is the solid line across the box. Individual datapoints have been overlaid across the boxplots.

5.1.5 Matching Date Analysis

Local meteorological conditions have a strong influence on day-to-day ozone production. Similar local meteorological conditions are expected to yield similar levels of local ozone production, barring any atypical influence on a given date. This section compares ozone concentrations between the exclusion date and dates that are meteorologically similar. If an external source of ozone or ozone precursors were present in the Las Vegas region on the exclusion date, the ozone concentrations are likely to be statistically different from the meteorologically similar dates. Days between 2017-2022 with similar meteorological conditions as the exclusion date were identified according to four key meteorological measurements: maximum daily wind speed, maximum daily temperature, mixing height at 16:00 LST (00:00 UTC), and average daily relative humidity. Table 31 shows the source of each meteorological parameter and the threshold used to define a "similar" measurement. Note that mixing height data is unavailable from NOAA's National Centers for Environmental Information (NCEI) Integrated Global Radiosonde Archive (IGRA) at Las Vegas between June 15-16, 2022. Mixing

heights were derived manually for the exclusion date, June 16, 2022, based on the same parcel method (i.e., Holzworth method) used by NCEI to derive mixing heights. Other atypical event dates identified in this document were omitted from the pool of potential similar dates. Table 32 shows the 10 dates identified with meteorological conditions similar to the exclusion date, June 16, 2022. The exclusion date had a maximum daily temperature of 108°F, daily average relative humidity of 7.38%, maximum hourly wind speed of 11.2 kts, and a mixing height of 3,015 m AGL at 16:00 LST. None of the 10 similar dates recorded an MDA8 ozone above the NAAQS at any of the sites that were in exceedance on the exclusion date.

Table 31. Meteorological parameters used to identify dates with similar meteorological conditions to the exclusion date. The threshold used to define a "similar" measurement to the observed measurement on the exclusion date is listed per parameter.

Parameter	Data Source	"Similar" Threshold
Hourly Wind Speed measured at Jerome Mack – NCore AQS site	U.S. EPA Air Quality System Data Mart	+/- 2.5 kts
Hourly Temperature measured at Jerome Mack – NCore AQS site	U.S. EPA Air Quality System Data Mart	+/- 5 °F
Hourly Relative Humidity measured at Jerome Mack – NCore AQS site	U.S. EPA Air Quality System Data Mart	+/- 10%
Mixing Height AGL at 16:00 LST (00 UTC) at NWS Forecast Office Las Vegas, NV	• NOAA NCEI IGRA • Manually derived from Skew-T diagrams available from the University of Wyoming Department of Atmospheric Science for June 16, 2022.	+/- 300 m

Table 32. Dates between 2017-2022 identified as meteorologically similar to the exclusion date based on the thresholds listed in Table 31. Measurements on the exclusion date are listed for reference in the first row (bold). Maximum Site MDA8 Ozone is the maximum concentration measured across the Paul Meyer, Joe Neal, and Mountains Edge monitoring sites. Note Mountains Edge data was not available before 2021.

Date	Max. Hourly Wind Speed (kts)	Mixing Height at 16:00 LST (m AGL)	Max. Hourly Temperature (°F)	Average Hourly RH (%)	Maximum Site MDA8 Ozone (ppb)
06/16/2022	**11.2**	**3,015**	**108**	**7.38**	**72**
06/27/2017	8.9	3,248	108	6.33	53
06/09/2018	12.0	3,083	103	10.58	65
06/28/2018	13.5	3,189	105	6.17	61
07/02/2019	11.2	2,896	105	7.62	69
07/17/2019	10.2	2,846	106	10.12	60
07/18/2019	10.8	2,746	107	10.88	51
07/19/2019	10.2	2,768	104	10.33	62
08/22/2019	11.3	2,777	106	8.00	59
08/02/2020	11.5	2,738	110	3.88	63
08/26/2020	10.1	3,168	109	10.08	63

Figure 145 shows the comparison of the exclusion date concentration to concentrations on meteorologically similar dates at each exceedance site. The Mountains Edge monitoring site began reporting ozone concentrations on September 30, 2020, after any of the similar dates. Therefore, a comparison of MDA8 ozone concentrations is not available for this site. The MDA8 ozone concentration is elevated on the exclusion date compared to the distribution of MDA8 ozone concentrations measured on meteorologically similar dates. At Paul Meyer and Joe Neal, the MDA8 ozone concentration measured on the exclusion date is higher than MDA8 ozone concentration measured on any other meteorologically similar date. Higher-than-expected ozone concentrations measured on the exclusion date compared to meteorologically similar dates provide evidence of an external source of ozone and/or ozone precursors on the exclusion date.

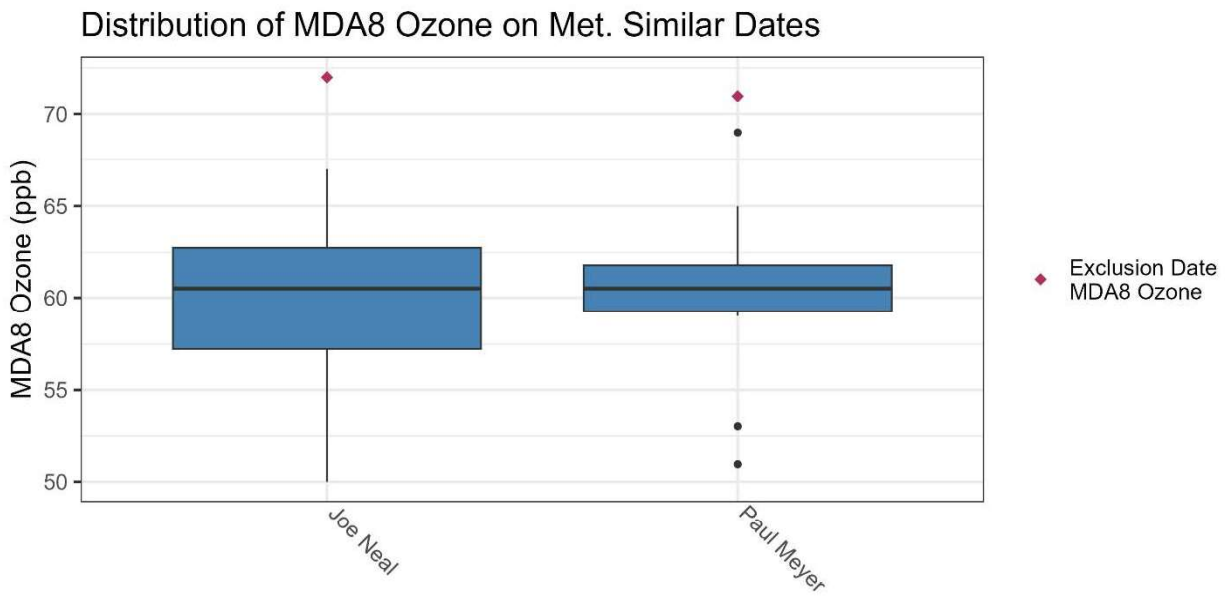

Figure 145. Distribution of MDA8 ozone concentrations on meteorologically similar days at the Paul Meyer and Joe Neal measurement sites (blue boxes). MDA8 ozone concentrations measured on the exclusion date (June 16, 2022) at each site are plotted as red diamonds. Mountains Edge data was unavailable for the meteorologically similar dates and not included in this figure.

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5.1.6 Event Statistics

Table 33 summarizes the daily measurements of ozone, $PM_{2.5}$, CO, and NO_2 concentrations collected at the Joe Neal, Paul Meyer, and Mountain Edge Park sites on the June 16, 2022, exclusion day, as well as the percentile rank of the observations compared to the previous five years of data (2018-2022) at both sites. On June 16, 2022, ozone MDA8 measurements at all three sites were above the 94.9th percentile. The 24-hr average $PM_{2.5}$ concentrations were above the 76th percentile at all three sites on June 16. The 1-hr daily maximum CO concentrations reached the 37th percentile at the Joe Neal site on June 16 and the 82nd percentile at the Paul Meyer site, and 1-hr daily maximum NO_2 measurements at the Joe Neal site reached the 65th percentile on June 16.

Table 33. Percentile of pollutant measurements on the June 16, 2022, exclusion day compared with most recent five years of pollutant concentration data (2018-2022).* The percentile rank is calculated across the ozone production season (May 1-October 31) of 2018-2022.

Date	Site Name	Site Code	Ozone		$PM_{2.5}$		CO		NO_2	
			Ozone MDA8 (ppb)	Percent Rank	$PM_{2.5}$ 24-hr Avg ($\mu g/m^3$)	Percent Rank	CO 1-hr Daily Max (ppb)	Percent Rank	NO_2 1-hr Daily Max (ppb)	Percent Rank
6/16/2022	Joe Neal	320030075	72	96.8	7.7	76.8	248	37*	16.7	65.7
6/16/2022	Paul Meyer	320030043	71	94.9	7.6	78.3	317	82.4*	--	--
6/16/2022	Mountain's Edge	320030044	70	96.2*	6.9	76.7*	--	--	--	--

*Sites that have less than five years of data available for a given parameter.

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5.2 July 17, 2022

5.2.1 Event Summary

An ozone event took place on July 17, 2022, and affected five sites in Clark County, Nevada. Regional wildfire smoke is suspected to have contributed to the NAAQS exceedances. The data presented in this document shows there was a large amount of smoke from wildfires in the western U.S. and Canada during the ozone event. Additionally, there is evidence of a large, well-mixed boundary layer above Clark County on July 17 that could mix smoke to the surface and affect ozone concentrations. This combination of evidence, which includes HMS smoke detection, PBL analysis, HYSPLIT back trajectories, and HRRR smoke data, suggests this may be an unrepresentative event for base and future design value ozone assessments.

Sites exceeding the NAAQS had MDA8 ozone concentrations ranging from 72-76 ppb (Table 34). Throughout the Las Vegas Valley, MDA8 ozone concentrations ranged from 64 to 76 ppb on July 17, with an average MDA8 concentration of 70 ppb. Figure 146 shows time series graphs of hourly ozone concentrations that exceeded the seasonal means (calculated using May 1 – October 31, 2017-2021) and 10th-90th percentiles at each affected site. Ozone levels exceeded 90th percentiles on July 17 during peak midday ozone hours and remained above the 90th percentile at most sites during the expected overnight minimum. This indicates well-above normal ozone production and likely influence from atypical sources of ozone precursors.

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Table 34. Sites with MDA8 ozone levels (ppb) exceeding the NAAQS on July 17, 2022.

Site Name	Site Code	Ozone MDA8 (ppb)
Garrett Jr. High	320030602	72
Green Valley	320030298	73
Jerome Mack-NCore	320030540	71
Liberty High School	320030299	72
Walnut Community Center	320032003	76

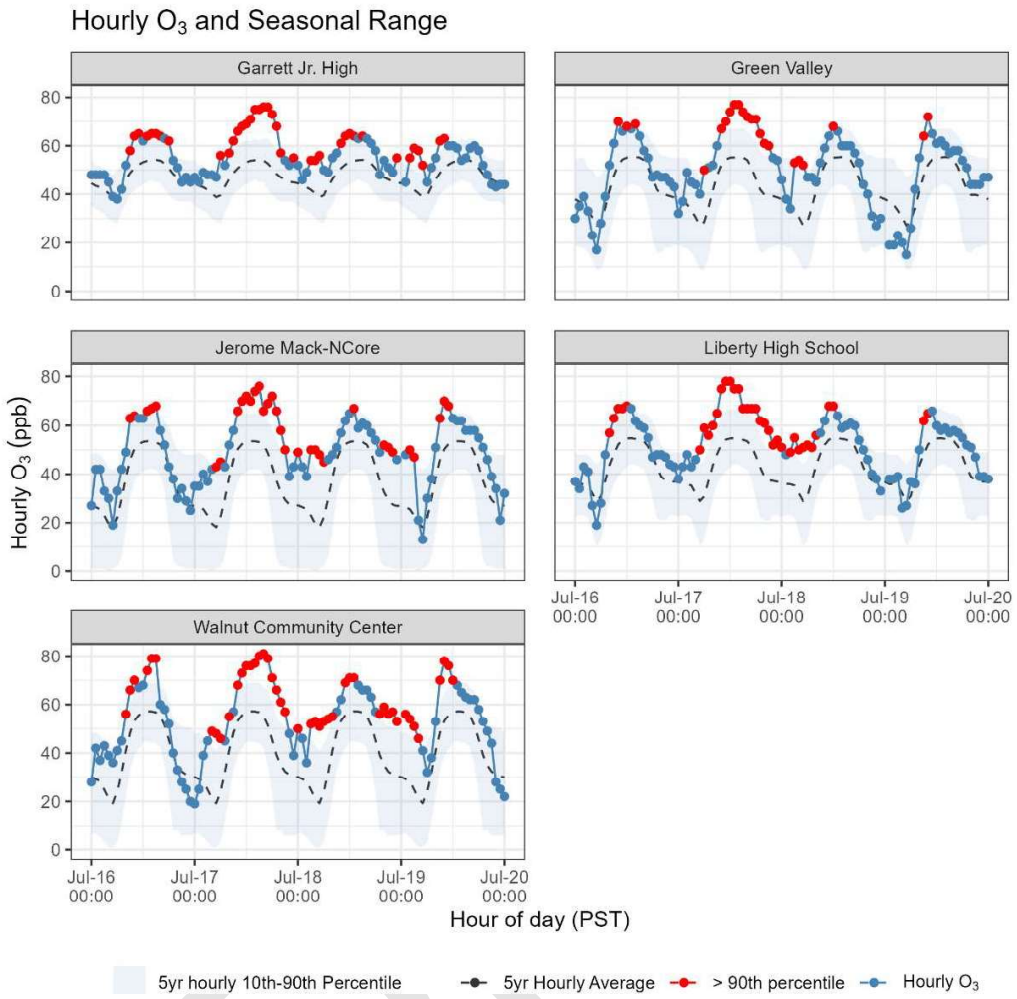

Figure 146. Hourly ozone concentrations (ppb) compared to 5-yr ozone season (May 1-October 31) hourly means and 10th-90th percentiles. Data collection did not begin until 2021 at Garrett Jr. High, Liberty High School, and Walnut Community Center, so data for these sites begins from the first available date in 2021.

5.2.2 Identification of Wildfires

Figure 147 shows the progression of smoke dispersion across the United States between July 14 and July 17, 2022. HMS smoke maps are created using visible satellite imagery from Geostationary Operational Environmental Satellites (GOES). Visible imagery is only available during the sunlit part of the GOES orbit. Therefore, smoke movement during nighttime hours is inferred between the daylight-generated smoke maps. Distinct northeasterly plumes from fires in northern Nevada and California are visible on July 14. In addition, significant smoke from extremely large Canadian wildfires is also visible. Over the next few days, this smoke was driven in a clockwise direction by a high-pressure system (as shown in Figure 148) over the southwestern United States, looping south across the center of the U.S., then through New Mexico and west towards southern Nevada. By July 17, 2022, HMS smoke was detected over Clark County, NV.

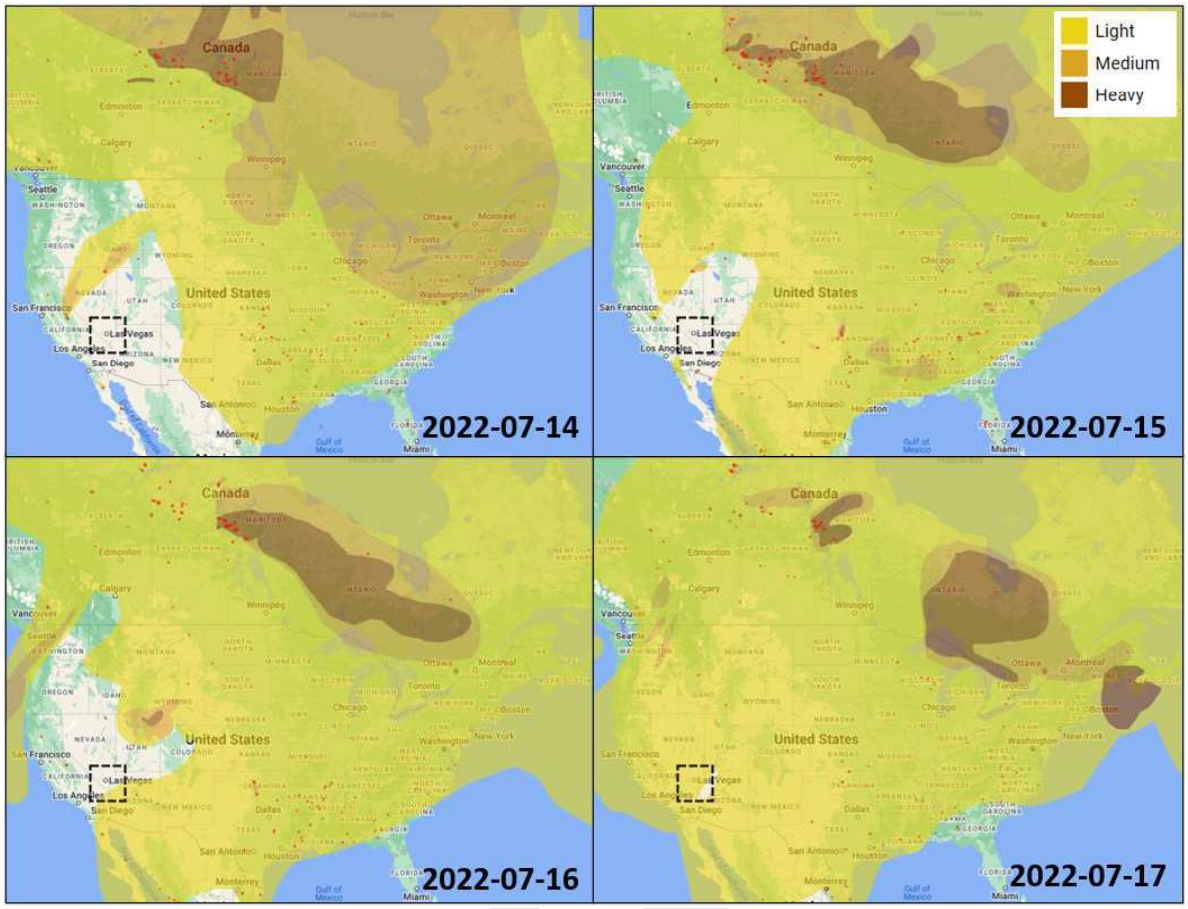

Figure 147. HMS smoke for July 14 - 17, 2022 is included with qualitative smoke density. Clark County, NV, is enclosed by black, dashed box.

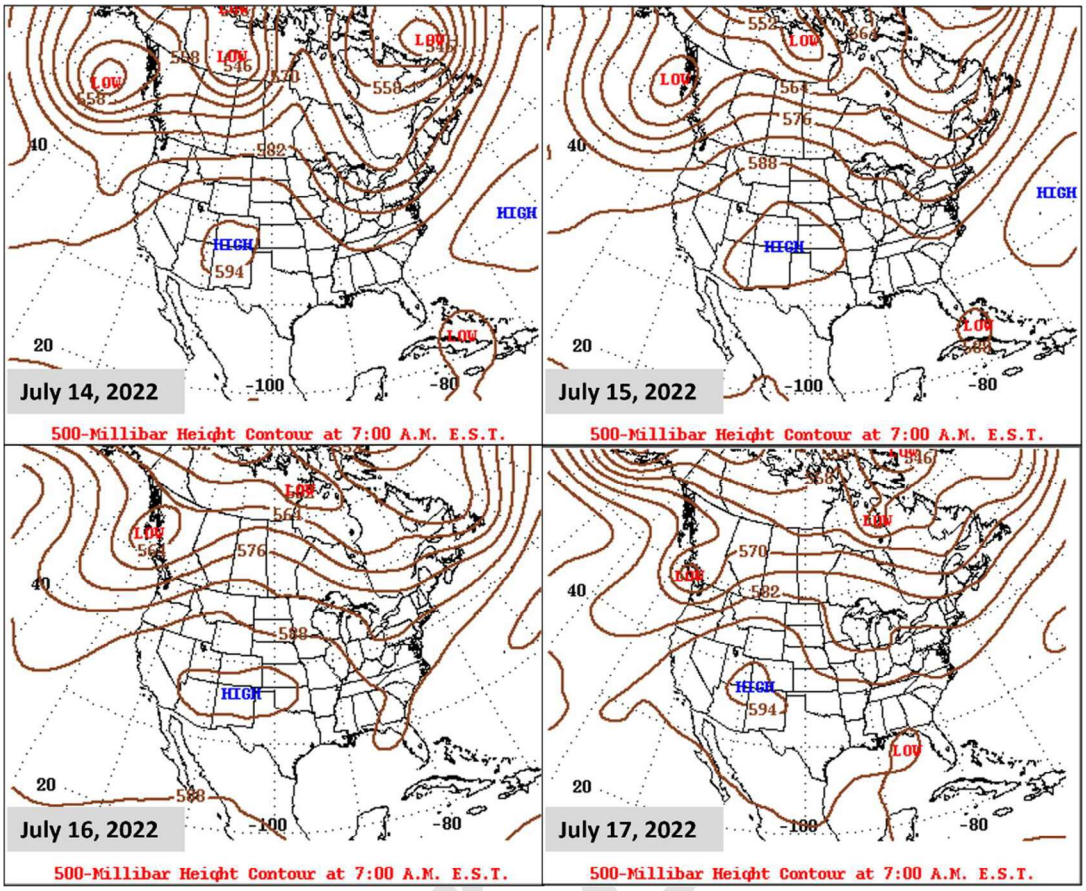

Figure 148. Daily 500-mb weather maps for July 14-17, 2022.

Two active wildfires in the United States, the Wildcat fire in Nevada and the Washburn fire in California, as well as three very large Canadian wildfires were active during the days leading up to and including the exclusion dates. All five fires had sizable growth leading up to July 17, as seen in Table 35, which presents the state, total acres within the fire perimeter, actively burning acres on the exclusion day, and the start date and containment date for each fire based on data from InciWeb.[30] Daily information on the Canadian wildfires is limited beyond satellite information. Fire perimeters for each fire identified in relation to Clark County are shown in Figure 149. A zoomed in view of each fire is shown in Figure 150.

[30] https://inciweb.nwcg.gov/

Table 35. Wildfires affecting Clark County on the exclusion days. Accurate daily fire sizes on or before the exclusion day for the Canadian fires are not available. Instead, these fires were chosen based on HMS fire points.

Wildfire Name	State	Total Acres	Acres Burned on or Before Exclusion Days	Start Date	Containment Date
Wildcat	Nevada	21,429	21,440 (Jul 16)[31]	Jul 13	Jul 23
Washburn	California	4,886	4,856 (Jul 17)[32]	Jul 7	Sep 30
Manitoba Complex	Manitoba-Canada	103,924[33]	--	Jul 13	Sep 5
Saskatchewan Fire	Saskatchewan - Canada	43,068[3]	--	Jun 29	Jul 27
Alberta Complex	Alberta-Canada	75,974[3]	--	Jun 15	Oct 9

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[31] https://inciweb.nwcg.gov/incident-publication/nvhtf-wildcat/wildcat-fire-7162022-news-release. Note this number is larger than the total acres burned because it was an estimate. Total area burned can then be lower when the final burn perimeter is identified.

[32] https://inciweb.nwcg.gov/incident-publication/caynp-washburn-fire/washburn-fire-daily-update-for-july-22-2022

[33] https://cwfis.cfs.nrcan.gc.ca/datamart/download/nbac

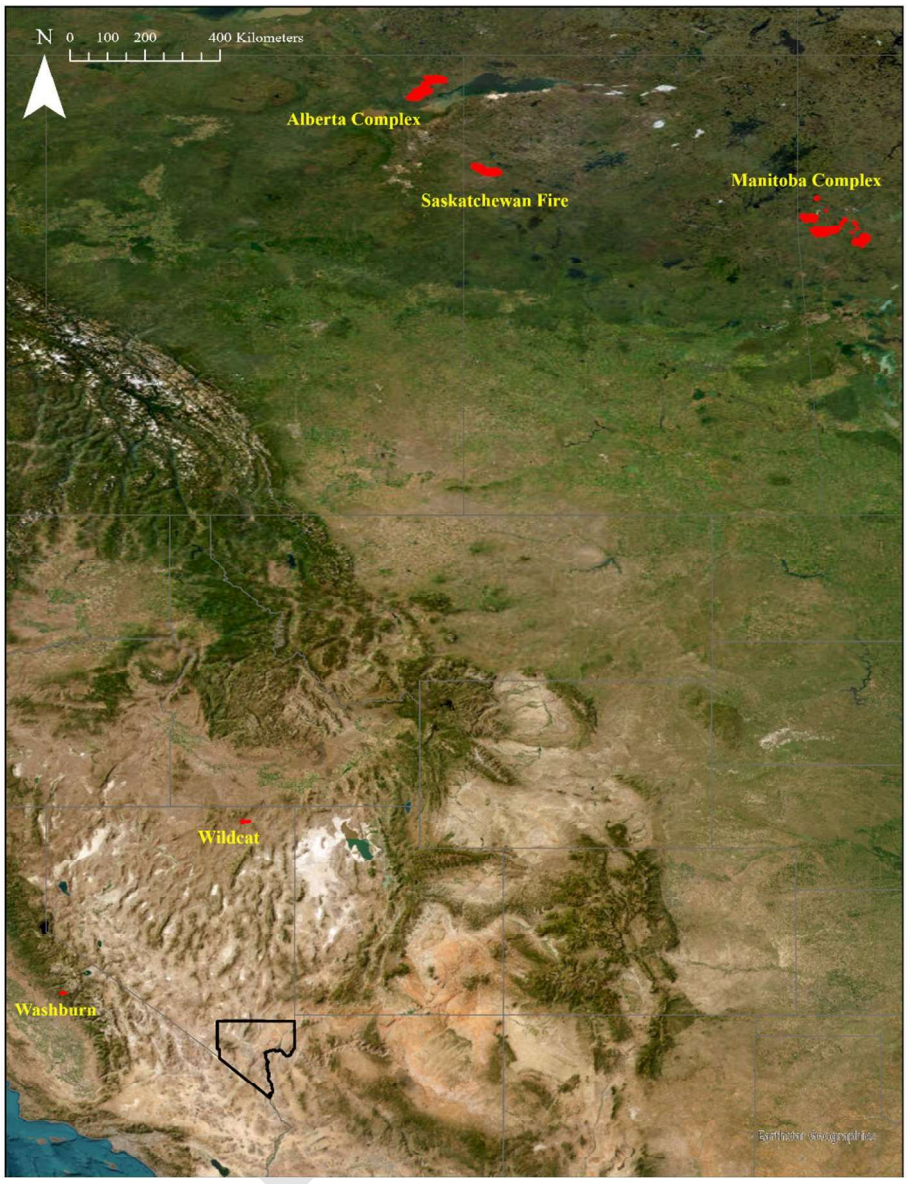

Figure 149. Final fire perimeters (red) for the five active fire regions during the July 17, 2022, exclusion date in relation to Clark County (black perimeter).

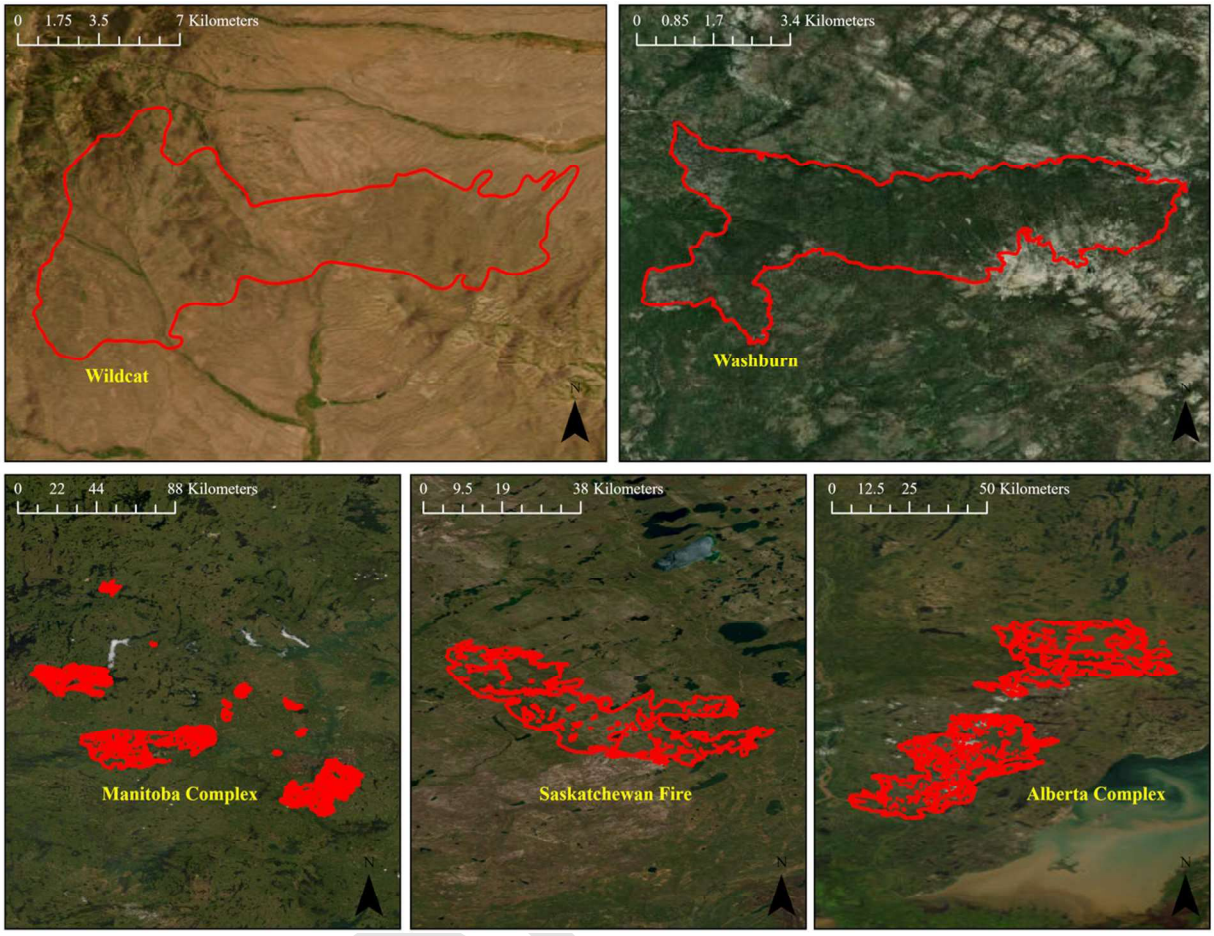

Figure 150. Final fire perimeters (red) for the five active fire regions during the July 17, 2022, exclusion date.

5.2.3 Regional Analysis

To examine the effect of wildfire smoke in Clark County (as indicated by HMS smoke in Section 5.2.2), we first determined the meteorological conditions on and before the July 17 event. We specifically focused on the boundary layer dynamics to determine the depth of mixing and possibility of smoke mixing to the surface. We then used this information to model smoke via HYSPLIT and compared the results with independent data sources (including HMS and HRRR data).

The PBL denotes the atmospheric layer closest to the surface, and the height of the PBL describes the vertical extent of surface air characteristics. Atmospheric soundings and PBL maps provide visualizations of the extent of vertical mixing in the lower troposphere. The three skew-T diagrams, shown in Figure 151, show the vertical profile of the atmosphere from the Las Vegas upper-air weather station (KVEF) on July 17 at 00:00 UTC (July 16 at 16:00 PST), July 17 at 12:00 UTC (04:00 PST), and July 18 at 00:00 UTC (July 17 at 16:00 PST). The three skew-T diagrams are characterized primarily by large, well-mixed boundary layers above the surface with the temperature line following

near the dry adiabatic lapse rate lines. While the sounding on July 17 at 04:00 PST shows a small inversion near 900 mb (~745 m), this inversion is gone by the afternoon on July 17. By July 17 at 16:00 PST (July 18 at 00:00 UTC), the lower PBL was well-mixed up to approximately 4,000 m above ground level (AGL). The estimated PBL of 4,000 m AGL on July 17 was higher than KVEF's 2017-2021 climatological average PBL for July 17 at 00:00 UTC, which is 3,200 m AGL.

The NAM-modeled PBL heights over Clark County on July 17 at 16:00 PST also correspond to the PBL heights of approximately 3,000 to 4,000 m shown on the sounding of the same time (Figure 152; this map shows PBL heights above 2 km in altitude in 1 km increments, with colors starting at 1 km). Both the skew-T diagrams and NAM-modeled PBL heights over Clark County on July 17 indicate a deep well-mixed boundary layer. The PBL analysis shows a well-mixed boundary layer up to 4,000 m on July 17, which suggests smoke transported into the well-mixed layer would be available for mixing with the surface and would potentially impact ground-level ozone concentration.

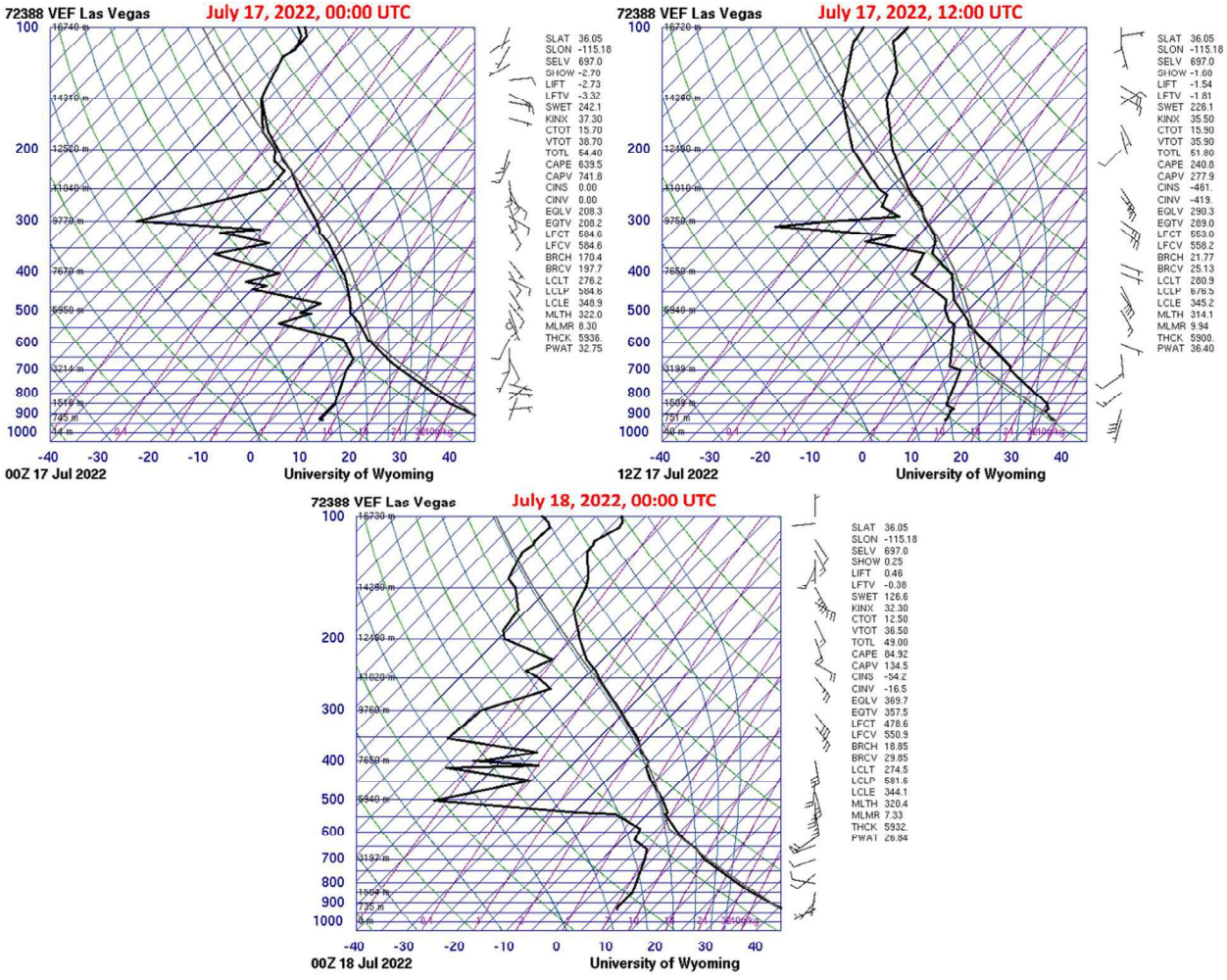

Figure 151. Skew-T soundings launched from KVEF from July 17, 2022, at 00:00 UTC (July 16 at 16:00 PST) (top left) to July 18 at 00:00 UTC (July 17 at 16:00 PST) (bottom right).

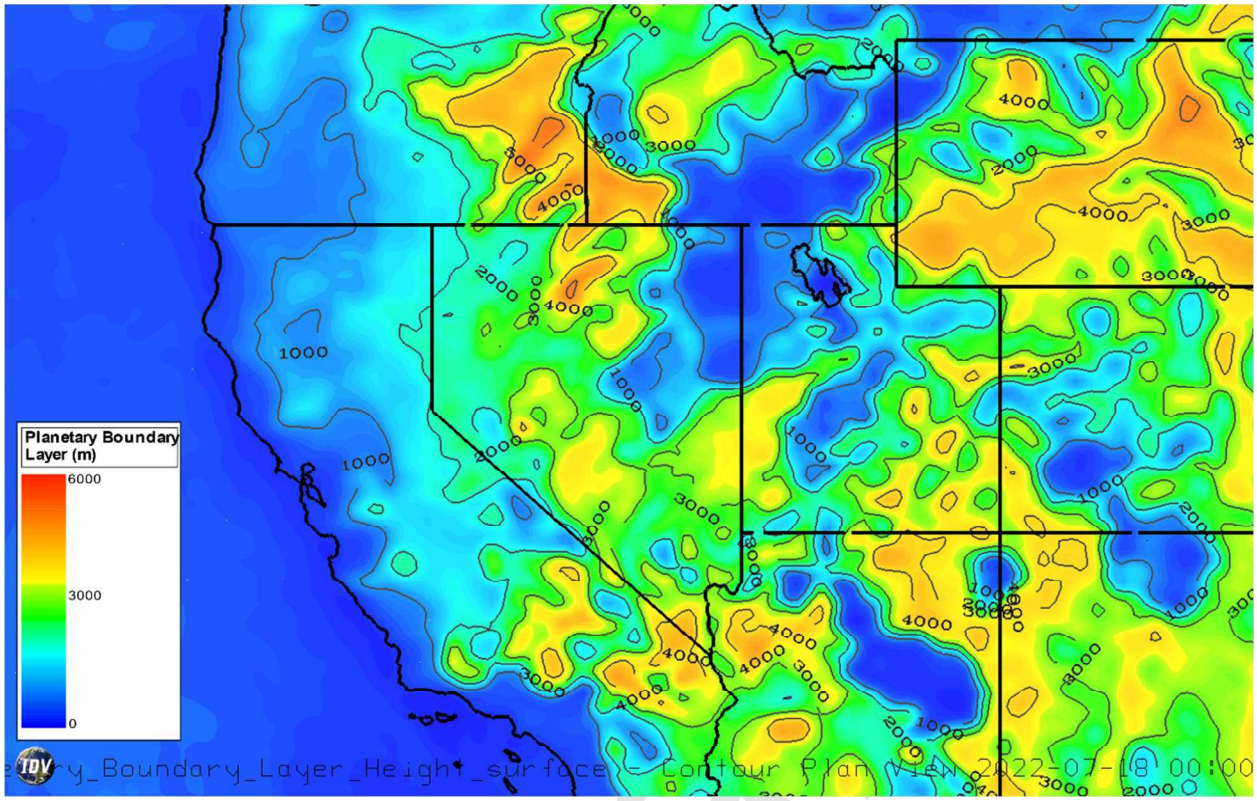

Figure 152. PBL height contour map based on the NAM model for July 18 at 00:00 UTC (July 17 at 16:00 PST). The gray lines denote PBL heights above 1 km in altitude in 1 km increments. Color contouring starts at 0 km.

HYSPLIT dispersion modeling could not be accurately performed for this exclusion date due to the large contributions from Canadian wildfires. The daily fire size data of the Canadian fires could not be obtained and, therefore, these fires could not be modeled accurately. A HYSPLIT back trajectory was performed for 16:00 UTC (08:00 PST) on July 17, 2022 (Figure 153). The back trajectory shows the general pattern of air from the California and Nevada fires, through the Canadian smoke plumes, and finally, descent of air into the boundary layer in the Las Vegas area from high altitude in the morning on July 17, providing smoke products and ozone precursors and setting up a day for enhanced ozone production. This is consistent with the HMS and meteorological narrative from Section 5.2.2 and shows air descending from 4,000 – 8,000 m into a well-mixed boundary layer.

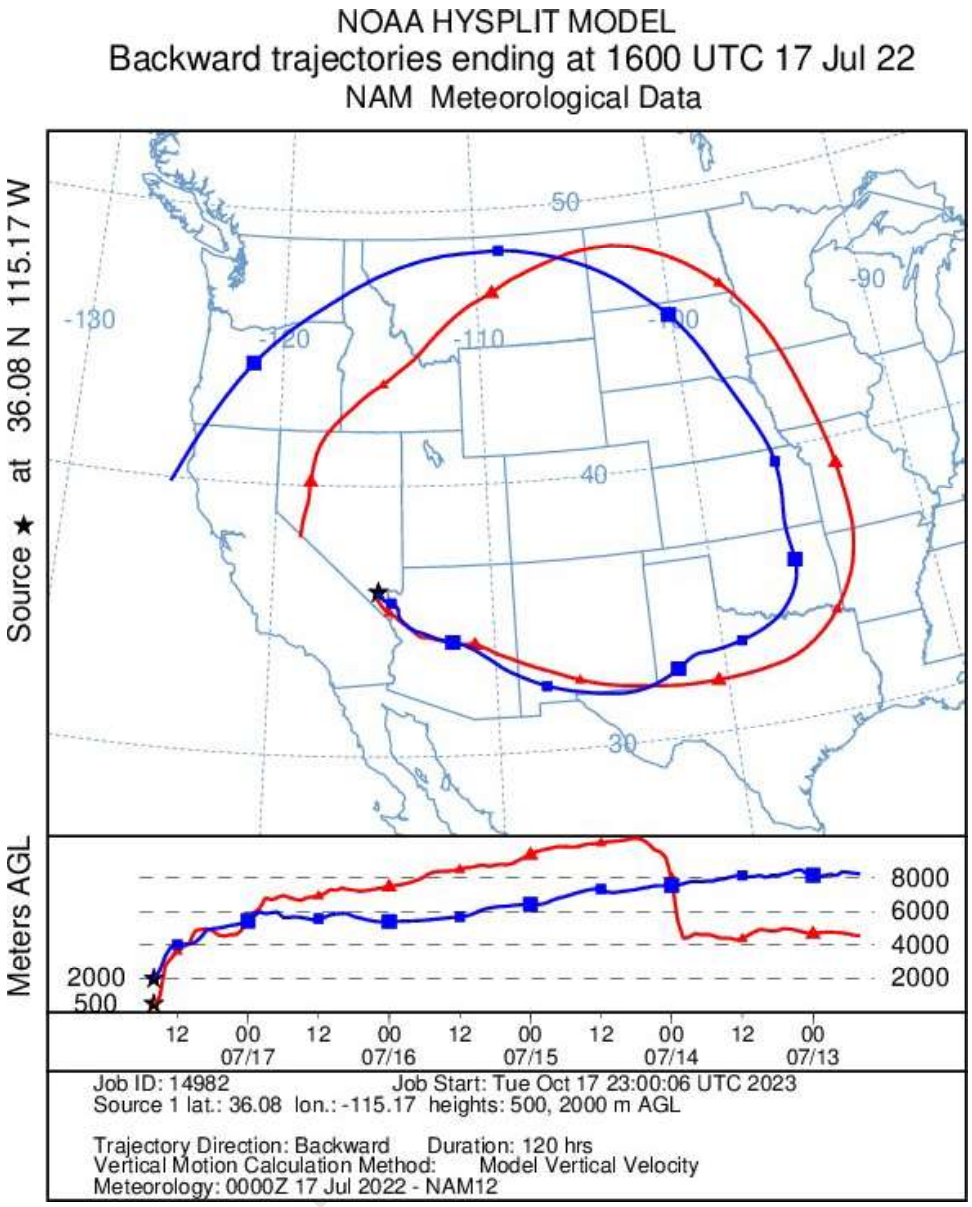

Figure 153. HYSPLIT back trajectory initiated at 16:00 UTC (08:00 PST) on July 17, 2022, using NAM 12 km meteorology. The back trajectory ran for 120 hours, ending in Las Vegas (36.08, -115.17) at 500 m and 2,000 m AGL.

In addition to the HMS smoke plumes analyzed directly over Clark County on July 17, 2022 (see Figure 147), HYSPLIT back-trajectories initiated on July 17 and extending back 72 hours indicated direct smoke transport from regional smoke plumes analyzed on previous days into Clark County on July 17. Specifically, low-level back-trajectories at 200, 400, and 600 m AGL showed transport from a smoke plume to the east, over eastern Arizona, New Mexico, and Texas, on July 15 (Figure 154). It should be noted that the extensive smoke plume observed to the east of Clark County on July 15 likely had its origins in the Canadian fires several days prior.

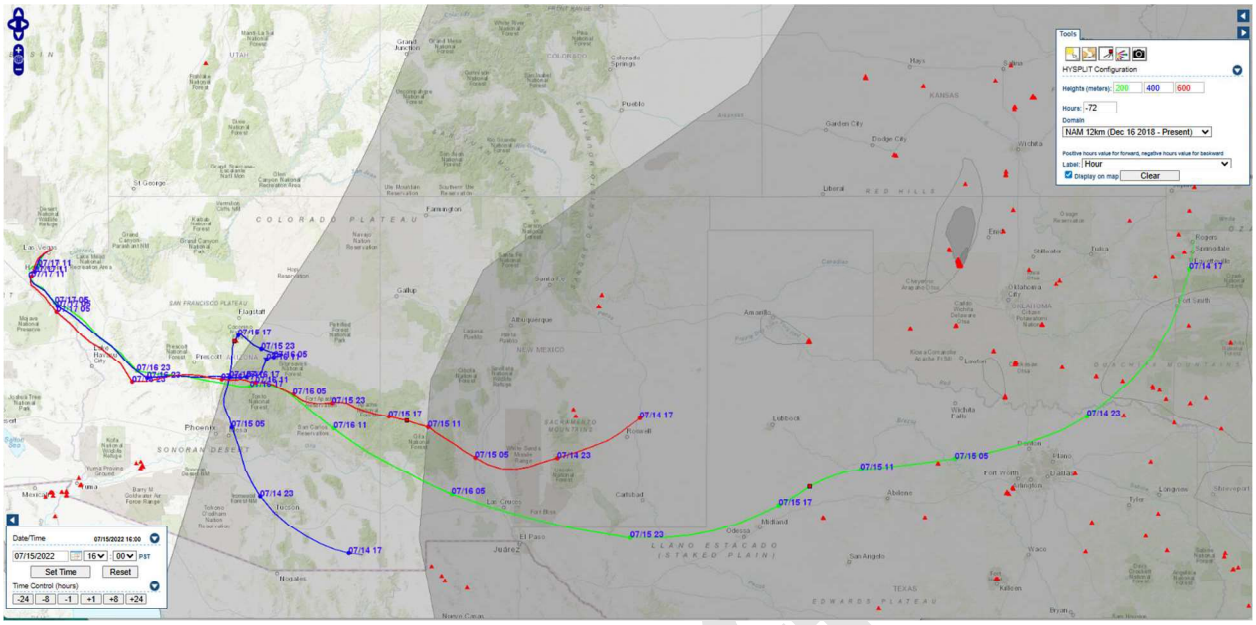

Figure 154. 72-hour HYSPLIT back-trajectories at 200 (green line), 400 (blue line), and 600 m (red line) AGL initiated at 00:00 UTC on July 18, 2022 (16:00 PST on July 17), using NAM 12 km meteorology, with HMS fire locations (red triangles) and smoke plumes (gray shading) shown on July 15. Source: AirNow-Tech.

The PBL height in Clark County on July 17 (4,000 m AGL) was deeper than the climatological average for the season (3,200 m AGL). This deep mixed layer allowed aloft smoke to reach the surface in Clark County on July 17. 72-hour HYSPSLIT back-trajectories at heights closer to the top of the boundary layer (3,200, 3,500, and 3,800 m AGL) indicate longer-range transport within the mixed layer. Specifically, these trajectories indicated transport from dense smoke plumes that existed to the east and northeast of Nevada, including the Upper Midwest (Figure 155). Similar to the smoke plumes shown in Figure 154 from July 15, the dense plumes over the central and north-central U.S. on July 14 (Figure 155) likely had their origins in Canadian fires on prior days.

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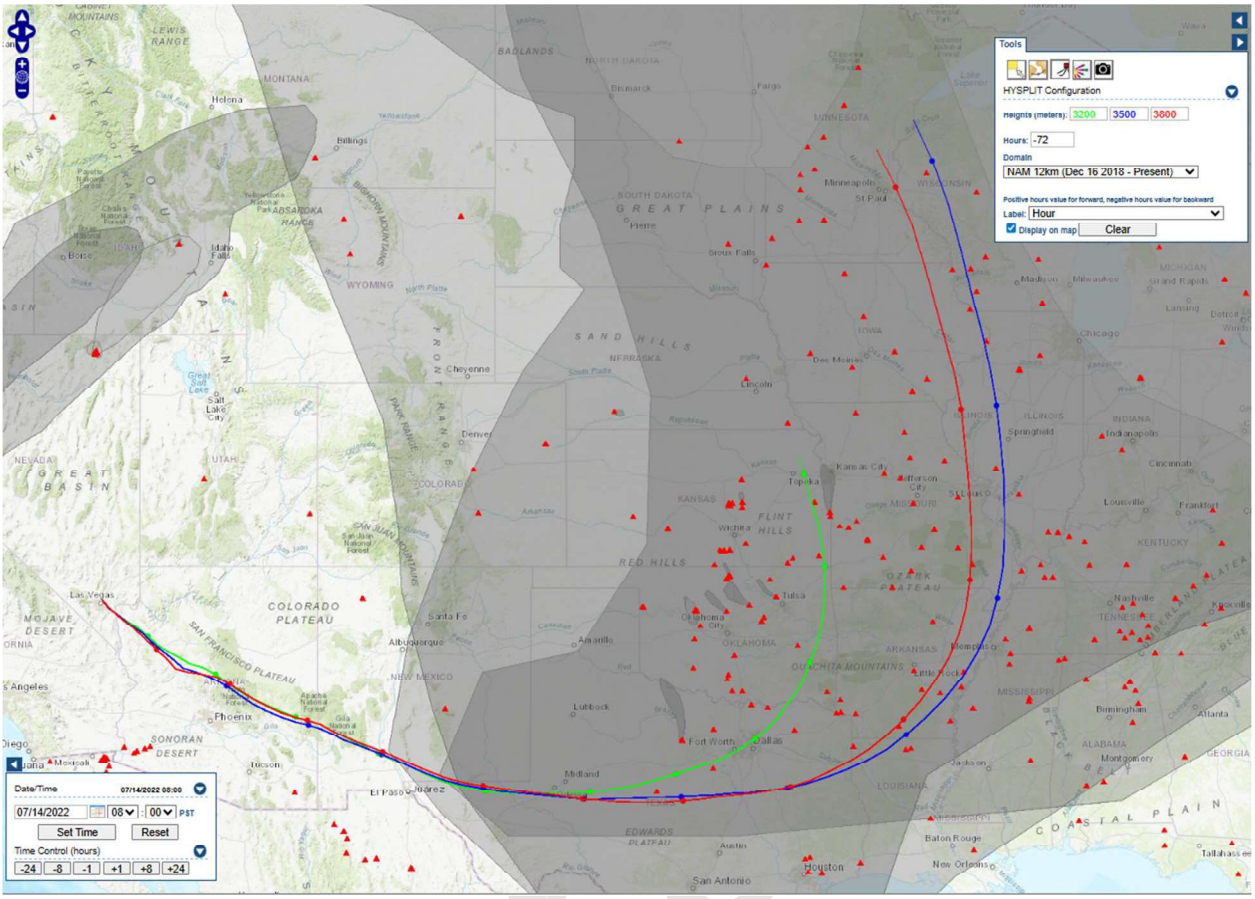

Figure 155. 72-hour HYSPLIT back-trajectories at 3,200 (green line), 3,500 (blue line), and 3,800 m (red line) AGL initiated at 16:00 UTC on July 17, 2022 (08:00 PST), using NAM 12 km meteorology, with HMS fire locations (red triangles) and smoke plumes (gray shading) shown on July 14. Source: AirNow-Tech.

The HRRR smoke product shown in Figure 156 indicates some vertically integrated smoke over the Clark County region on July 17, 2022. Based on the boundary layer analysis, smoke entering the area would have been well mixed from aloft to the surface. Taken together, the HMS smoke plumes, meteorological information, PBL analysis, HYSPLIT back trajectories, and HRRR modeled smoke data indicate plumes of smoke merged between the California, Nevada, and Canadian fires into a large, regional pool of smoke. This pool of smoke was transported around a high-pressure system in the southwest U.S. and descended into the well-mixed boundary layer in Las Vegas, enhancing ozone formation on July 17, 2022.

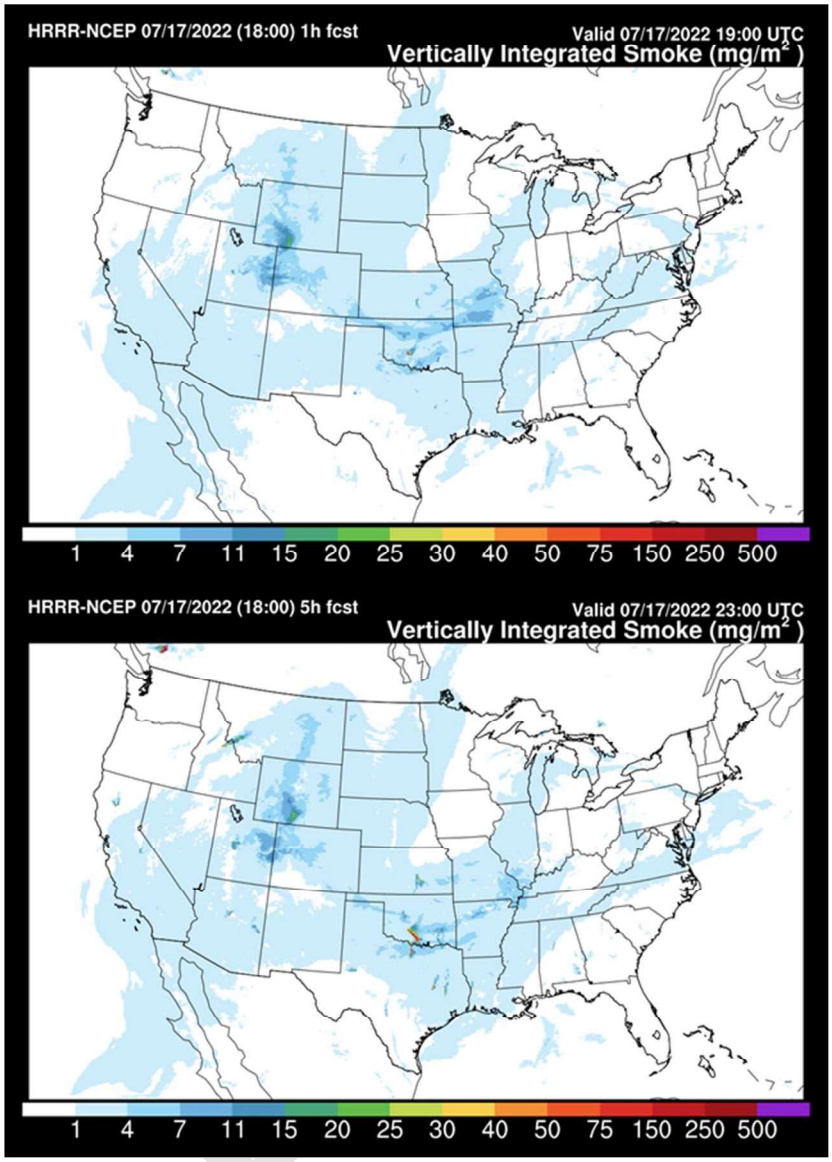

Figure 156. HRRR vertically integrated smoke forecast for July 17, 2022, at 11:00 PST and 15:00 PST.

5.2.4 Surface Impacts

Visible imagery is unavailable for this event due to a thunderstorm and associated dust event on the morning of July 17, 2022. METAR reports from July 17 showing the reports of the thunderstorm during early morning are shown in **Figure 157**.

Time	Temperature	Dew Point	Humidity	Wind	Wind Speed	Wind Gust	Pressure	Precip.	Condition
12:53 AM	93 °F	53 °F	26 %	CALM	0 mph	0 mph	27.53 in	0.0 in	Fair
1:53 AM	92 °F	52 °F	26 %	SE	5 mph	0 mph	27.53 in	0.0 in	Fair
2:53 AM	91 °F	52 °F	26 %	E	5 mph	0 mph	27.54 in	0.0 in	Fair
3:53 AM	93 °F	55 °F	28 %	CALM	0 mph	0 mph	27.55 in	0.0 in	Fair
4:53 AM	92 °F	55 °F	29 %	E	5 mph	0 mph	27.56 in	0.0 in	Fair
5:53 AM	92 °F	58 °F	32 %	ESE	8 mph	0 mph	27.58 in	0.0 in	Fair
6:53 AM	92 °F	61 °F	35 %	VAR	3 mph	0 mph	27.61 in	0.0 in	Light Rain
7:19 AM	92 °F	62 °F	37 %	E	3 mph	0 mph	27.62 in	0.0 in	Thunder in the Vicinity
7:34 AM	90 °F	66 °F	45 %	NNE	7 mph	0 mph	27.62 in	0.0 in	Light Rain
7:53 AM	89 °F	68 °F	50 %	CALM	0 mph	0 mph	27.63 in	0.0 in	Thunder in the Vicinity
8:00 AM	90 °F	66 °F	45 %	CALM	0 mph	0 mph	27.63 in	0.0 in	Thunder
8:15 AM	91 °F	64 °F	41 %	W	14 mph	0 mph	27.61 in	0.0 in	Thunder in the Vicinity
8:28 AM	91 °F	61 °F	36 %	W	15 mph	0 mph	27.59 in	0.0 in	Light Rain
8:53 AM	92 °F	59 °F	33 %	NE	10 mph	0 mph	27.62 in	0.0 in	Partly Cloudy
9:53 AM	94 °F	56 °F	28 %	E	6 mph	0 mph	27.63 in	0.0 in	Fair
10:53 AM	98 °F	54 °F	23 %	VAR	3 mph	0 mph	27.61 in	0.0 in	Fair

Figure 157. METAR report at Las Vegas International Airport (KLAS) during the morning of July 17, 2022, showing the thunderstorm that occurred early in the morning.

In this section, we provide the typical pollutant concentrations at each affected site, but the morning thunderstorm obscured any useful $PM_{2.5}$ information. $PM_{2.5}$ concentrations compared to the diurnal 10th-90th percentile $PM_{2.5}$ concentrations, calculated from 2017-2022, are shown for event-affected and supporting measurement sites in Figure 158. Hourly $PM_{2.5}$ concentrations exceeded the diurnal 90th percentile $PM_{2.5}$ concentration at multiple sites in the Las Vegas Valley between 03:00 and 06:00 PST on July 17 due to outflow from an approaching thunderstorm. The $PM_{2.5}/PM_{10}$ ratios for this event (Figure 159) show a decrease during the thunderstorm and outflow boundary event early in the morning on July 17, consistent with a dust storm. After the dust storm concluded mid-morning on July 17, the ratio increased sharply and stays above average for most sites during the early afternoon. Higher $PM_{2.5}/PM_{10}$ values are more consistent with wildfire smoke. While the $PM_{2.5}/PM_{10}$ ratio does not increase significantly, neither do the absolute $PM_{2.5}$ concentrations (Figure 158). Due to the regional nature and very long-range transport, $PM_{2.5}$ is more likely to be dispersed and not significantly enhanced. The high altitude back trajectory shown in Section 5.2.3, however, indicates that smoke and ozone precursors could have been stored along a cold transport path to decompose and enhance ozone once mixed into the boundary layer in Las Vegas.

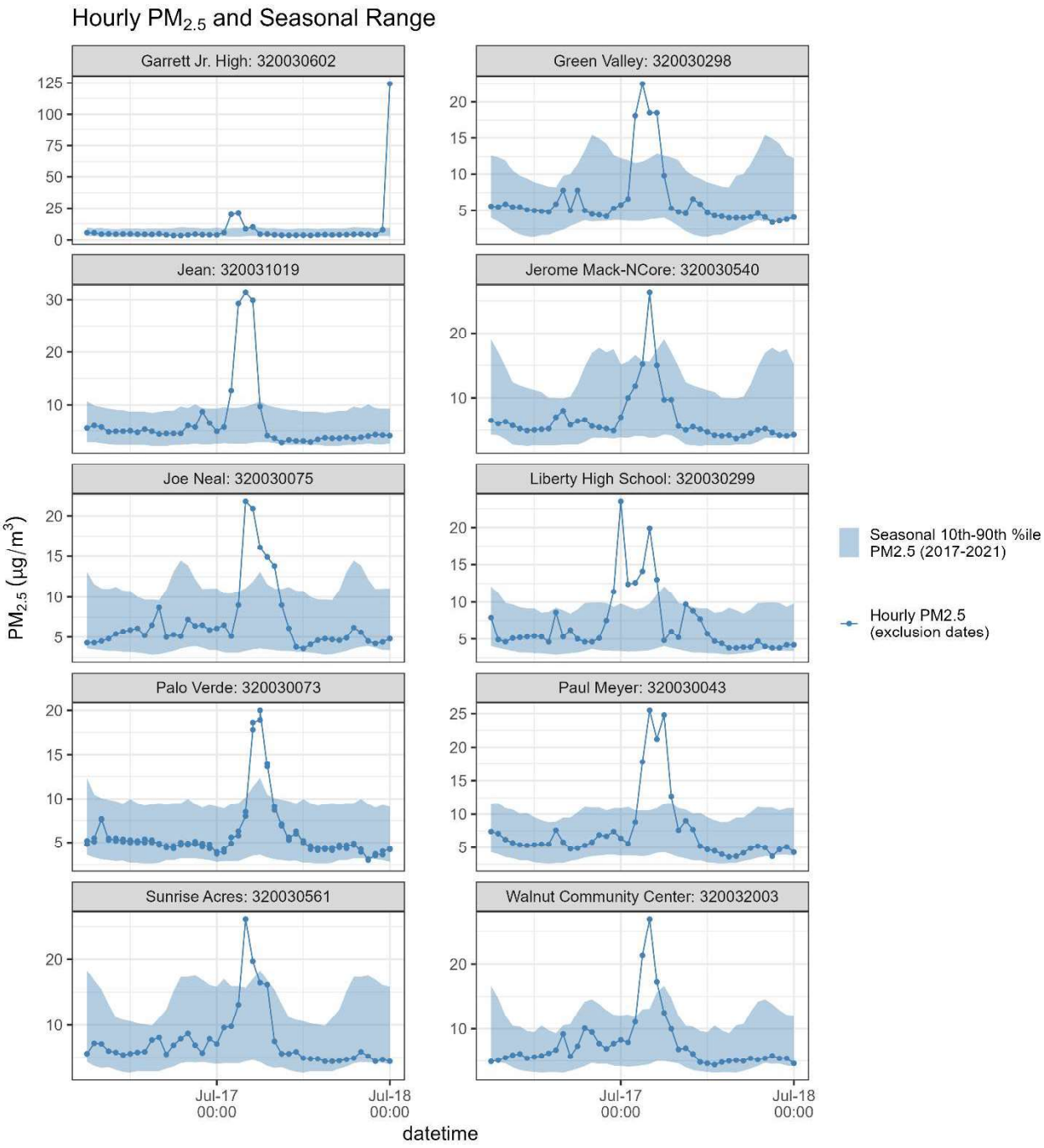

Figure 158. Hourly $PM_{2.5}$ measurements overlaid on the 10th-90th percentile diurnal concentration at event-affected measurement sites that measure $PM_{2.5}$ and supporting sites. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2022.

Figure 159. Ratio of $PM_{2.5}/PM_{10}$ concentrations at the Green Valley, Jean, Jerome Mack-NCore, Paul Meyer, and Sunrise Acres monitoring sites during the July 17, 2022, event period. The 5-yr average $PM_{2.5}/PM_{10}$ diurnal ratio is displayed as a dotted line, and the 5th-95th percentile range is shown as a shaded ribbon. The 5th-95th percentile concentration is calculated across the ozone production season (June-August) of 2018-2022.

Figure 160 and Figure 161 show a time series of the organic carbon (OC) to elemental carbon (EC) ratio and EC and OC during the ten days surrounding the atypical event, and a boxplot of OC to EC ratios compared to the dates surrounding the atypical event, respectively, collected at the Jerome Mack-NCore site. Elevated OC to EC ratios are indicative of wildfire smoke. As shown in the time series, the OC to EC ratio steadily increases from July 7 to a local maximum on July 16, 2022, the day before the atypical event. For context, OC to EC ratios on July 16, 2022, were above the median relative to all ratios during primary ozone production season (May-October) from 2017-2022.

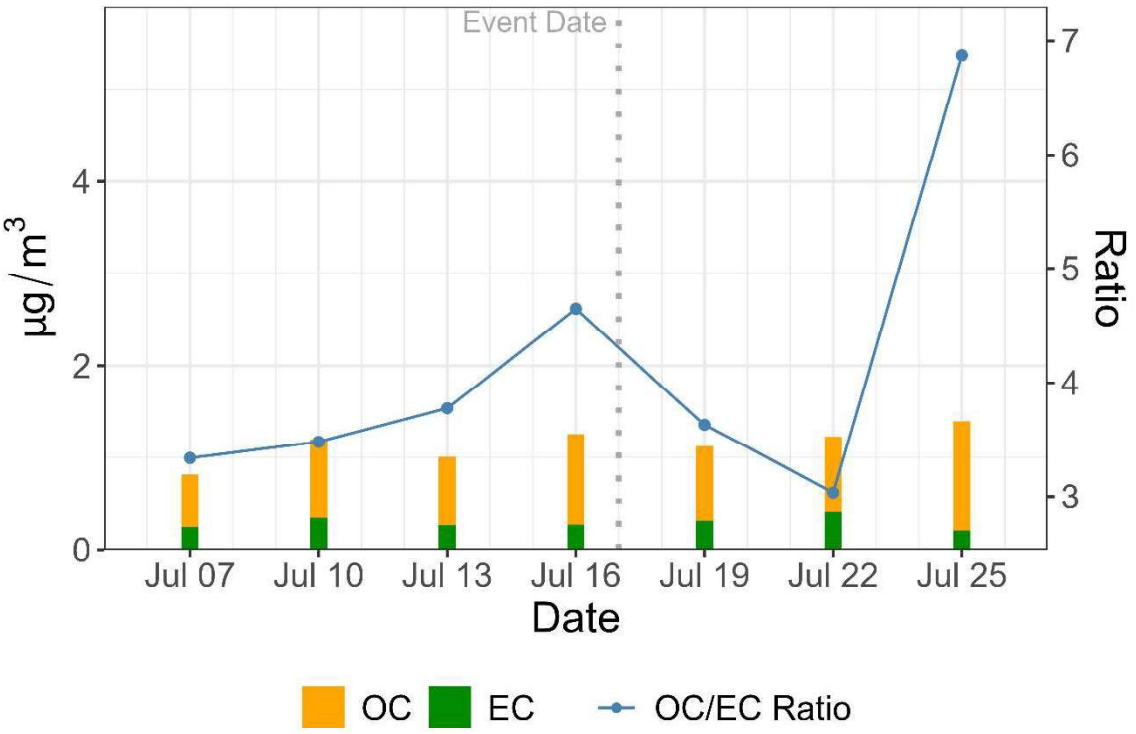

Figure 160. OC to EC ratios imposed on staked bar plots of OC and EC concentrations during the ten days before and after the July 17, 2022, atypical ozone event.

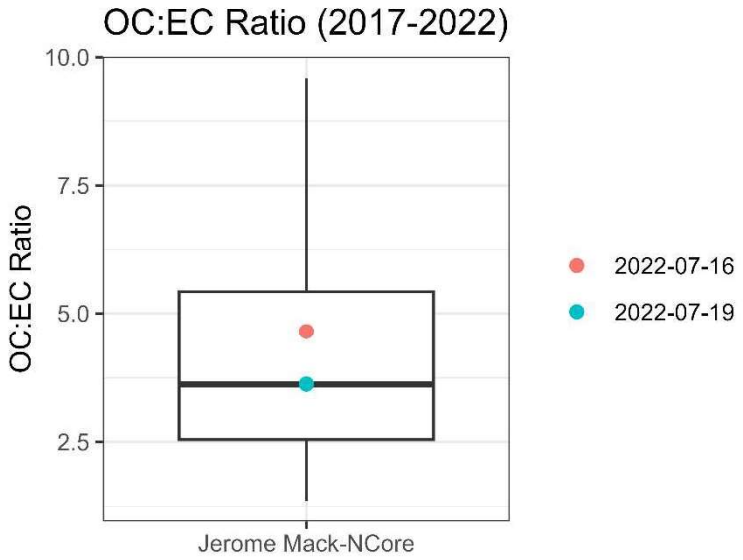

Figure 161. OC to EC ratio boxplot of ratios collected from 2017-2022 during the May-October ozone production season. Samples taken nearest to the atypical event date are displayed as points.

5.2.5 Matching Date Analysis

Local meteorological conditions have a strong influence on day-to-day ozone production. Similar local meteorological conditions are expected to yield similar levels of local ozone production, barring any atypical influence on a given date. This section compares ozone concentrations between the exclusion date and dates that are meteorologically similar. If an external source of ozone or ozone precursors were present in the Las Vegas region on the exclusion date, the ozone concentrations are likely to be statistically different from the meteorologically similar dates. Days between 2017-2022 with similar meteorological conditions as the exclusion date were identified according to four key meteorological measurements: maximum daily wind speed, maximum daily temperature, mixing height at 16:00 LST (00:00 UTC), and average daily relative humidity. Table 36 shows the source of each meteorological parameter and the threshold used to define a "similar" measurement. Other atypical event dates identified in this document were omitted from the pool of potential similar dates. Table 37 shows the 12 dates identified as similar to the exclusion date, July 17, 2022. The exclusion date had a maximum daily temperature of 111°F, daily average relative humidity of 17.38%, maximum hourly wind speed of 3.8 kts, and a mixing height of 4,122 m AGL at 16:00 LST. Only one other date of the 12 similar dates recorded an MDA8 ozone concentration above the NAAQS at any of the sites that were in exceedance on the exclusion date.

Table 36. Meteorological parameters used to identify dates with similar meteorological conditions to the exclusion date. The threshold used to define a "similar" measurement to the observed measurement on the exclusion date is listed per parameter.

Parameter	Data Source	"Similar" threshold
Hourly Wind Speed measured at Jerome Mack – NCore AQS site	U.S. EPA Air Quality System Data Mart	+/- 2 kts
Hourly Temperature measured at Jerome Mack – NCore AQS site	U.S. EPA Air Quality System Data Mart	+/- 5 °F
Hourly Relative Humidity measured at Jerome Mack – NCore AQS site	U.S. EPA Air Quality System Data Mart	+/- 10%
Mixing Height AGL at 16:00 LST (00 UTC) at NWS Forecast Office Las Vegas, NV	NOAA NCEI IGRA	+/- 250 m

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Table 37. Dates between 2017-2022 identified as meteorologically similar to the exclusion date based on the thresholds listed in Table 36. Measurements on the exclusion date are listed for reference in the first row (bold). Maximum Site MDA8 Ozone is the maximum concentration measured across the sites that were in exceedance on the exclusion date.

Date	Max. Hourly Wind Speed (kts)	Mixing Height at 16:00 LST (m AGL)	Max. Hourly Temperature (°F)	Average Hourly RH (%)	Maximum Site MDA8 Ozone (ppb)
07/17/2022	**3.8**	**4,122**	**111**	**17.38**	**76**
06/16/2017	4.0	3,887	109	8.00	68
09/01/2017	4.0	4,227	108	17.46	55
07/23/2018	3.6	4,178	112	20.79	74
08/18/2018	4.9	4,002	109	23.83	70
08/02/2019	3.9	4,011	110	12.83	62
08/14/2019	2.4	4,334	111	11.12	63
09/03/2019	4.1	3,994	109	23.25	59
07/26/2020	3.5	3,936	106	10.00	53
08/09/2020	4.7	3,934	106	7.96	56
09/16/2020	2.3	3,881	106	13.54	62
06/27/2022	5.7	4,038	108	18.33	57
08/30/2022	3.6	3,982	110	15.67	61

Figure 162 shows the comparison of the exclusion date concentration to concentrations on meteorologically similar dates at each exceedance site. The MDA8 ozone concentration is elevated on the exclusion date compared to the distribution of MDA8 ozone concentrations measured on meteorologically similar dates. At the Garrett Jr. High, Liberty High School and Walnut Community Center sites, the MDA8 ozone concentration measured on the exclusion date is much higher than MDA8 ozone concentration measured on any other meteorologically similar date. At the Green Valley and Jerome Mack sites, the MDA8 ozone concentrations are above the 95th and 90th percentile, respectively, of the MDA8 ozone concentrations recorded on the meteorologically similar dates. Higher-than-expected ozone concentrations measured on the exclusion date compared to meteorologically similar dates at several sites in Las Vegas provide evidence of an external source of ozone and/or ozone precursors on the exclusion date.

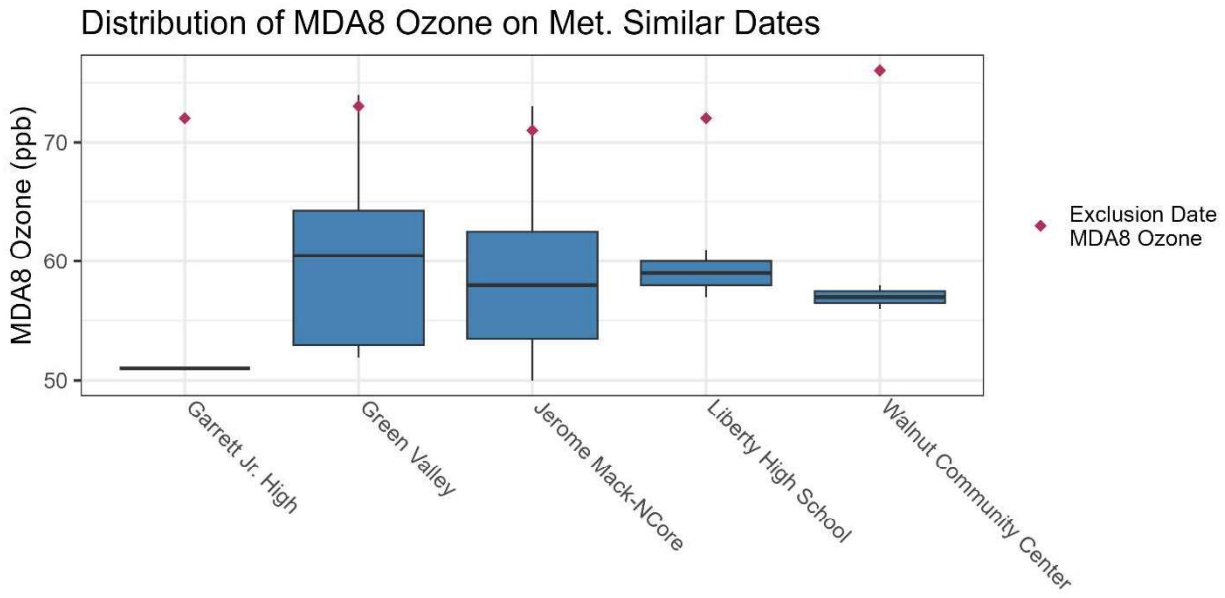

Figure 162. Distribution of MDA8 ozone concentrations on meteorologically similar days at measurement sites that were in exceedance on the exclusion date (blue boxes). MDA8 ozone concentrations measured on the exclusion date (July 17, 2022) at each site are plotted as red diamonds.

5.2.6 Event Statistics

Table 38 summarizes daily measurements of ozone, CO, and NO_2 concentrations on the exclusion day, as well as the percentile rank of the observation compared to the previous five years of ozone season data (May 1-October 31 of 2018-2022). $PM_{2.5}$ statistics are not included because the thunderstorm event anomalously enhanced the percentiles but is not associated with wildfire impacts. On July 17, 2022, ozone MDA8 measurements at all sites were above the 98th percentile. CO and NO_2 were not significantly enhanced, with CO 1-hr daily maximum concentrations and NO_2 1-hr daily maximum measurements below the 38th percentile at all sites. Lower concentrations of co-pollutants are consistent with very long-range transport of smoke.

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Table 38. Percentile of pollutant measurements on the exclusion day compared with most recent five years* (2018-2022). The percentile rank is calculated across the ozone production season (May 1-October 31) of 2018-2022.

Date	Site Name	Site Code	Ozone		CO		NO_2	
			Ozone MDA8 (ppb)	Percent Rank	CO 1-hr Daily Max (ppb)	Percent Rank	NO_2 1-hr Daily Max (ppb)	Percent Rank
7/17/2022	Garrett Jr. High	320030602	72	99.7*				
7/17/2022	Green Valley	320030298	73	98.3	34	1.6*		
7/17/2022	Jerome Mack-NCore	320030540	71	98.1	167	11.7*	17.4	25
7/17/2022	Liberty High School	320030299	72	98.1*				
7/17/2022	Walnut Community Center	320032003	76	98.8*	300	38.3*	21.1	35.9*

*Sites that have less than five years of data available for a given parameter.

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5.3 July 28-29, 2022

5.3.1 Event Summary

An ozone event took place across July 28-29, 2022, in Clark County, NV, and affected six monitoring sites on July 28 and one site on July 29, 2022. Regional wildfire smoke is suspected to have contributed to the NAAQS exceedances on these days. Major evidence includes smoke detection maps from the NOAA's HMS, dispersion model results from HYSPLIT, and meteorological data for July 28 and 29. This combination of evidence suggests that this may be an unrepresentative event for base and future design value ozone assessments.

Sites exceeding the NAAQS on July 28 had MDA8 ozone concentration ranging from 72-81 ppb (see Table 39). All sites within the Las Vegas Valley experienced MDA8 values on July 28 between 62 and 81 ppb, with an average MDA8 of 71 ppb. The high-altitude background site at the Spring Mountain (SM) Youth Camp also experienced an MDA8 value of 78 ppb on July 28, suggesting background enhancement to ozone concentrations, but as this site is outside of the Las Vegas Valley it is not significant for the design value assessments. On July 29, ozone concentrations had decreased in the Las Vegas Valley; on this day, the average MDA8 ozone concentration for the sites within the Las Vegas Valley was 65 ppb. However, the Palo Verde site recorded a NAAQS exceedance.

Table 39. Sites with MDA8 ozone levels above the NAAQS on July 28 or 29, 2022, in Clark County, NV.

Date	Site	Site Code	MDA8 Ozone (ppb)
7/28/2022	Palo Verde	320030073	81
7/28/2022	Walter Johnson	320030071	78
7/28/2022	Paul Meyer	320030043	77
7/28/2022	Mountain's Edge	320030044	74
7/28/2022	Joe Neal	320030075	73
7/28/2022	Liberty High School	320030299	72
7/29/2022	Palo Verde	320030073	71

Time series graphs showing hourly ozone concentrations that exceeded the seasonal means and 10th-90th percentiles (calculated using data from May 1-October 31, 2017-2021) at each affected site are shown in Figure 163. For both days and all sites, we see an enhancement in ozone production, which indicates likely influence from atypical sources of ozone precursors.

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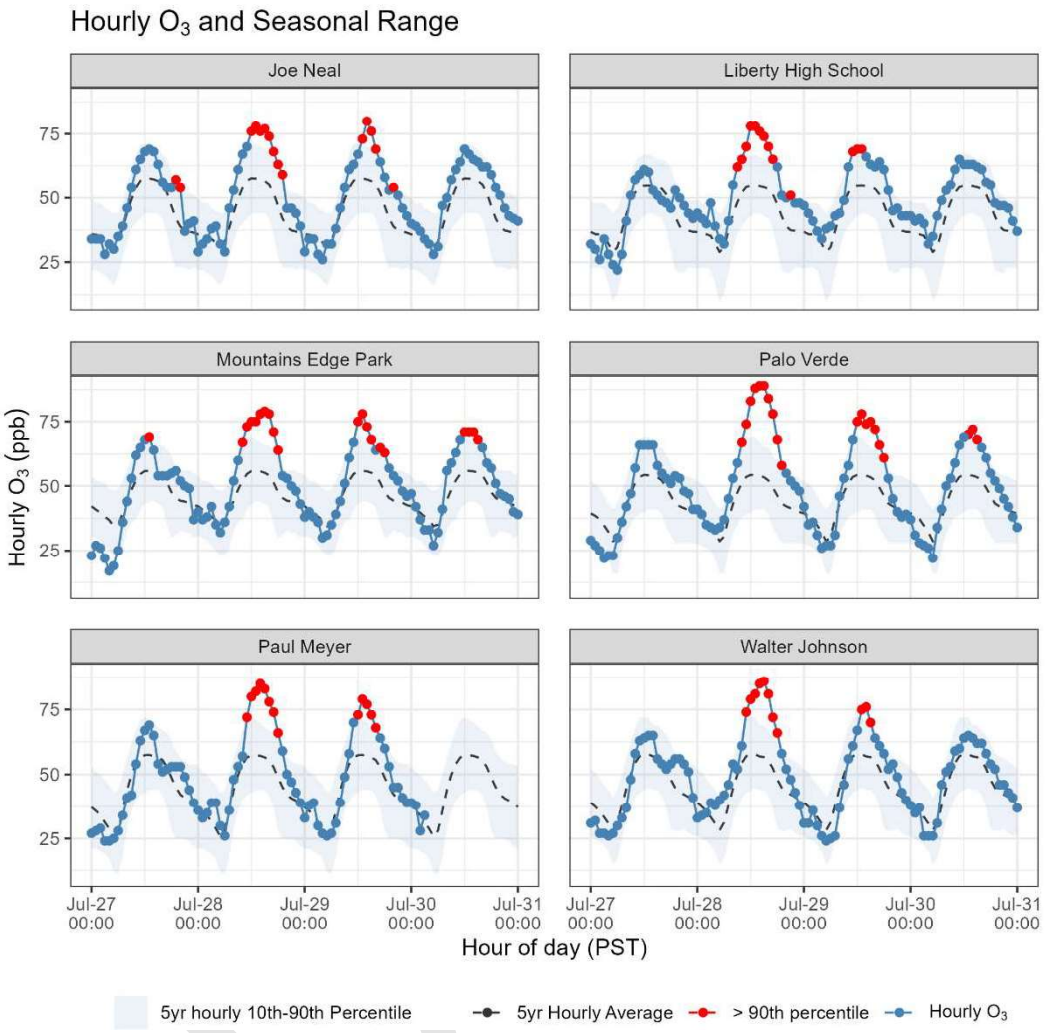

Figure 163. Hourly ozone concentrations (ppb) across June 27-31, 2022, compared to 5-yr* ozone season (May 1-October 31) hourly means and 10th-90th percentiles. Note: data collection at the Data collection at the Liberty High School and Mountain's Edge sites did not begin until 2021.

5.3.2 Identification of Wildfires

Figure 164 shows HMS maps of analyzed smoke across the United States between July 26 and 29, 2022. HMS smoke maps are created using visible satellite imagery from Geostationary Operational Environmental Satellites (GOES). Visible imagery is only available during the sunlit part of the GOES orbit; therefore, smoke movement during nighttime hours is inferred between the daylight-generated smoke maps. On July 26, smoke from fires in California and Idaho spread mostly northward and eastward in dense plumes. Over the next three days, plumes from both regions contributed to a broader area of smoke that covered the western U.S., including Clark County, on July 28 and 29, 2022.

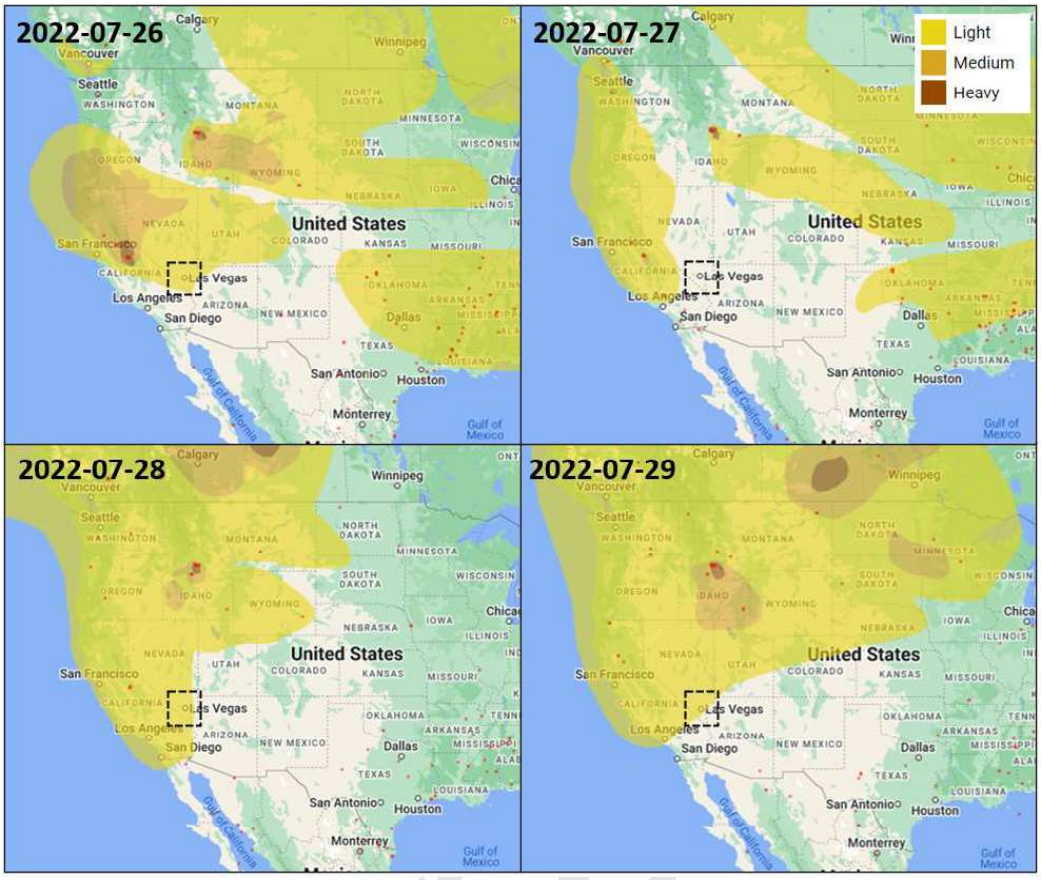

Figure 164. HMS smoke maps for July 26-29, 2022, showing smoke transport and qualitative smoke density. Clark County, NV, is enclosed by a dashed, black box on each map.

Two fires (the Moose Fire in Idaho and the Oak Fire in California) were active during the days leading up to and including the exclusion dates. Both fires had sizable growth leading up to July 28-29 (Table 40). The active fire area on July 28 is provided based on a post from the Salmon-Challis National Forest U.S. Forest Service account for the Moose Fire, and InciWeb data for the Oak Fire. Fire perimeters in relation to Clark County are in Figure 165, and a closer view of each is in Figure 166.

Table 40. Wildfires affecting Clark County on July 28-29.

Wildfire Name	State	Total Acres	Acres Burned on or Before July 28-29	Start Date	Containment Date
Moose	Idaho	130,144	40,388 (July 28)[34]	Jul 17	Nov. 9
Oak	California	19,244	19,191 (July 28)[35]	Jul 22	Aug. 11

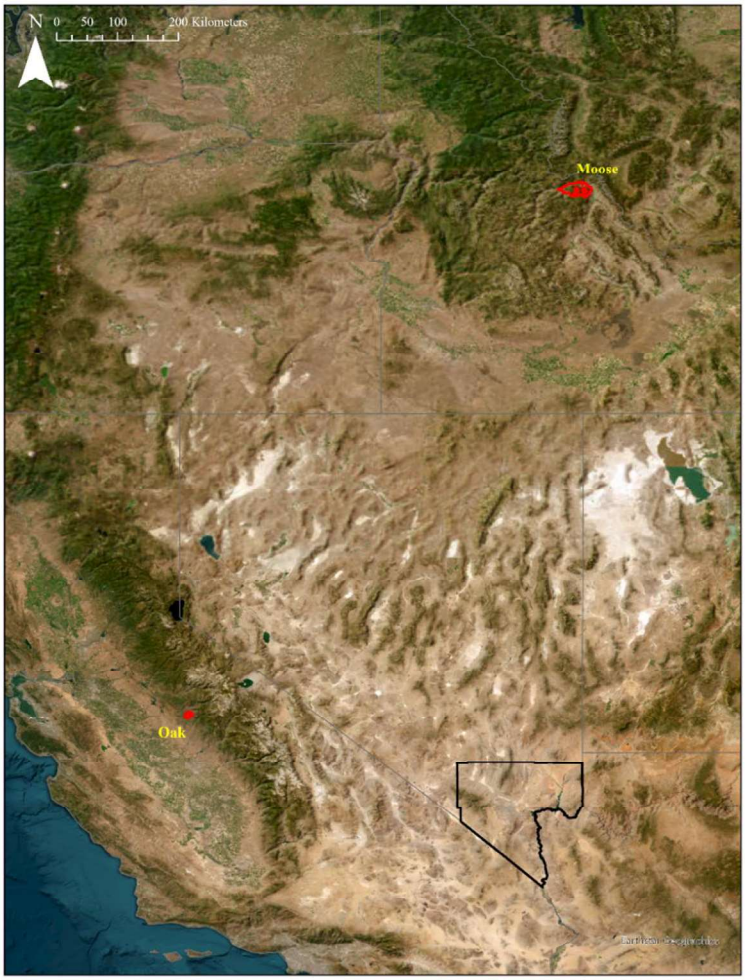

Figure 165. Final fire perimeters (red) for the two active fire regions during the July 28-29, 2022, exclusion dates in relation to Clark County (black perimeter).

[34] https://www.facebook.com/plugins/post.php?href=https%3A%2F%2Fwww.facebook.com%2Fsalmonchallisnf%2Fposts%2Fpfbid02fsCqh6BDaSbXqmH4NZzbhaqnXwLWf7VrMhuafof6kSTRTvJ1qsXwSwGCS5hTwGHzl

[35] https://inciweb.nwcg.gov/incident-publication/casnf-oak-fire/oak-fire-update-72822-pm

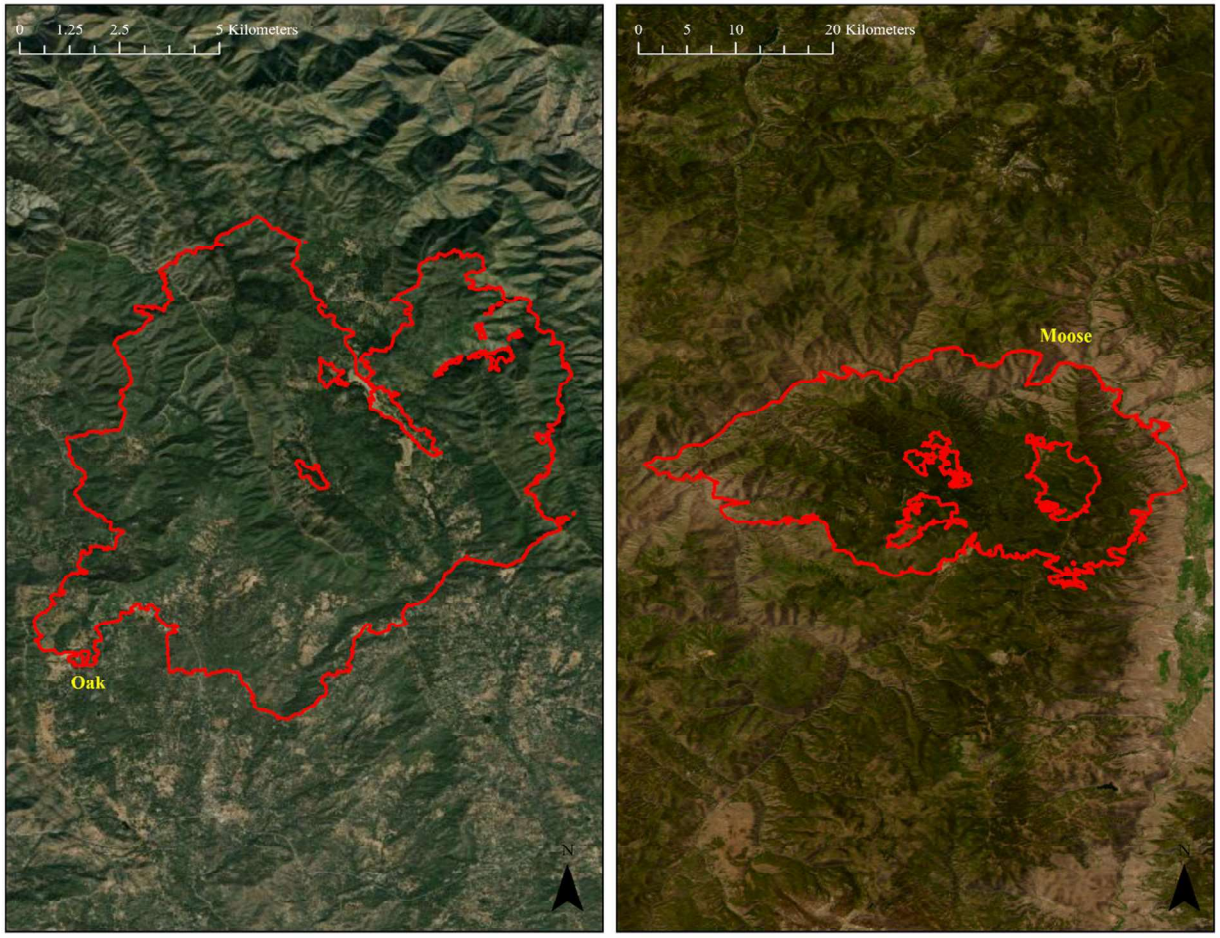

Figure 166. Final fire perimeters (red) for the two active fire regions during the July 28-29, 2022, exclusion dates.

5.3.3 Dispersion Modeling and Regional Analysis

To examine the effect of wildfire smoke in Clark County (as indicated by the HMS smoke maps shown in Section 5.3.2), we first determined the meteorological conditions on and before the July 28-29, 2022, event. We specifically focused on the boundary layer dynamics to determine the depth of mixing and possibility of vertical transfer of aloft smoke to the surface. We then used this information to model smoke via HYSPLIT and compare the results with independent data sources (including HMS).

The PBL denotes the atmospheric layer closest to the surface, and the height of the PBL describes the vertical extent of surface air characteristics. Atmospheric soundings and PBL maps provide visualizations of the extent of vertical mixing in the lower troposphere. The five skew-T diagrams in Figure 167 show the vertical profile of the atmosphere from the Las Vegas upper-air weather station (KVEF) every 12 hours from July 28 at 00:00 UTC (July 27 at 16:00 PST) to July 30 at 00:00 UTC (July 29 at 16:00 PST). The five skew-T diagrams are characterized primarily by their diurnal changes in the

lower troposphere from consecutive soundings; the soundings taken at 12:00 UTC (i.e., 04:00 PST) show a near-surface temperature inversion that inhibited vertical mixing between the near-surface and mid-troposphere, whereas the soundings taken at 00:00 UTC (i.e., 16:00 PST) show an approximately dry-adiabatic temperature lapse rate, indicating that the lower troposphere was well mixed with a PBL of approximately 2,500 m AGL (~700 mb). While morning conditions typically include capping inversions, a deep well-mixed boundary layer had formed in Clark County during the afternoon hours on each exclusion date. When comparing KVEF's 2017-2021 climatological average PBL for each respective date at 00:00 UTC, the 2,500 m AGL PBL for July 28-29, 2022, are lower than average. The climatological average PBL for July 28 is 4,200 m AGL, while the climatological average PBL for July 29 is 3,600 m AGL.

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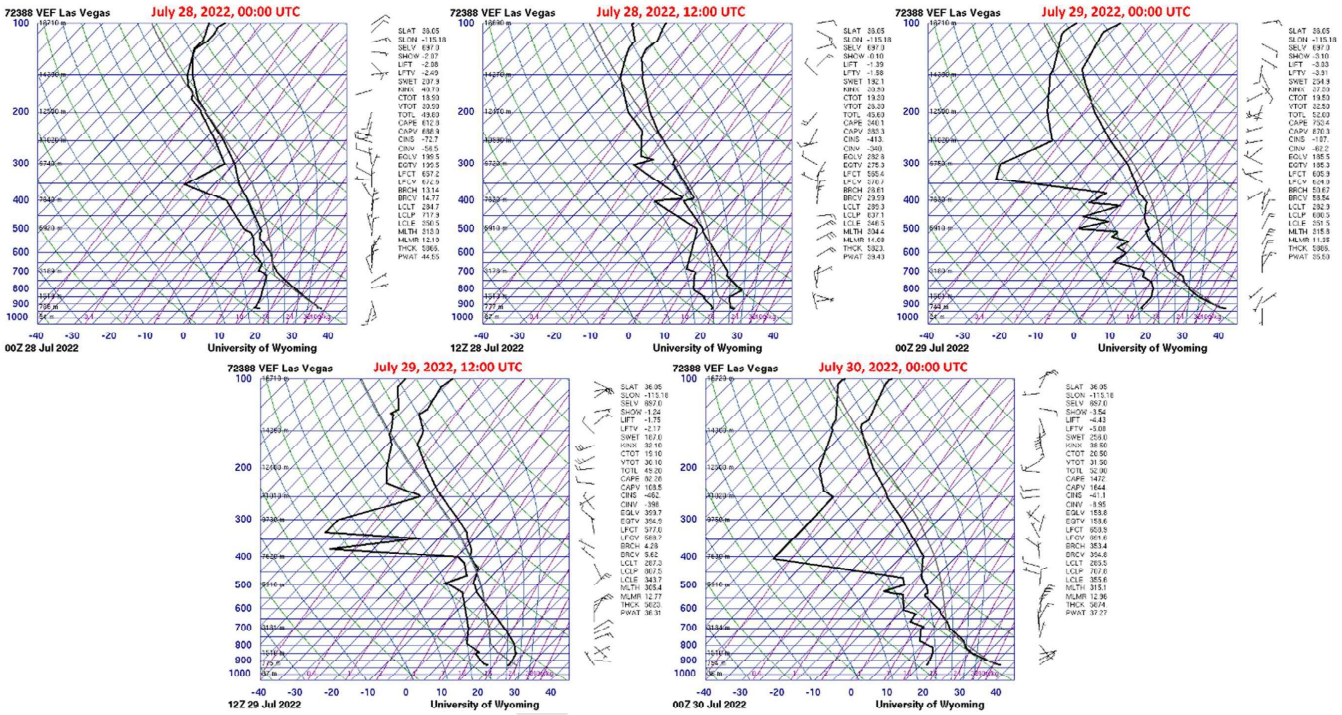

Figure 167. Skew-T soundings launched from KVEF from July 28, 2022, at 00:00 UTC (July 27 at 16:00 PST) (top left), to July 30 at 00:00 UTC (July 29 at 16:00 PST) (bottom right).

The depth of the PBL from July 28 to 29 was influenced by upper-level high pressure at 500 mb (5,500 m AGL) over California, Oregon, and Nevada (Figure 168). This feature led to periods of sunshine, which allowed afternoon surface high temperatures at the Harry Reid International Airport (KLAS) to reach 100°F on July 28 and 99°F on July 29. These conditions are conducive for ozone development. In addition, easterly to northeasterly surface winds at KLAS were around 6 MPH on average each day. Due to the light winds, dispersion of pollutants and ozone precursors was inhibited in Clark County during the exclusion period.

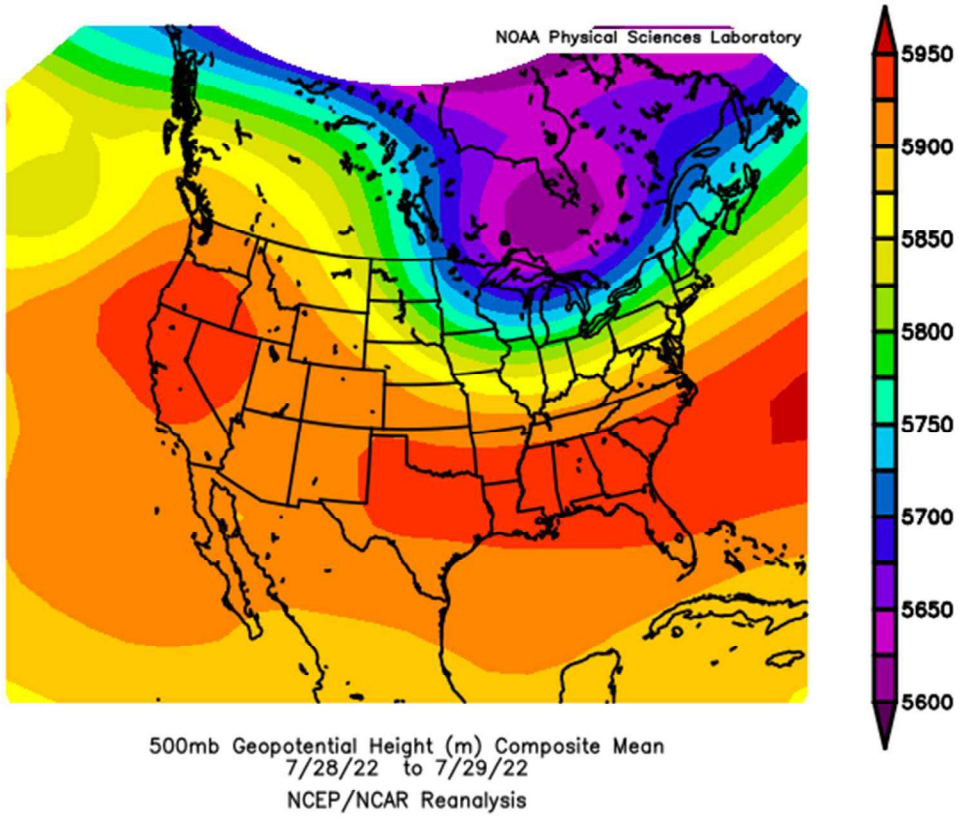

Figure 168. Mean 500 mb geopotential heights (m) for the July 28-29, 2022, period. The dark orange shading over California, Oregon, and Nevada denotes a high-pressure system. Source: NOAA

To identify air mass source regions on the exclusion dates, HYSPLIT back trajectories were generated for July 28 and 29. Trajectory heights of 100 m, 1,200 m, and 2,400 m AGL were selected since each level was within KVEF's estimated PBL of 2,500 m AGL. NOAA HMS smoke analysis and satellite fire detections are also included on the HYSPLIT back trajectories to identify if any pathway intersects fires or smoke at the source region. For July 28, a 48-hour back trajectory (Figure 169) was generated ending at 16:00 PST. The 2,400 m AGL path originated north of Clark County and intersected an

analyzed area of smoke over Nevada and far southeastern Idaho from July 26. Figure 170 contains the NOAA smoke discussion valid 20:00 PST July 26 (04:00 UTC July 27). The discussion mentions varying densities of smoke from central California wildfires reaching portions of Nevada on the evening of July 26, which is evidence that source air reaching Clark County on July 28 likely contained smoke, and that any lofted pollutants and smoke at the 2,400 m AGL level would be capable of being transferred vertically to the surface given its altitude within the PBL.

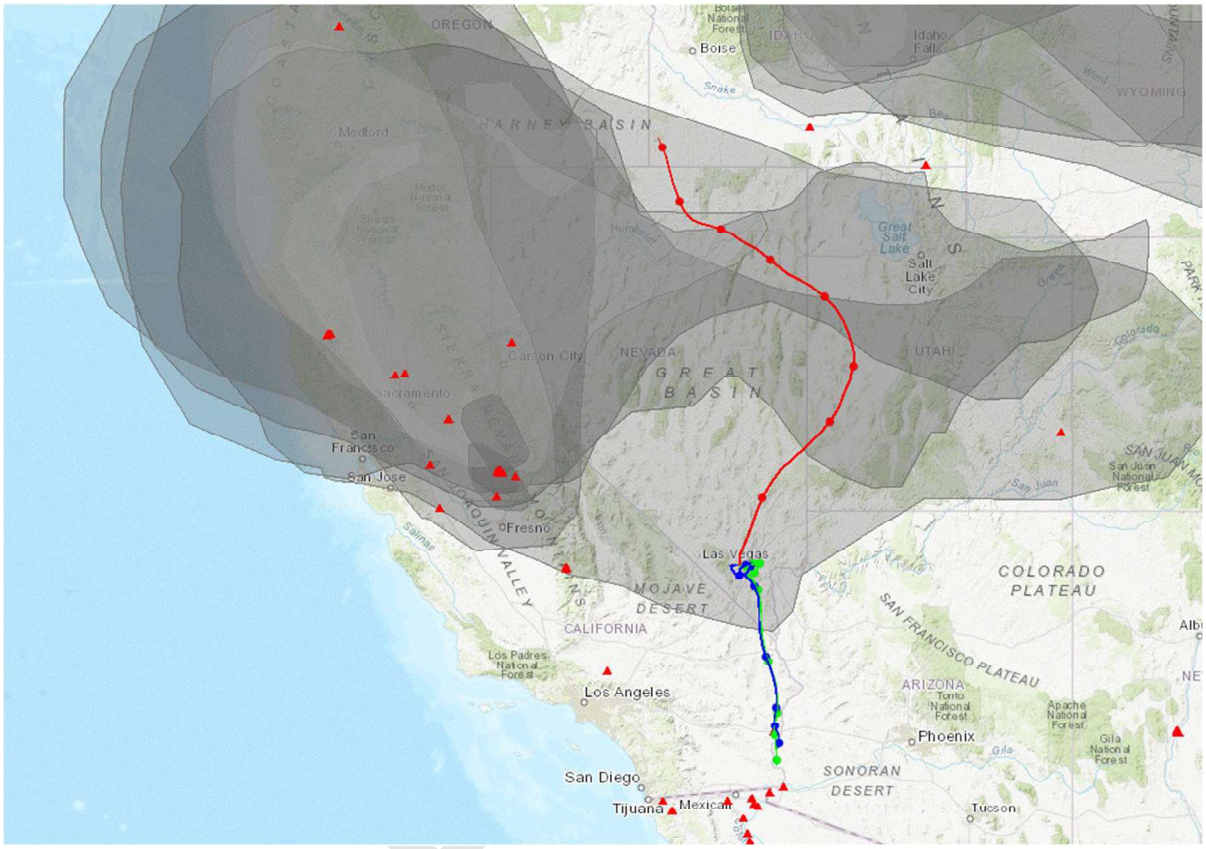

Figure 169. HYSPLIT 48-hour back trajectory ending 16:00 PST July 28, 2022 (00:00 UTC July 29), and July 26 NOAA HMS smoke analysis (grey contours) and satellite fire detections (red triangles). The 2,400 m AGL transport path (red line) shows air advecting into Clark County from regions of analyzed smoke on July 26. Source: AirNow-Tech.

Tuesday, July 26, 2022

DESCRIPTIVE TEXT NARRATIVE FOR SMOKE/DUST OBSERVED IN SATELLITE IMAGERY
THROUGH 0042Z July 27, 2022

SMOKE:
Northwestern Canada...
An area of light to moderate density smoke was detected over the northern parts of the Yukon and Northwest Territories, this was most likely due to fires in Alaska along with fires within that area that is cloud covered preventing the detection of every fire. Fires along The southern Yukon and Northwest Territories was producing At least light to moderate smoke that was seen stretching south over parts of British Columbia and Alberta.

California/Nevada/Oregon/Utah...
A large area of light to heavy density smoke from wildfires in central California was moving north covering all of central and northern California (into the Pacific), most of Oregon and parts of Nevada. Heaviest density smoke can be seen moving around the source in central California.

Idaho...
The Moose Fire in east central Idaho was observed producing moderate smoke which moved to the east into parts of Montana, Wyoming, The Dakotas, Nebraska and looks to possibly mix with smoke from northwestern Canada in Minnesota.

Heavy cloud cover throughout our area or responsibility precluded a more detailed smoke analysis this evening.

DUST:
Tropical Atlantic and Caribbean Sea...
An area of Saharan dust extended across the Tropical Atlantic with a portion extending through the eastern/central Caribbean Sea and north off the southeast coast of the U.S., mainly Florida.

Eglin

Figure 170. NOAA smoke discussion valid 20:00 PST July 26 (04:00 UTC July 27). Smoke from central California wildfires covered portions of Nevada, which likely impacted ozone development in Clark County. Source: NOAA

HYSPLIT analysis for July 29 used a 24-hour back trajectory (**Figure 171**) that ended at 16:00 PST. Similar to Figure 169, the 2,400 m AGL transport path shown in Figure 171 originated north of Clark County and intersected an analyzed smoke plume over eastern Nevada from July 28. In **Figure 172**, the NOAA smoke discussion valid 17:00 PST July 28 (01:00 UTC July 29) highlighted that light smoke from central California wildfires covered a large portion of the western United States, including Nevada. This is evidence that source air transported into Clark County on July 29 likely contained smoke, and that any lofted pollutants and smoke at the 2,400 m AGL level would be capable of being transferred vertically to the surface given its altitude within the PBL.

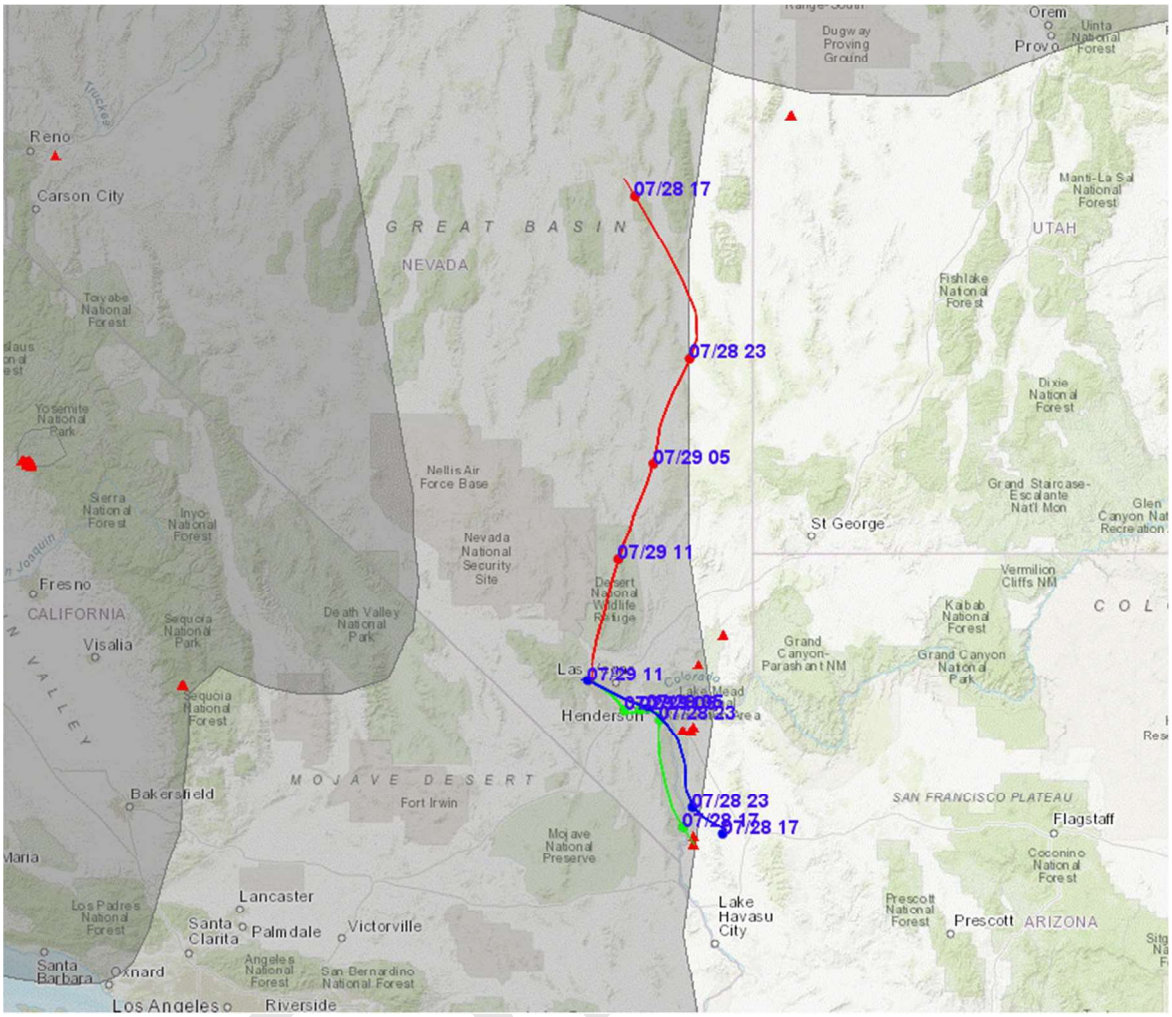

Figure 171. HYSPLIT 24-hour back trajectory ending 16:00 PST July 29, 2022 (00:00 UTC July 30), and July 28 NOAA HMS smoke analysis (grey contours) and satellite fire detections (red triangles). The 2,400 m AGL transport path (red line) shows air advecting into Clark County from regions of analyzed smoke on July 28. Source: AirNow-Tech

Thursday, July 28, 2022

DESCRIPTIVE TEXT NARRATIVE FOR SMOKE/DUST OBSERVED IN SATELLITE IMAGERY
THROUGH 0111Z July 29, 2022

SMOKE:
Northwestern Canada...
An area of light to moderate density smoke with swathes of thick density smoke was detected across southwestern Canada this evening. This was most likely due to fires in Alaska along with fires within the area that is cloud covered preventing the detection of every fire. Fires along The southern Yukon and Northwest Territories was probably responsible for a large area of heavy smoke that was seen stretching over parts of northern British Columbia and Alberta. another swath of heavy density smoke was visible over western Saskatchewan.

California/Nevada/Oregon/Utah...
A large area of light density smoke from wildfires in central California was was covering all of California (into the Pacific), Oregon, Nevada, Washington, most of Idaho and Montana. This smoke extended north mixing with the ongoing wildfire smoke from Canada. Moderate density smoke can be seen moving around the source in central California.

Idaho...
The Moose Fire in east central Idaho was observed producing moderate to heavy density smoke expanding south right into cloud cover.

DUST:
Tropical Atlantic and Caribbean Sea...
An area of Saharan dust extended across the Tropical Atlantic with a portion extending through the Caribbean Sea and north off the southern and southeast coast of the U.S. into the central portion of the Gulf of Mexico.

Eglin

Figure 172. NOAA smoke discussion valid 17:00 PST July 28, 2022 (01:00 UTC July 29). Light density smoke from central California wildfires covered Nevada, which likely impacted ozone development in Clark County. Source: NOAA

To further assess the potential for smoke transport from fire locations, HYSPLIT dispersion modeling was performed from July 25 through July 29, 2022. Dispersion was initiated on July 25 at 11:00 PST from the two identified active fires and modeled through the exclusion dates to simulate smoke transport. Global Data Assimilation System (GDAS) data at 1.0° horizontal resolution was used for meteorological input. Output from the dispersion modeling is aggregated in 12-hr increments starting at July 27 at 23:00 PST through July 29 at 11:00 PST. This time period was chosen to correspond with the period of enhanced ozone measured in Clark County, NV. The accumulation of smoke in the boundary layer at 0-2,600 m is shown in Figure 173.

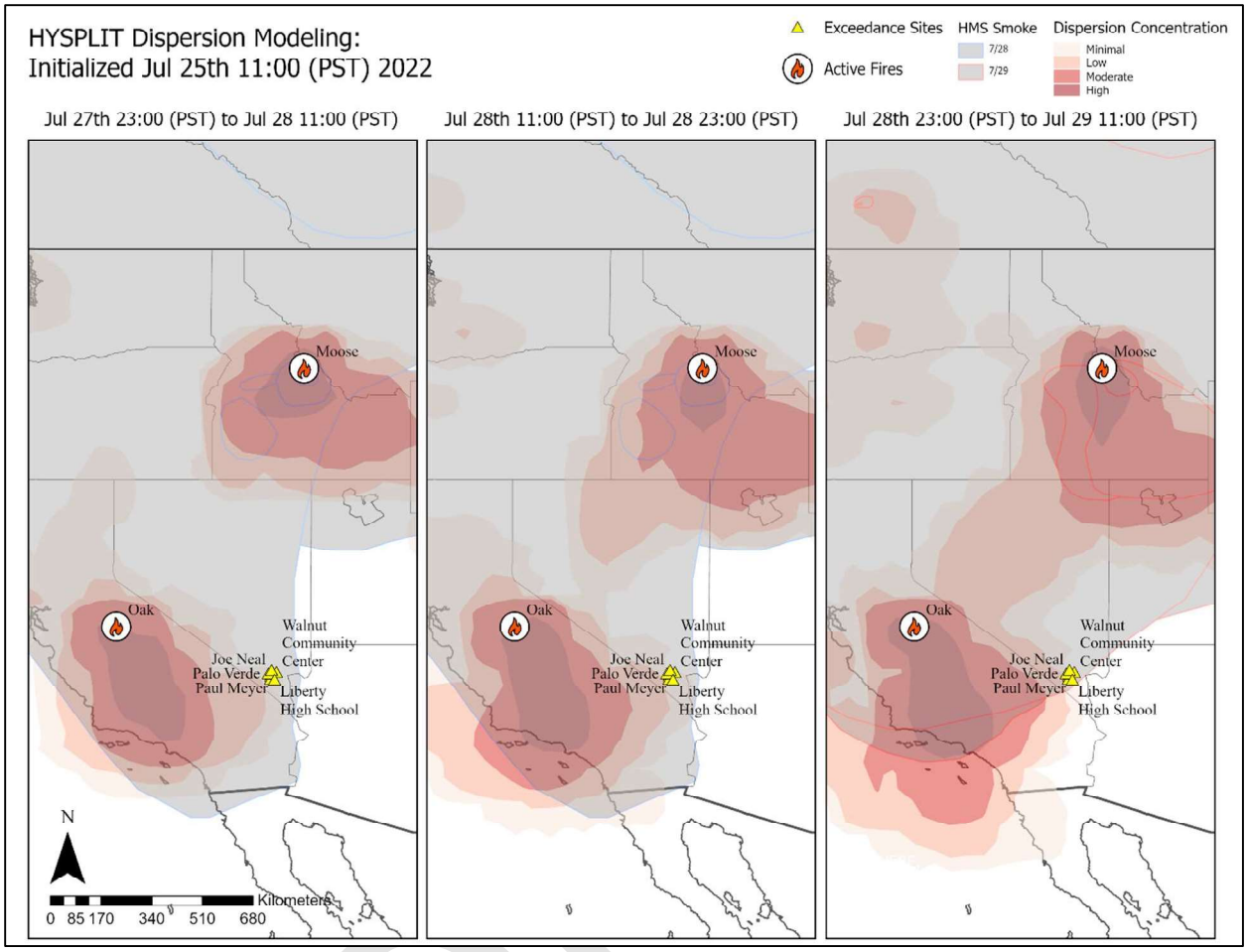

Figure 173. HYSPLIT dispersion modeling for two large fires (labeled as "Active Fires") in California and Idaho on or before the exclusion dates of July 28-29, 2022. GDAS 1.0° meteorological data was used, and dispersion was initiated on July 25 at 11:00 PST to model the regional smoke transport. HYSPLIT-modeled qualitative concentrations of particulate matter are shown in shades of red, and independently sourced HMS satellite-detection smoke plumes are shown in gray. HYSPLIT accumulation of particulate matter is shown at 0-2,600 m.

The HYSPLIT dispersion modeling shows that smoke from two fires produced dense layers of smoke that expanded over Nevada from July 28 into July 29, 2022 (red plumes, Figure 173). The modeling results, and eastern smoke perimeters, are consistent with the HMS smoke plume (shown by the gray layer in Figure 173), an independent smoke identification database. The HMS smoke plume extends farther to the north, likely due to additional smoke from Canadian fires that were not added to the dispersion modeling run. Dispersion modeling indicates that low concentrations of smoke from the Oak and Moose Fires would have entered Clark County during the day on July 28.

5.3.4 Impacts at the Surface

Visible imagery is unavailable for this event due to a thunderstorm and an associated dust event late in the evening on July 27, 2022 (just before the exclusion days). Figure 174 shows METAR reports from July 27 showing the thunderstorm during the early morning hours.

Time	Temperature	Dew Point	Humidity	Wind	Wind Speed	Wind Gust	Pressure	Precip.	Condition
6:53 PM	95 °F	61 °F	32 %	S	8 mph	0 mph	27.57 in	0.0 in	Fair
7:32 PM	87 °F	61 °F	41 %	NE	43 mph	59 mph	27.62 in	0.0 in	Haze / Windy
7:38 PM	85 °F	62 °F	46 %	NE	33 mph	59 mph	27.65 in	0.0 in	Light Rain / Windy
7:53 PM	84 °F	61 °F	46 %	NE	33 mph	46 mph	27.65 in	0.0 in	Cloudy / Windy
8:32 PM	81 °F	63 °F	54 %	NE	29 mph	46 mph	27.68 in	0.0 in	Thunder in the Vicinity
8:53 PM	81 °F	62 °F	52 %	NE	18 mph	35 mph	27.68 in	0.0 in	Thunder in the Vicinity
9:15 PM	81 °F	62 °F	52 %	VAR	5 mph	0 mph	27.72 in	0.0 in	Light Rain
9:53 PM	80 °F	64 °F	58 %	S	7 mph	0 mph	27.70 in	0.0 in	Light Rain
10:53 PM	80 °F	66 °F	62 %	ENE	3 mph	0 mph	27.67 in	0.0 in	Light Rain
11:53 PM	78 °F	68 °F	71 %	ENE	3 mph	0 mph	27.64 in	0.0 in	Fair

Figure 174. METAR report at the Las Vegas International Airport (KLAS) during the evening of July 27, 2022, showing the thunderstorm associated with the dust event.

In this section, we provide the pollutant concentrations at each affected site; however, the evening thunderstorm on July 27, 2022, obscures any useful $PM_{2.5}$ concentrations information. In cases like this, with longer range smoke transport and non-local fires, $PM_{2.5}$ is more likely to be dispersed and thus less likely to be significantly enhanced. In this case, however, hourly $PM_{2.5}$ concentrations did exceed the diurnal 90th percentile $PM_{2.5}$ concentration at multiple sites in the Las Vegas Valley between 18:00 and 19:00 PST on July 27 due to outflow from the approaching thunderstorm (Figure 175). The $PM_{2.5}/PM_{10}$ ratios for this event at all sites throughout Clark County (Figure 176 and Figure 177) showed the decrease of the $PM_{2.5}/PM_{10}$ ratio during the thunderstorm and outflow boundary event in the late evening on July 27, consistent with a dust storm. After the dust storm concluded by early morning July 28, the ratio increased and stayed above average for most sites during the rest of the daytime on July 28. The Virgin Valley site (which would be the first site to experience smoke from the California/Idaho fires due to its location in the far northeast corner of Clark County, outside the Las Vegas Valley) experienced values for the $PM_{2.5}/PM_{10}$ ratio well above the 95th percentile for the rest of the daytime period on July 28. While the $PM_{2.5}/PM_{10}$ ratio at most sites did not increase above the 95th percentile, neither did the absolute $PM_{2.5}$ concentrations (Figure 175). This is again likely due to smoke dispersion during longer range transport, where $PM_{2.5}$ is more likely to be dispersed and not significantly enhanced.

Figure 178 shows the hourly CO concentrations alongside the 10th-90th percentile diurnal concentrations, calculated from 2017-2022, recorded at the event-affected sites that measure CO

concentrations. Hourly CO concentrations were equal to or greater than the diurnal 90th percentile CO concentrations recorded at the Paul Meyer and Joe Neal sites during the afternoon of July 28.

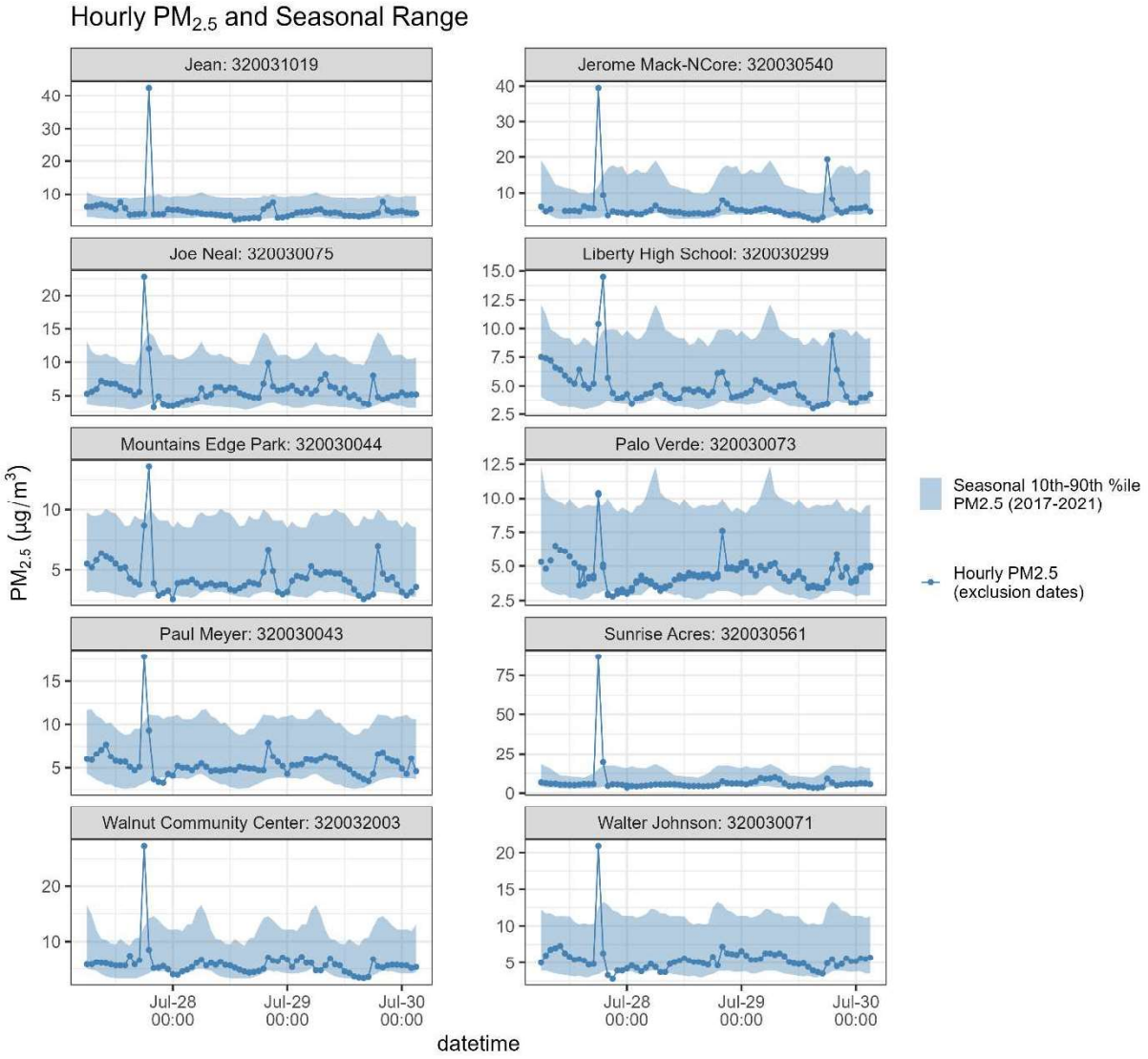

Figure 175. Hourly $PM_{2.5}$ measurements overlaid on the 10th-90th percentile diurnal concentration recorded at the event-affected measurement sites and supporting sites that measure $PM_{2.5}$ concentrations. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2022.

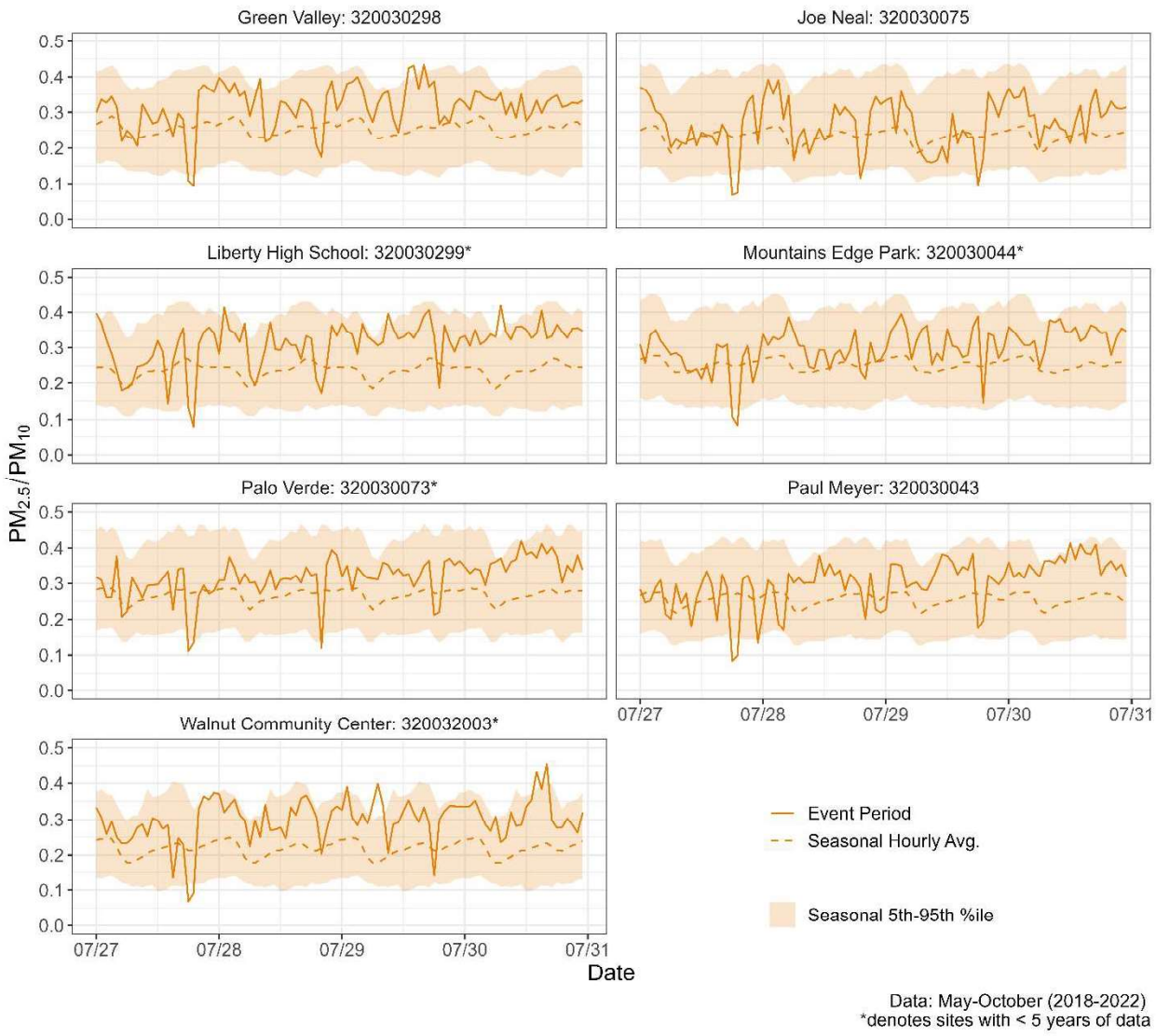

Figure 176. Ratio of $PM_{2.5}/PM_{10}$ concentrations recorded at the Green Valley, Joe Neal, Liberty High School, Mountain's Edge, Palo Verde, Paul Meyer, and Walnut Community Center sites during the July 28-29, 2022, event period. The 5-yr average $PM_{2.5}/PM_{10}$ diurnal ratio is displayed as a dotted line, and the 5th-95th percentile range is shown as a shaded ribbon. The 5th-95th percentile concentration is calculated across the ozone production season (May-October) of 2018-2022.

Figure 177. Ratio of $PM_{2.5}/PM_{10}$ concentrations recorded at the Garrett Jr. High, Jean, Jerome Mack, Sunrise Acres, Virgin Valley High School, and Walter Johnson monitoring sites during the July 28-29, 2022, event period. The 5-yr average $PM_{2.5}/PM_{10}$ diurnal ratio is displayed as a dotted line, and the 5th-95th percentile range is shown as a shaded ribbon. The 5th-95th percentile concentration is calculated across the ozone production season (May-October) of 2018-2022.

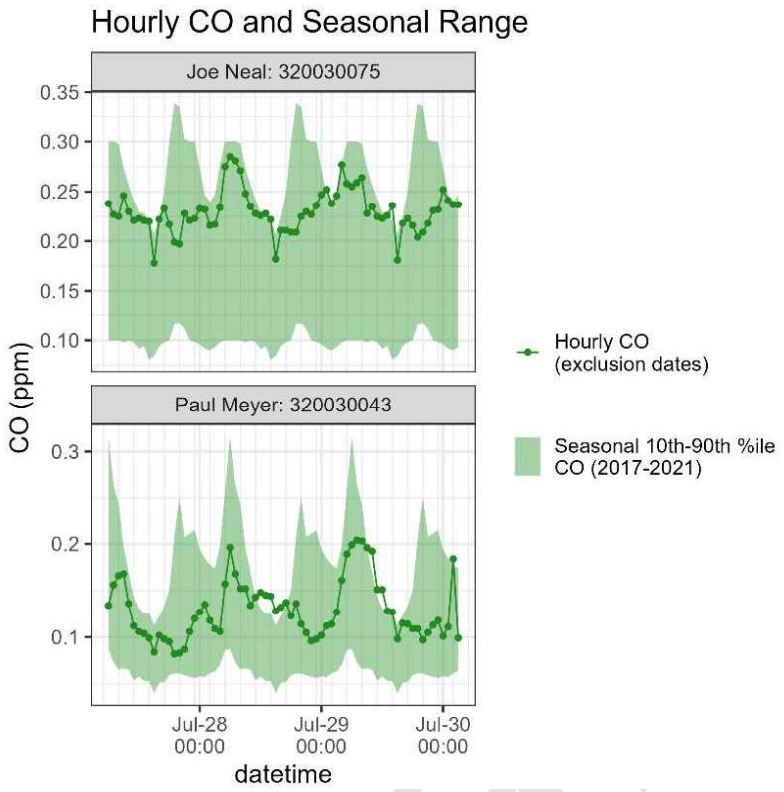

Figure 178. Hourly CO measurements overlaid on the 10th-90th percentile diurnal concentrations recorded at each event-affected measurement site that measures CO concentrations. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2022.

5.3.5 Matching Date Analysis

Local meteorological conditions have a strong influence on day-to-day ozone production. Similar local meteorological conditions are expected to yield similar levels of local ozone production, barring any atypical influence on a given date. This section compares ozone concentrations between the exclusion date and dates that are meteorologically similar. If an external source of ozone or ozone precursors were present in the Las Vegas region on the exclusion date, the ozone concentrations are likely to be statistically different from the meteorologically similar dates. Days between 2017-2022 with similar meteorological conditions as the exclusion date were identified according to four key meteorological measurements: maximum daily wind speed, maximum daily temperature, mixing height at 16:00 LST (00:00 UTC), and average daily relative humidity. Table 41 shows the source of each meteorological parameter and the threshold used to define a "similar" measurement. Other atypical event dates identified in this document were omitted from the pool of potential similar dates. Table 42 and Table 43 show dates identified as similar to each date in the exclusion period of July 28-29, 2022. July 28 and 29 showed similar meteorological conditions, with maximum daily temperatures of 102°F and 100°F, average relative humidities of 44.71% and 52.17%, maximum hourly wind speeds of 6.7 and 7.6 kts, and mixing heights of 2,102 and 2,626 m AGL at 16:00 LST,

respectively. The maximum daily temperatures recorded during the exclusion period are both below the median July maximum daily temperature of 107°F recorded at the Jerome Mack site. Nine meteorologically similar dates were identified for each of the two dates in the exclusion period. None of the similar dates recorded an MDA8 ozone concentration above the NAAQS at any of the sites that were in exceedance during the exclusion period.

Table 41. Meteorological parameters used to identify dates with similar meteorological conditions to the exclusion date. The threshold used to define a "similar" measurement to the observed measurement during the exclusion period is listed per parameter.

Parameter	Data Source	"Similar" threshold
Hourly Wind Speed measured at Jerome Mack – NCore AQS site	U.S. EPA Air Quality System Data Mart	+/- 2.5 kts
Hourly Temperature measured at Jerome Mack – NCore AQS site	U.S. EPA Air Quality System Data Mart	+/- 5 °F
Hourly Relative Humidity measured at Jerome Mack – NCore AQS site	U.S. EPA Air Quality System Data Mart	+/- 20%
Mixing Height AGL at 16:00 LST (00 UTC) at NWS Forecast Office Las Vegas, NV	NOAA NCEI IGRA	+/- 400 m

Dr

Table 42. Dates between 2017-2022 identified as meteorologically similar to the exclusion date of July 28, 2022, based on the thresholds listed in Table 41. Measurements on July 28, 2022, are listed for reference in the first row (bold). Maximum Site MDA8 ozone is the maximum concentrations across the sites that were in exceedance during the exclusion period.

Date	Max. Hourly Wind Speed (kts)	Mixing Height at 16:00 LST (m AGL)	Max. Hourly Temperature (°F)	Average Hourly RH (%)	Maximum Site MDA8 Ozone (ppb)
07/28/2022	**6.7**	**2,102**	**102**	**44.71**	81
07/20/2017	6.8	2,277	102	37.54	58
07/24/2017	9.1	2,296	99	35.08	46
08/03/2017	7.9	2,042	99	34.00	62
07/10/2018	7.9	2,193	101	46.71	73
07/12/2018	8.4	2,025	98	43.21	60
07/24/2019	8.0	2,156	101	31.54	54
07/25/2019	6.3	1,749	101	32.08	67
07/30/2022	6.5	2,290	97	46.21	67
08/15/2022	5.5	2,232	99	37.62	67

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Table 43. Dates between 2017-2022 identified as meteorologically similar to the exclusion date of July 29, 2022, based on the thresholds listed in Table 41. Measurements on July 29, 2022, are listed for reference in the first row (bold). Maximum Site MDA8 Ozone is the maximum concentration measured across the sites that were in exceedance during the exclusion period.

Date	Max. Hourly Wind Speed (kts)	Mixing Height at 16:00 LST (m AGL)	Max. Hourly Temperature (°F)	Average Hourly RH (%)	Maximum Site MDA8 Ozone (ppb)
07/29/2022	**7.6**	**2,626**	**100**	**52.17**	**71**
07/20/2017	6.8	2,277	102	37.54	58
07/24/2017	9.1	2,296	99	35.08	46
07/26/2017	5.9	2,772	101	42.88	55
09/10/2017	5.2	2,508	97	41.96	53
08/12/2018	7.8	2,997	104	34.38	70
07/30/2022	6.5	2,290	97	46.21	67
08/15/2022	5.5	2,232	99	37.62	67
08/20/2022	6.9	2,785	103	32.96	69
08/25/2022	5.6	2,685	100	34.62	64

Figure 179 shows the comparison of the exclusion period concentrations to concentrations on meteorologically similar dates at each exceedance site. Each date in the exclusion period is displayed separately alongside similar dates listed in Table 42 (July 28, 2022) or Table 43 (July 29, 2022). The MDA8 ozone concentration is elevated during the exclusion period compared to the distribution of MDA8 ozone concentration measured on the meteorologically similar dates. On July 29, 2022, two sites measured MDA8 concentrations below the maximum MDA8 ozone concentration measured on the meteorologically similar dates. Despite these sites having slightly lower MDA8 ozone concentrations on July 29, the MDA8 concentrations at both sites were above the 95th percentile on the meteorologically similar dates. Higher-than-expected ozone concentrations measured during the exclusion period compared to the meteorologically similar dates at multiple sites in Las Vegas provides evidence of an external source of ozone and/or ozone precursors during the exclusion period.

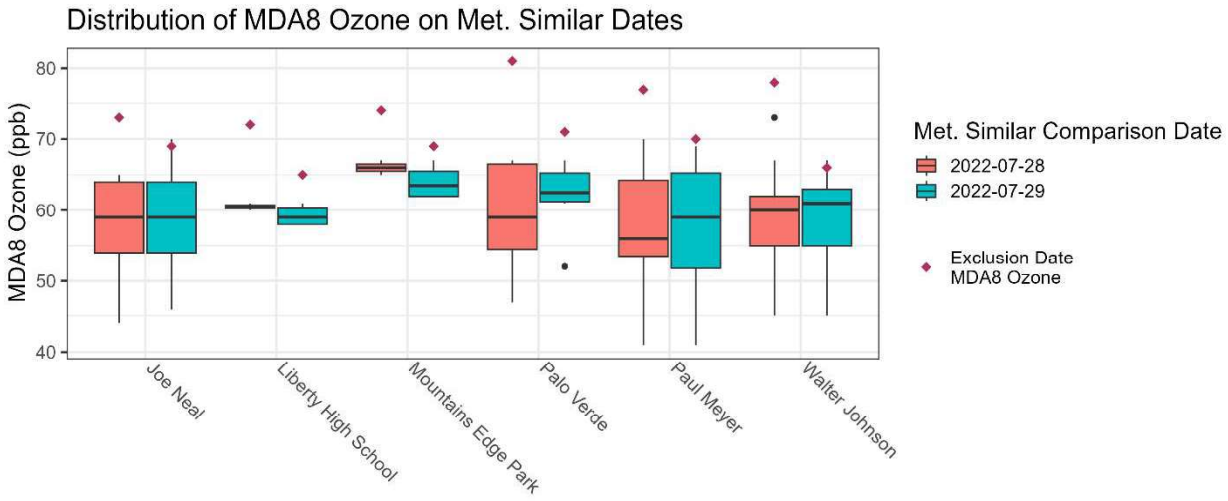

Figure 179. Distribution of MDA8 ozone concentrations on meteorologically similar days at measurement sites that were in exceedance during the exclusion period of July 28 (pink boxes) and July 29, 2022 (green boxes). MDA8 ozone concentrations measured on each exclusion date at each site are plotted as red diamonds.

5.3.6 Event Statistics

Table 44 summarizes the daily measurements of ozone, $PM_{2.5}$, CO, and NO_2 concentrations on the July 28-29, 2022, exclusion days, as well as the percentile rank of the observations compared to the previous five years of data (2018-2022) at both sites. Ozone MDA8 measurements at all sites were above the 97th percentile. $PM_{2.5}$, CO, and NO_2 concentrations are not significantly enhanced above typical concentrations during this event, likely due to light smoke conditions. 24-hr average $PM_{2.5}$ concentrations ranged from the 21st - 41st percentile at the sites. CO and NO_2 1-hr daily maximum concentrations ranged from the 30th-50th percentile. Lower concentrations of co-pollutants are more consistent with longer-range smoke transport and upwind ozone formation and transport. They may also occur when there is transport of ozone precursors in the Las Vegas urban area without significantly impacting other pollutants.

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Table 44. Percentile of pollutant measurements on the July 28-29, 2022, exclusion days compared with most recent five years of pollutant concentration data (2018-2022).* The percentile rank is calculated across the ozone production season (May 1-October 31) of 2018-2022.

Date	Site Name	Site Code	Ozone		$PM_{2.5}$		CO		NO_2	
			Ozone MDA8 (ppb)	Percent Rank	$PM_{2.5}$ 24-hr Avg ($\mu g/m^3$)	Percent Rank	CO 1-hr Daily Max (ppb)	Percent Rank	NO_2 1-hr Daily Max (ppb)	Percent Rank
7/28/2022	Joe Neal	320030075	73	97.6	5.4	41.2	285	49.9*	11.4	32.9
7/28/2022	Liberty High School	320030299	72	98.1*	4.4	21.5*				
7/28/2022	Mountain's Edge	320030044	74	98.5*	3.8	22.3*				
7/28/2022	Palo Verde (POC 3)	320030073	81	99.9	4.2	28.1*				
7/28/2022	Palo Verde (POC 4)	320030073	--	--	4.1	25.9*				
7/28/2022	Paul Meyer	320030043	77	99	5	31.4	196	36.6*		
7/28/2022	Walter Johnson	320030071	78	99.3	4.9	27.8*				
7/29/2022	Palo Verde (POC 3)	320030073	71	97.8	4.4	32.8*				
7/29/2022	Palo Verde (POC 4)	320030073	--	--	4.3	30.5*				

*Sites that have less than five years of data available for a given parameter.

5.4 September 1-2, 2022

5.4.1 Event Summary

An ozone event took place across September 1-2, 2022, affecting the Paul Meyer and Walter Johnson monitoring sites in Clark County, Nevada. The MDA8 ozone concentrations at the Paul Meyer site were 74 ppb on September 1, and 73 ppb on September 2. While only the Paul Meyer site recorded MDA8 values above the NAAQS threshold during this event, sites throughout the Las Vegas Valley (regulatory area HA212) experienced MDA8 values ranging from 53 to 74 ppb (with an average of 63 ppb and median of 67 ppb) on September 1, and MDA8 values ranging from 54 to 73 (with an average of 64 ppb and median of 65 ppb) on September 2. While the Walter Johnson site did not record an exceedance on either day, this site also showed significantly higher-than-normal hourly ozone with MDA8 values on September 1 of 68 ppb and September 2 of 70 ppb. Regional wildfire smoke is suspected to have contributed to the NAAQS exceedances these days. Major evidence includes smoke detection maps from NOAA's HMS smoke detection, dispersion model results from the HYSPLIT, meteorological analyses, PBL analyses, and a reduction in visibility recorded by ground-based cameras. This combination of evidence suggests that this could be an unrepresentative event for base and future design value ozone assessments.

A time series graph for August 31-September 4, 2022, is provided in **Figure 180**, showing hourly ozone concentrations that exceeded the hourly seasonal means and 10th-90th percentiles (calculated using May 1-October 31, 2017-2021) at the Paul Meyer and Walter Johnson sites. For both days and both sites, we see well-above normal ozone production that indicates likely influence from atypical sources of ozone precursors.

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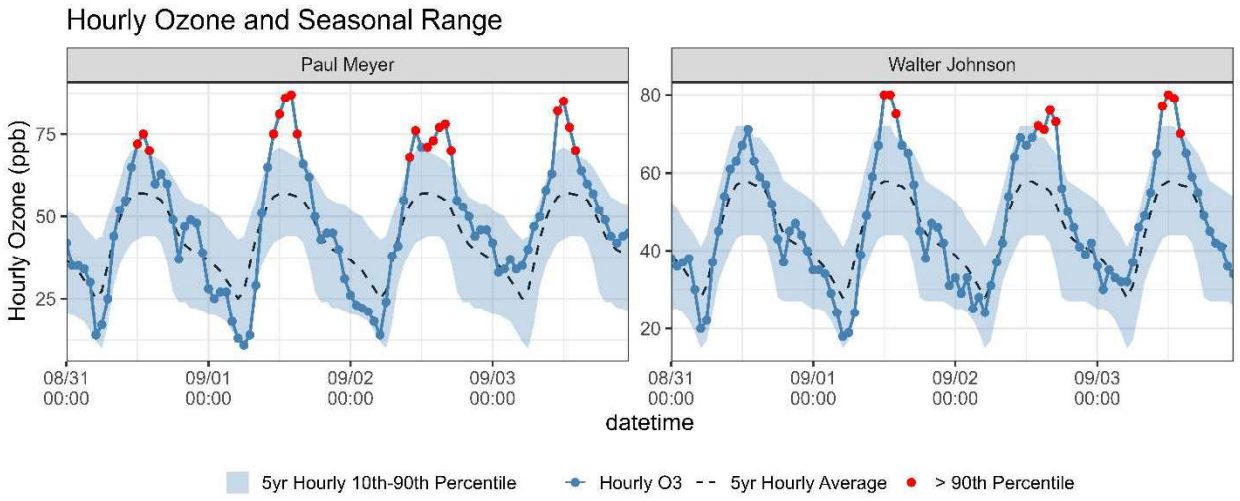

Figure 180. Hourly ozone concentrations (ppb) recorded at the Paul Meyer site across August 31-September 4, 2022, compared to 5-yr ozone season (May 1-October 31) hourly means and 10-90th percentiles.

5.4.2 Identification of Wildfires

Figure 181 shows HMS maps that display the progression of smoke dispersion across the United States between August 30 and September 2, 2022. HMS smoke maps are created using visible satellite imagery from Geostationary Operational Environmental Satellites (GOES). Visible imagery is only available during the sunlit part of the GOES orbit; therefore, smoke movement during nighttime hours is inferred between the daylight-generated smoke maps. On August 30, smoke plumes from fires in the northwest U.S. traveled northward and eastward. Over the next few days, these smoke plumes dispersed and spread over most of the western U.S. in a clockwise direction, driven by an upper-level high-pressure system. HMS smoke was present over Clark County, Nevada, on September 1 and 2. Figure 182 and Figure 183 show the surface-level and 500-mb weather maps for the days corresponding to the HMS maps in Figure 181. The weather maps show a surface and upper-level high pressure system over the southwest U.S. and moving to center over Clark County from August 30 through September 2. Since high-pressure systems are associated with stagnant and sinking air, this may have resulted in smoke aloft reaching the ground level.

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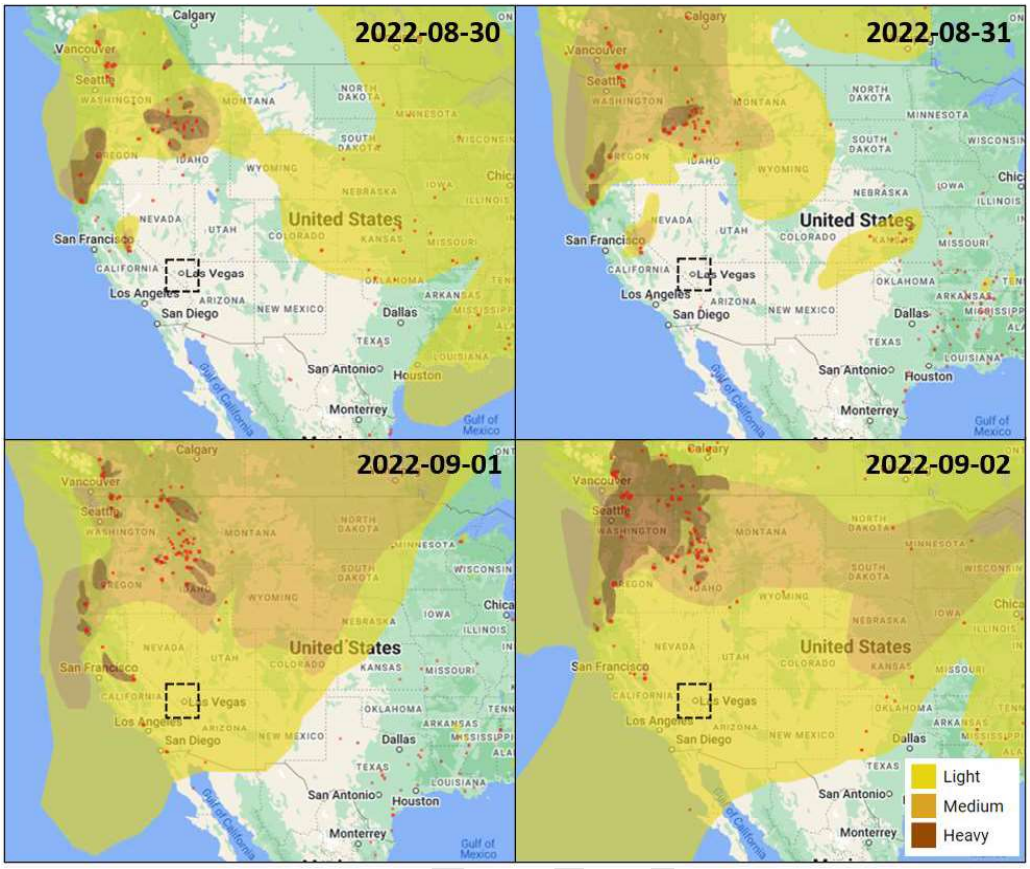

Figure 181. HMS smoke maps for August 30-September 2, 2022, showing smoke transport and qualitative smoke density. Clark County, NV, is enclosed by a dashed, black box on each map.

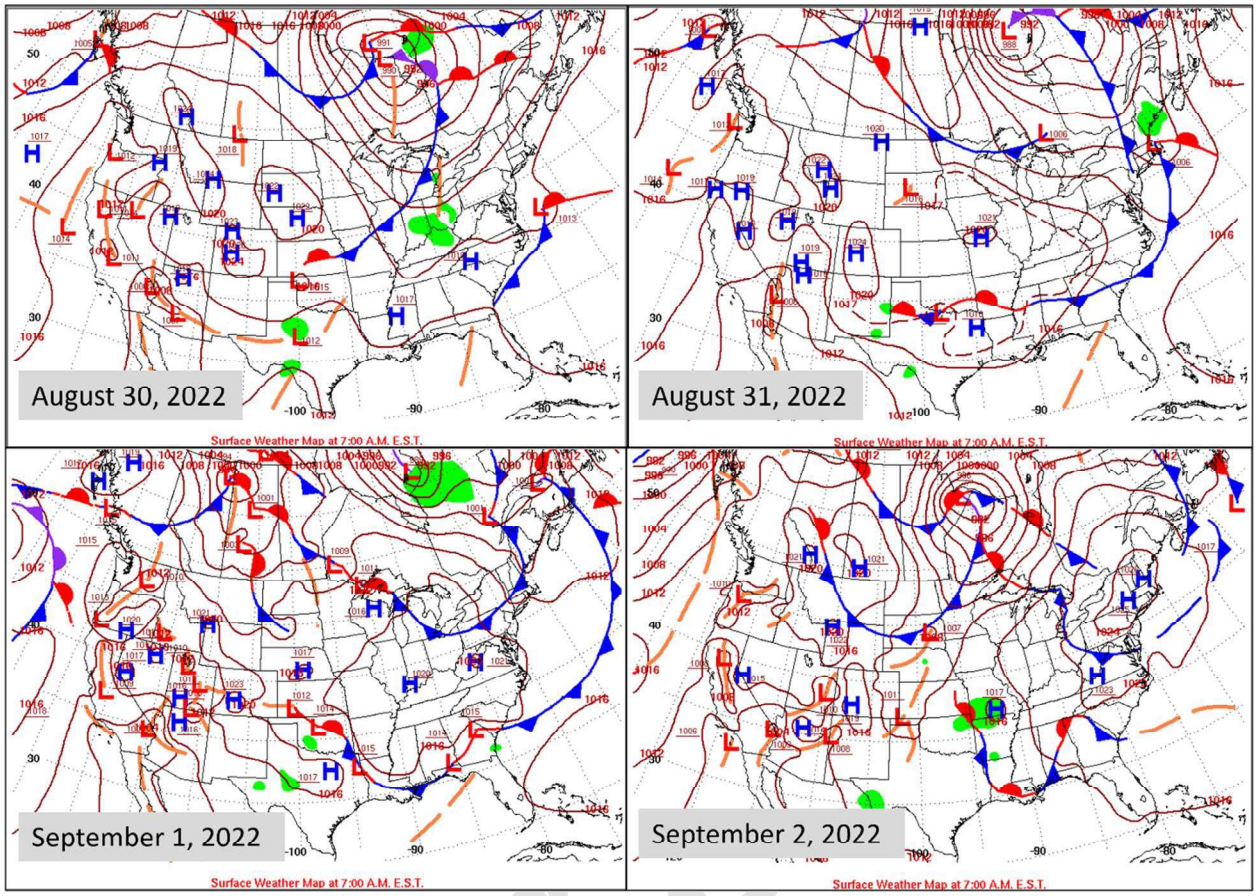

Figure 182. Daily surface-level weather maps for August 30-September 2, 2022. Source: NOAA's Weather Prediction Center

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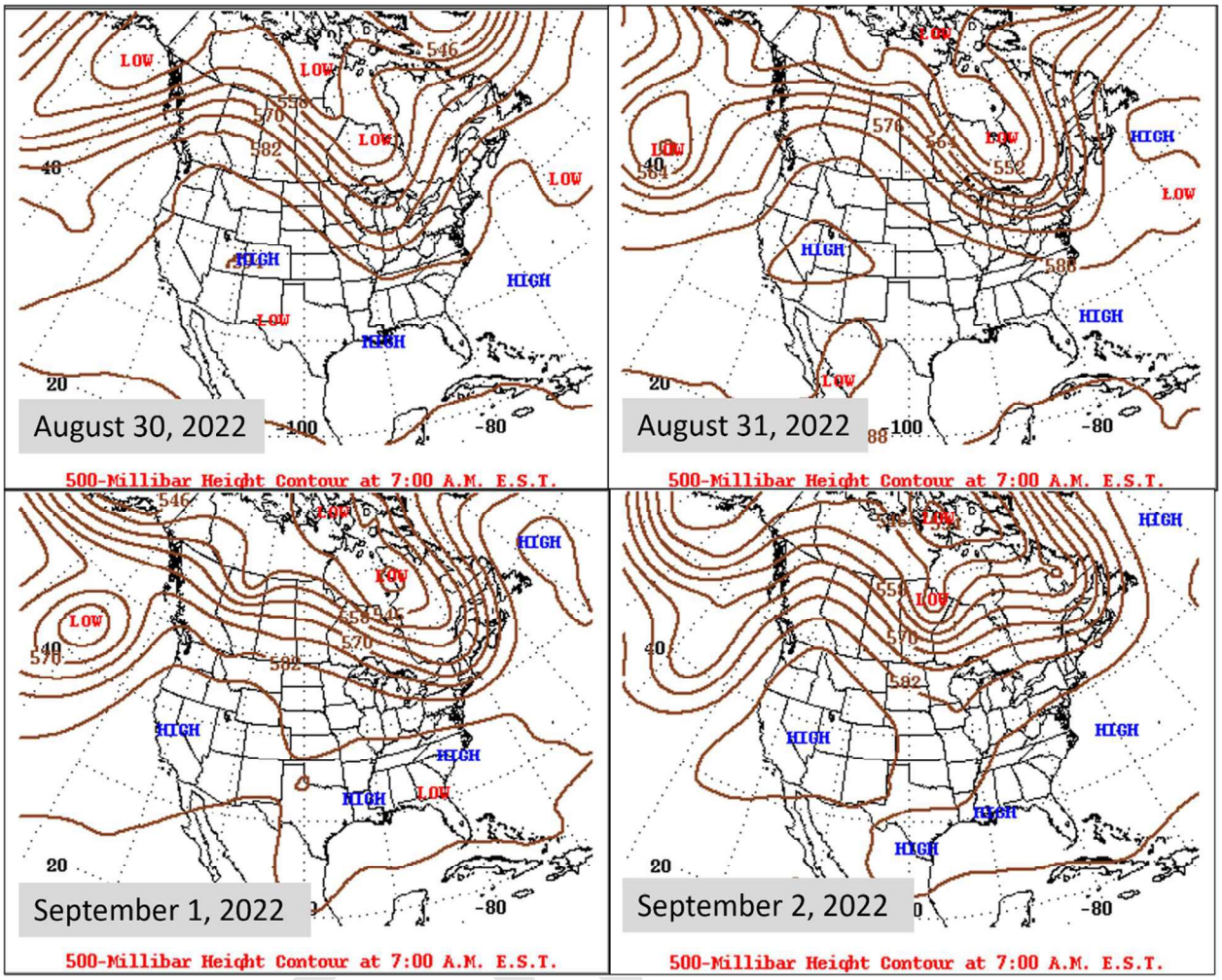

Figure 183. Daily 500-mb weather maps for August 30-September 2, 2022. Source: NOAA's Weather Prediction Center

Seventeen wildfires were active in the western and northwestern U.S. during the days leading up to and including the exclusion dates and are recorded in Table 45. The active fire area for each fire on and before the exclusion dates is provided, based on a post from the Six Rivers National Forest U.S. Forest Service account and InciWeb data for all 17 fires. Fire perimeters for each fire in relation to Clark County are shown in Figure 184. Zoomed-in views of most of the fires are shown in Figure 185 through Figure 187. Although the fires range in size, the HMS smoke images suggest that regional smoke was generated and spread due to the high volume of fire activity in the western U.S., including California, Oregon, and Idaho.

Table 45. Wildfires affecting Clark County on the exclusion days of September 1-2, 2022. The fire name, state location, total acreage, acres burned on or before the exclusion days, and the start and containment dates are included. Italicized containment dates indicate fire "out" status.

Wildfire Name	State	Total Acres	Acres Burned on or Before Exclusion Days	Start Date	Containment Date
Campbell (Lightning Complex)	California	41,540	37,081 (Sept. 1)[36]	Aug. 5	Nov. 3
Cedar Creek	Oregon	128,602	8,817 (Sept. 1)[37]	Aug. 1	Nov. 1
Crockets Knob	Oregon	4,333	2,840 (Sept. 1)[38]	Aug. 22	Oct. 27
Dismal	Idaho	8,197	1,876 (Aug. 31)[39]	July 23	Nov. 3
Double Creek	Oregon	175,938	2,946 (Sept. 1)[40]	Aug. 30	Oct. 25
Four Corners	Idaho	13,703	12,817 (Sept. 1)[41]	Aug. 13	Oct. 20
Moose	Idaho	130,144	99,232 (Sept. 1)[42]	July 17	Nov. 09
Nebo	Oregon	12,608	3,086 (Sept. 1)[43]	Aug. 25	Oct. 25
Norton	Idaho	9,080	1,859 (Aug. 29)[44]	Aug. 1	Oct. 25
Patrol Point	Idaho	16,130	735 (Sept. 1)[45]	Aug. 20	Nov. 03
Rum Creek	Oregon	21,227	15,635 (Sept. 1)[46]	Aug. 17	Sep. 30
Sturgill	Oregon	21,636	4,815 (Sept. 1)[47]	Aug. 22	Oct. 24
Trail Ridge	Montana	17,509	517 (Sept. 1)[48]	Aug. 26	Oct. 29
Williams Creek	Idaho	16,083	626 (Sept. 1)[49]	Aug. 29	Nov. 3
Ross Fork	Idaho	37,928	1,944 (Sept. 1)[50]	Aug. 14	Nov. 1
Red	California	8,408	3,558 (Sept. 1)[51]	Aug. 4	*Nov. 6*
Rodgers	California	2,774	1,644 (Sept. 1)	Aug. 8	*Nov. 6*

[36] https://www.facebook.com/plugins/post.php?href=https%3A%2F%2Fwww.facebook.com%2FSixRiversNF%2Fposts%2Fpfbid0Yth9ZfKE3izWXzkn3wDoMyuDm4iHKgKf7CYoUVGasnxAU4MkhNTPfutK9ii7KsMul&

[37] https://inciweb.nwcg.gov/incident-publication/orwif-cedar-creek-fire/cedar-creek-fire-update-sept-1

[38] https://inciweb.nwcg.gov/incident-publication/ormaf-crockets-knob-fire/912022-crockets-knob-fire-update

[39] https://inciweb.nwcg.gov/incident-maps-gallery/idpaf-dismal-fire?page=0

[40] https://inciweb.nwcg.gov/incident-information/orwwf-double-creek-fire

[41] https://inciweb.nwcg.gov/incident-information/idpaf-four-corners-fire

[42] https://inci-web-media-bucket.s3.us-gov-west-1.amazonaws.com/s3fs-public/2022-10/pict20220805-153223-0.pdf

[43] https://incitest.nwcg.gov/incident-information/orwwf-nebo-fire

[44] https://inci-web-media-bucket.s3.us-gov-west-1.amazonaws.com/s3fs-public/2022-10/pict20220805-153223-0.pdf

[45] https://incitest.nwcg.gov/incident-information/idpaf-patrol-point

[46] https://inciweb.nwcg.gov/incident-maps-gallery/ormed-rum-creek-fire?page=2

[47] https://inciweb.nwcg.gov/incident-maps-gallery/orwwf-sturgill-fire?page=3

[48] https://inciweb.nwcg.gov/incident-information/mtbdf-trail-ridge-fire

[49] https://inciweb.nwcg.gov/incident-information/idncf-williams-creek-fire

[50] https://inciweb.nwcg.gov/incident-information/idstf-ross-fork

[51] https://www.facebook.com/YosemiteFire/posts/5724107654307870?ref=embed_post

Figure 184. Final fire perimeters (red) for the 17 active fire regions during the September 1-2, 2022, exclusion dates in relation to Clark County (black perimeter).

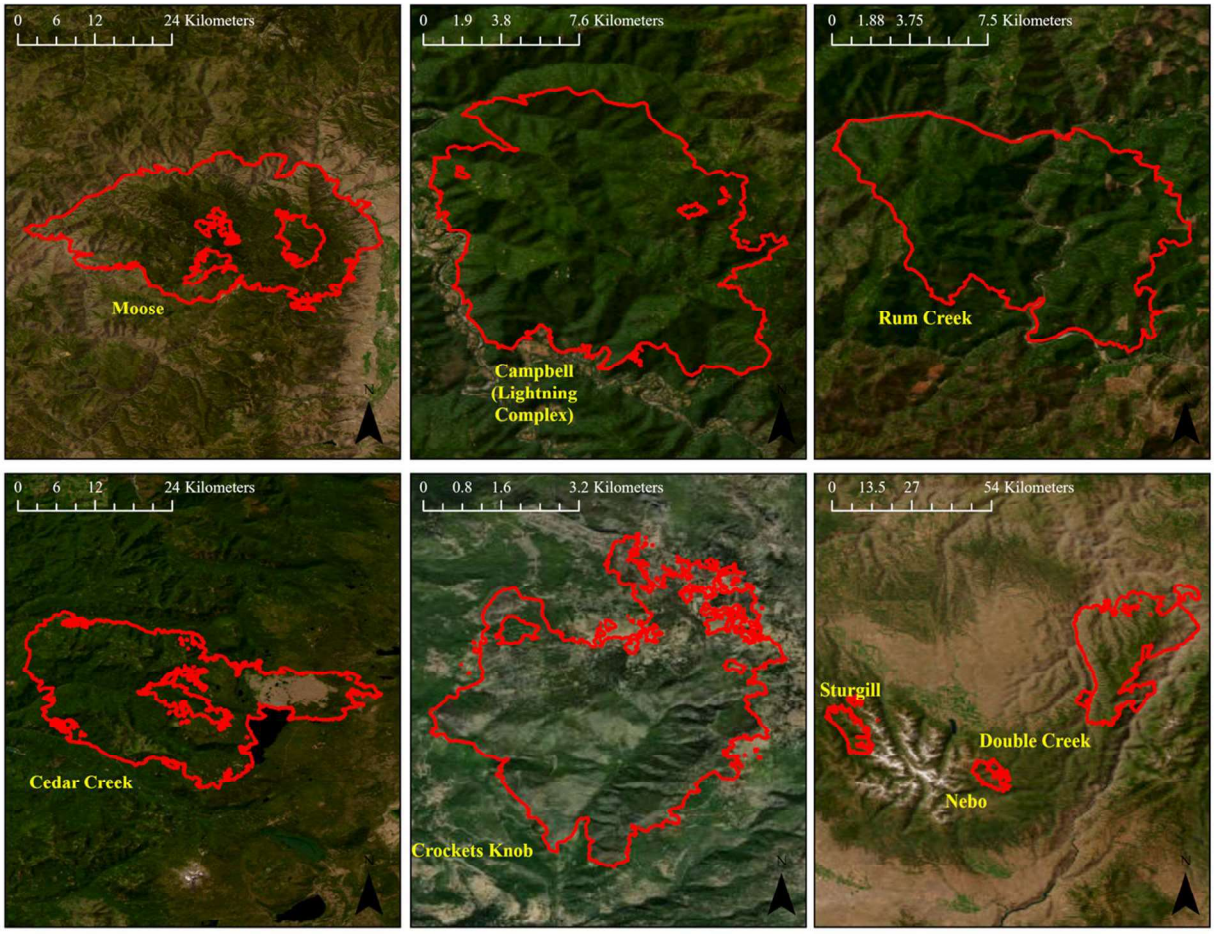

Figure 185. Final fire perimeters (red) for six of the 17 active fire regions during the September 1-2, 2022, exclusion dates.

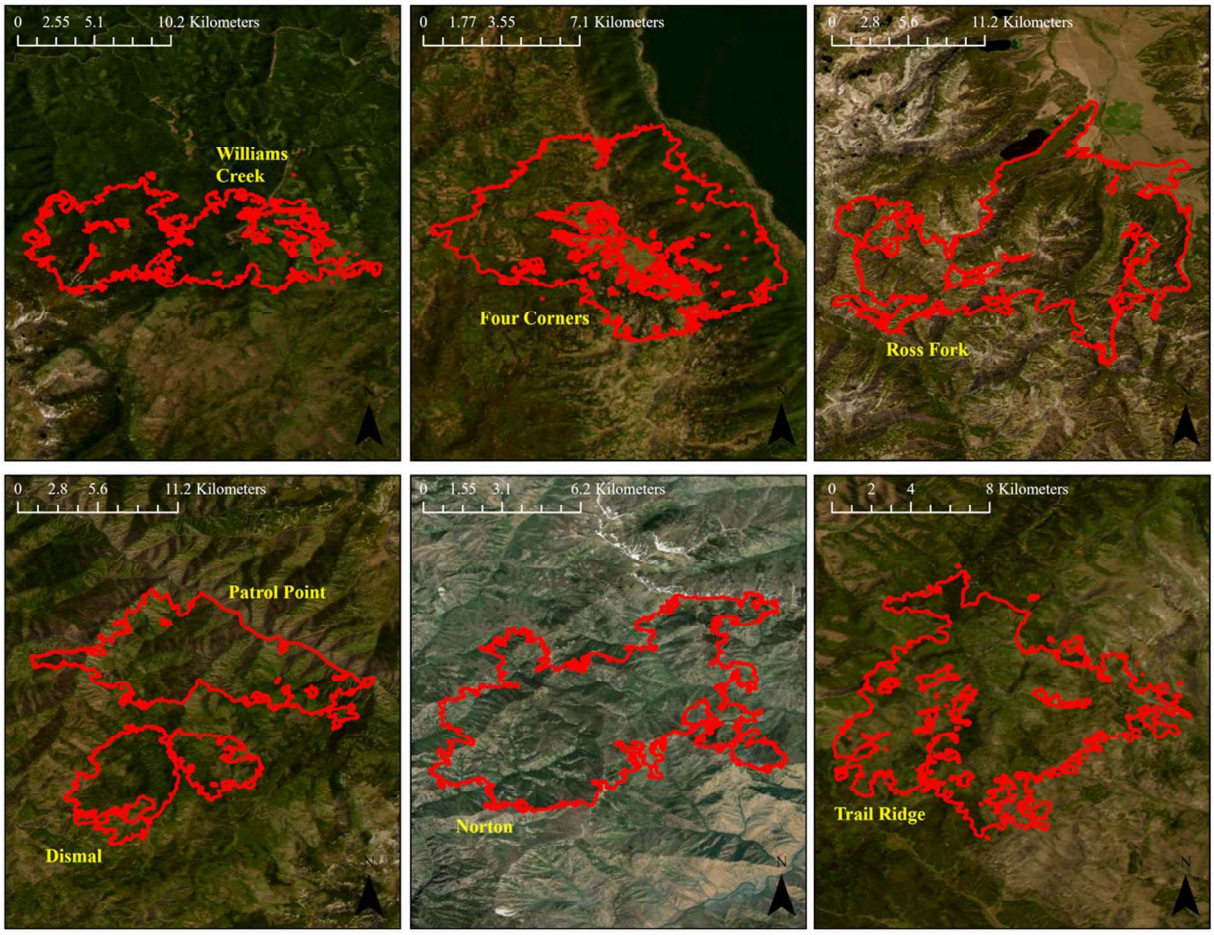

Figure 186. Final fire perimeters (red) for six of the 17 active fire regions during the September 1-2, 2022, exclusion dates.

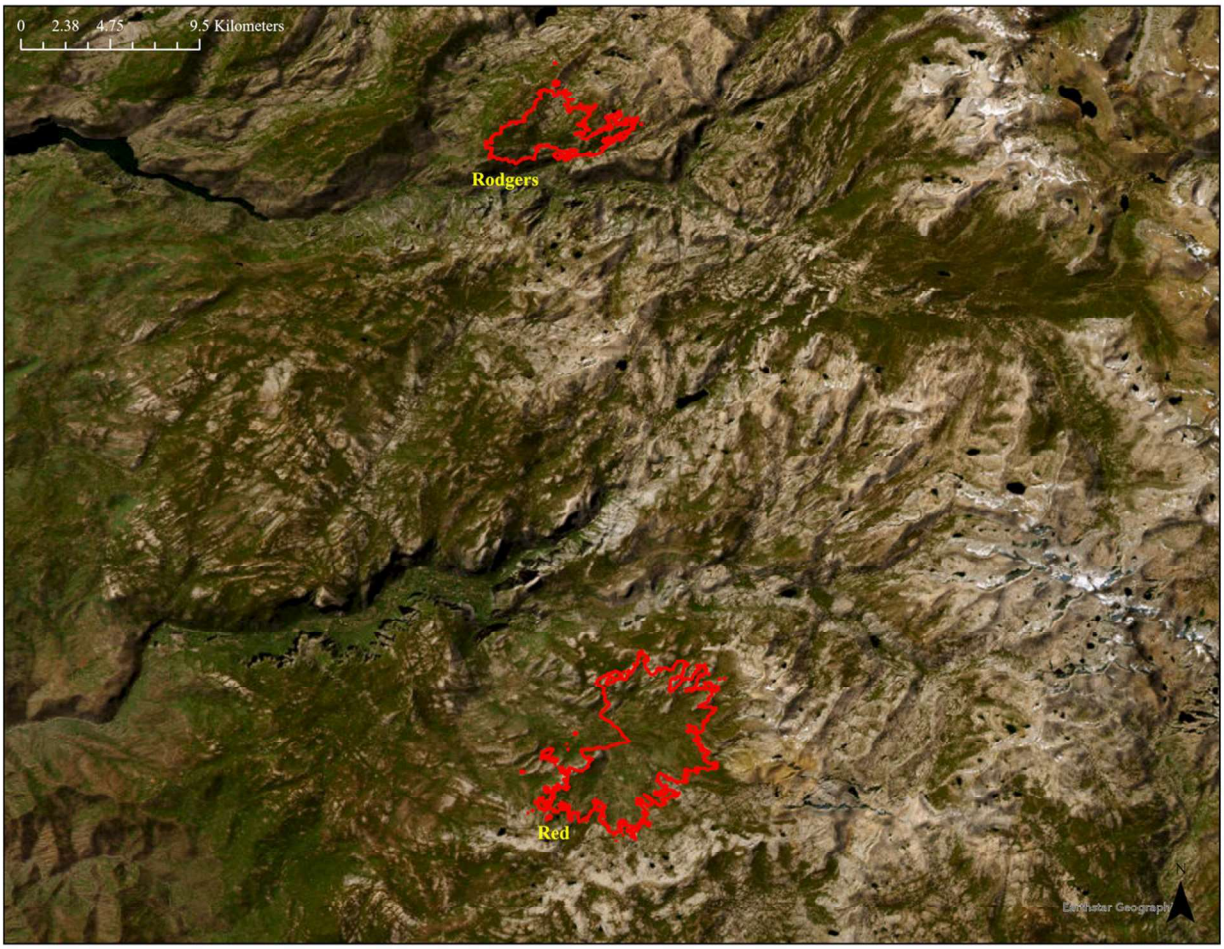

Figure 187. Final fire perimeters (red) for two of the 17 active fire regions during the September 1-2, 2022, exclusion dates.

5.4.3 Dispersion Modeling and Regional Analysis

To examine the effect of wildfire smoke in Clark County (as indicated by the HMS smoke maps shown in Section 5.4.2), we first determined the meteorological conditions on and before the September 1-2, 2022, event. We specifically focused on the boundary layer dynamics to determine the depth of mixing and possibility of smoke mixing to the surface. We then used this information to model smoke via HYSPLIT and compare the results to independent data sources (including HMS and HRRR data).

The PBL denotes the atmospheric layer closest to the surface, and the height of the PBL describes the vertical extent of surface air characteristics. Atmospheric soundings and PBL maps provide visualizations of the extent of vertical mixing in the lower troposphere. The five skew-T diagrams from the Las Vegas upper-air weather station (KVEF) in Figure 188 show the vertical profile of the atmosphere every 12 hours from September 1 at 00:00 UTC (August 31 at 16:00 PST) to September 3

at 00:00 UTC (September 2 at 16:00 PST). The five skew-T diagrams are characterized primarily by their diurnal changes in the lower troposphere from consecutive soundings. Soundings taken at 12:00 UTC (i.e., 04:00 PST) show a near-surface temperature inversion that inhibited vertical mixing between the near-surface and mid-troposphere, whereas soundings taken at 16:00 PST show an approximately dry-adiabatic temperature lapse rate, indicating that the lower troposphere was well mixed with a PBL of approximately 4,000 m AGL on September 1 and approximately 5,000 m AGL on September 2. The PBL on September 1 was higher than the 2017-2021 climatological average PBL at KVEF for 00:00 UTC, which is approximately 3,500 m AGL. For September 2, the 4,000 m AGL PBL at KVEF was slightly higher than the 2017-2021 climatological average PBL at KVEF for 00:00 UTC, which is 3,800 m AGL.

The NAM-modeled PBL heights over Clark County on September 1 at 16:00 PST (Figure 189) and September 2 at 16:00 PST (Figure 190) correspond to the PBL heights shown on the sounding taken at these same times, and also indicate a PBL height of approximately 4,000 to 6,000 m. Both the skew-T diagrams and NAM-modeled PBL heights over Clark County on the exclusion dates indicate a deep, well-mixed boundary layer each afternoon, conducive to smoke mixing to the surface.

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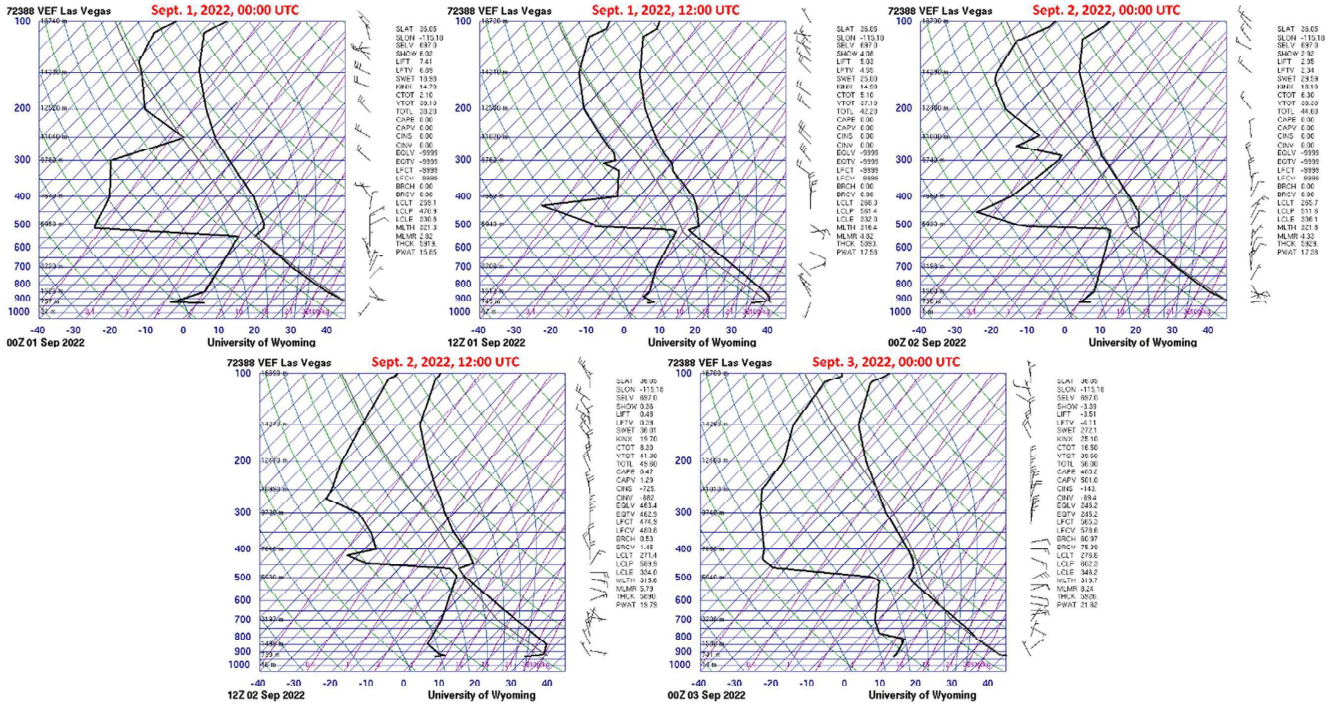

Figure 188. Skew-T soundings launched from KVEF from September 1, 2022, at 00:00 UTC (August 31 at 16:00 PST) (top left), to September 3 at 00:00 UTC (September 2 at 16:00 PST) (bottom right). Source: University of Wyoming

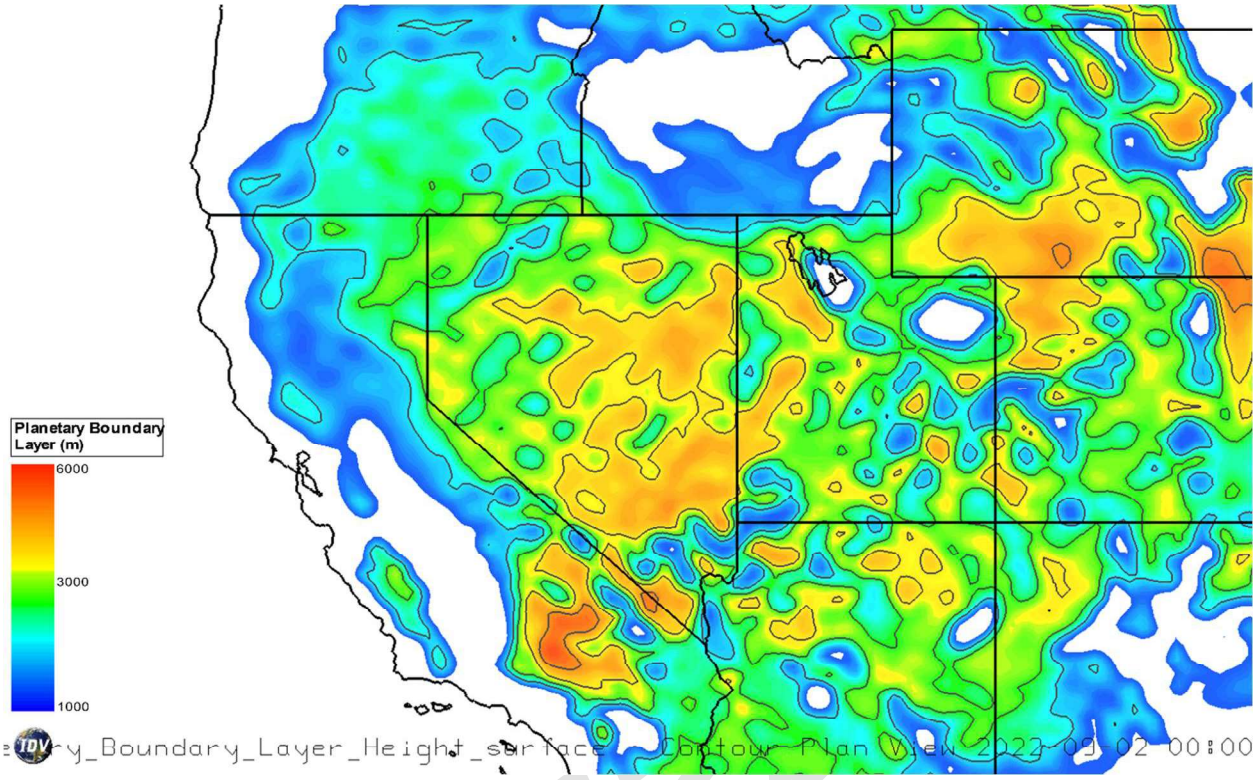

Figure 189. PBL height contour map based on the NAM model for September 2, 2022, at 00:00 UTC (September 1 at 16:00 PST). The gray lines denote PBL heights above 2 km in altitude in 1 km increments. Color contours start at 1 km.

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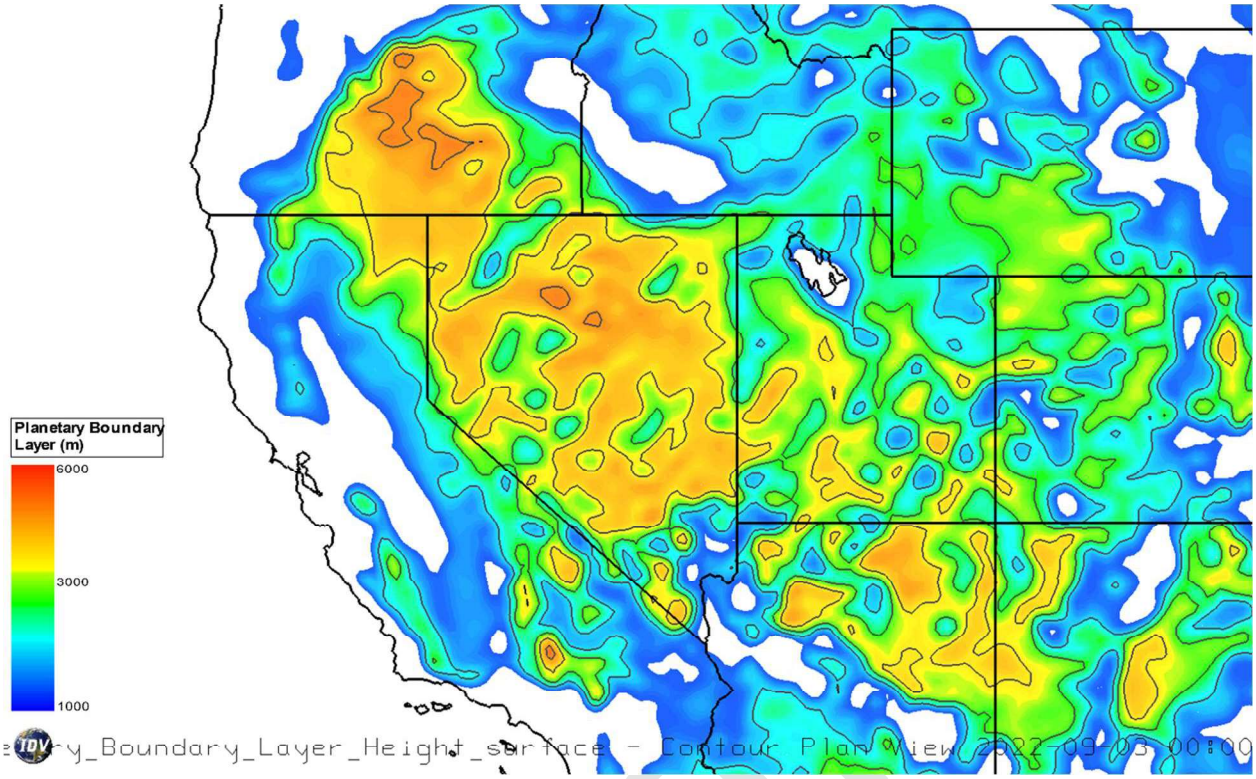

Figure 190. PBL height contour map based on the NAM model for September 3, 2022, at 00:00 UTC (September 2 at 16:00 PST). The gray lines denote PBL heights above 2 km in altitude in 1 km increments. Color contours start at 1 km.

HYSPLIT dispersion modeling was performed from August 30 through September 3, 2022. Dispersion modeling was initiated on August 30 at 00:00 PST from the 17 identified active fires impacting the exclusion dates and modeled through the exclusion dates to simulate the smoke patterns seen in satellite imagery and HMS smoke data. GDAS data at 1.0° horizontal resolution was used for meteorological input. Output from the dispersion modeling has been integrated over 6-hr periods starting 00:00 PST on September 1 and ending 00:00 PST on September 3. This time period was chosen to correspond with the exclusion dates. The accumulation of smoke throughout the boundary layer at 0-4,500 m for the time periods is shown in Figure 191. The modeling results are somewhat consistent with the HMS smoke plumes shown in Figure 181; HMS is an independent smoke identification database. The results likely miss some smoke from additional fires in the western U.S. and Canada that were burning at or before the exclusion dates.

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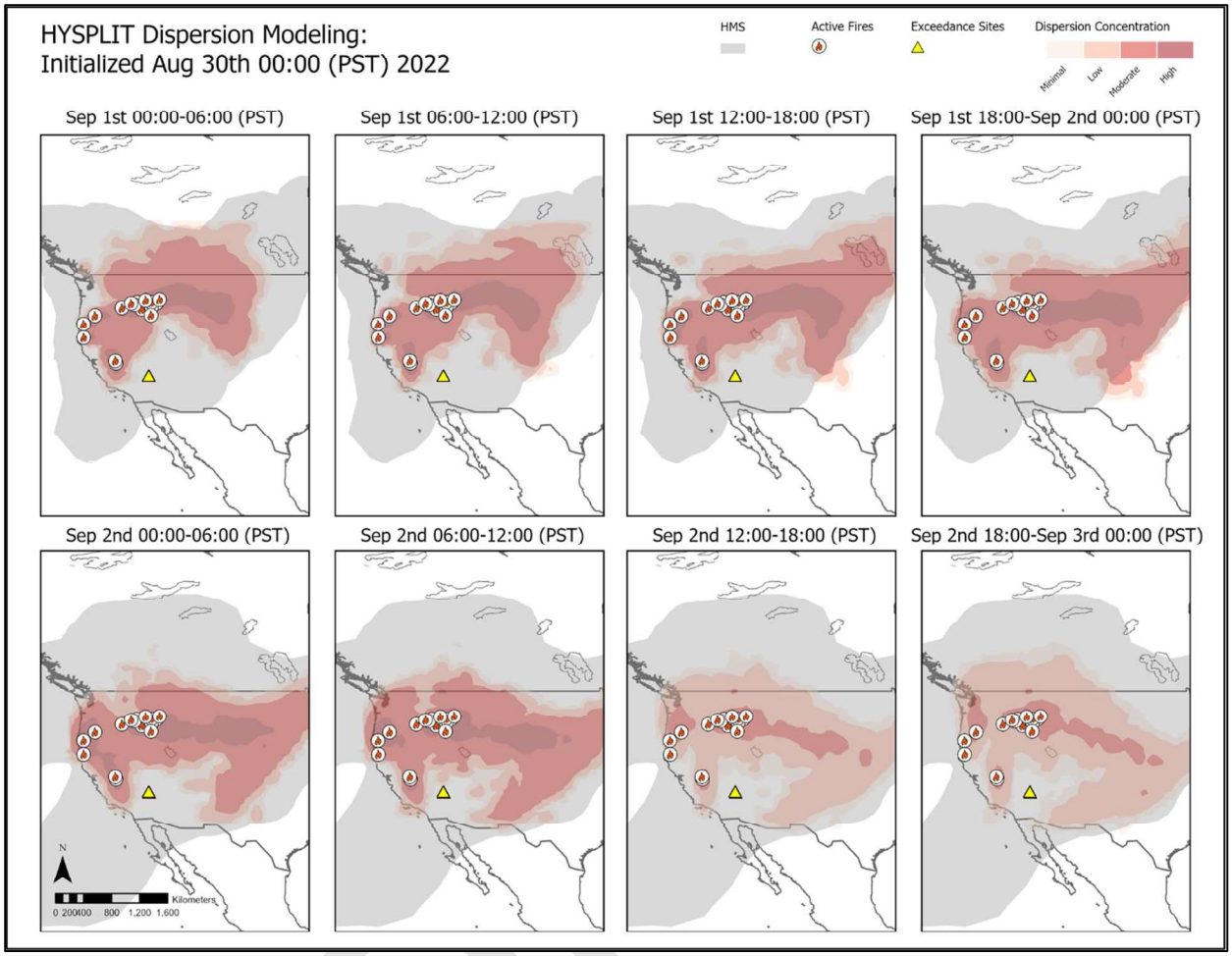

Figure 191. HYSPLIT dispersion modeling for 17 large fires (labeled as "Active Fires") in the western U.S. on or before the exclusion dates of September 1-2, 2022. GDAS 1.0° meteorological data was used, and dispersion was initiated on August 30, at 00:00 PST, to model the regional smoke observed in satellite and HMS products. HMS smoke is shown in gray, and qualitative concentrations of particulate matter are shown in shades of red. Accumulation of particulate matter is shown at 0-4,500 m.

120-hour HYSPLIT back trajectories were run from the Paul Meyer air monitoring site at 16:00 PST on September 1 (00 UTC September 2), 2022, shown in Figure 192 (right). These back trajectories were run near the surface (100 m), at the mid-boundary-layer (2,000 m), and at the top of the boundary-layer (4,000 m) to determine potential smoke transport from upwind locations. While the mid- and upper-boundary-layer back trajectories circulate through the Desert Southwest, the 100-meter back trajectory passes directly through the large smoke plume over the Pacific Northwest and Intermountain West (Figure 192, left). The height diagram below the trajectories also indicates aloft air descending to near the surface and into the boundary layer in the Las Vegas area on September 1. Once the smoke arrived in Clark County, light and variable surface winds allowed the smoke and associated ozone precursors to linger, enhancing ozone production on September 1 and 2. This is consistent with the HMS and meteorological narrative from Section 5.4.2, and shows air circling

around a high-pressure system in the southwestern U.S. and descending into a well-mixed boundary layer.

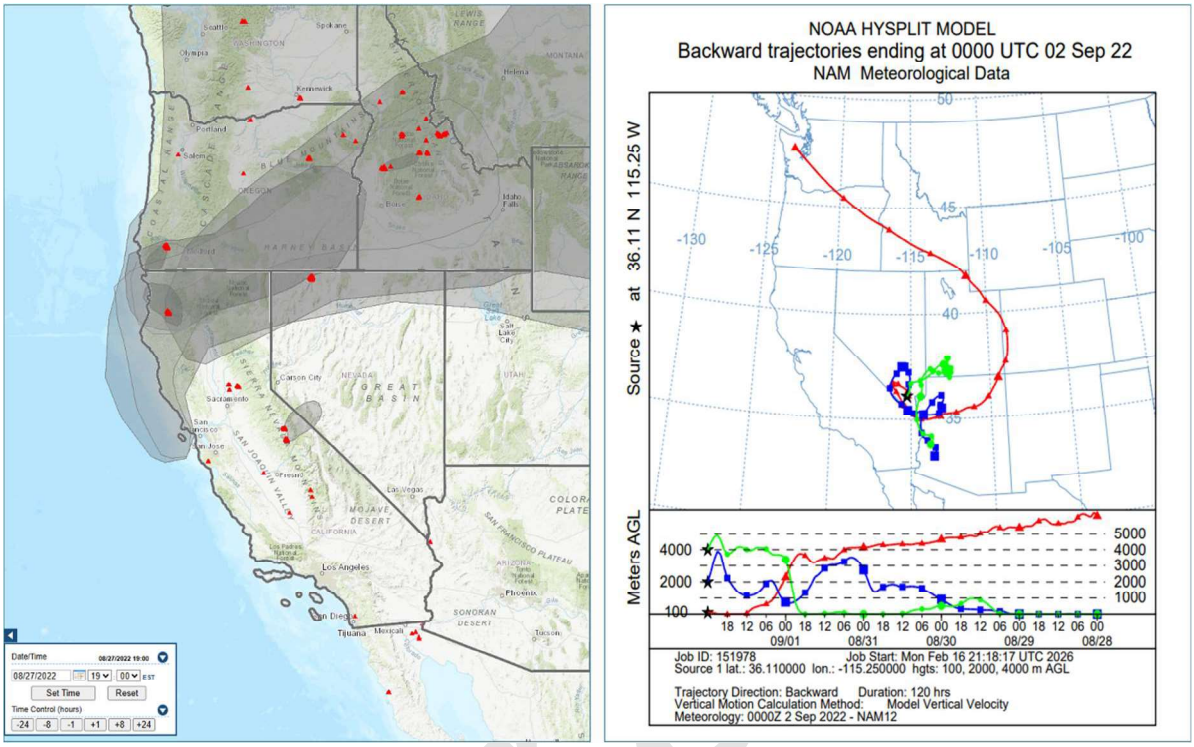

Figure 192. (Left) HMS smoke analysis from August 27, 2022 (120 hours prior to the September 1, 2022 exceedance). (Right) 120-hour NAM 12-km HYSPLIT back trajectories at 100 m (red), 2,000 m (blue), and 4,000 m (green), initiated at 16:00 PST on September 1 (00 UTC September 2) at the Paul Meyer air quality monitor. Sources: EPA's AirNow-Tech and NOAA's Air Resources Laboratory.

In addition, HMS smoke analysis confirmed the presence of moderate-density smoke over Clark County on September 1 and light density smoke over Clark County on September 2 (Figure 193).

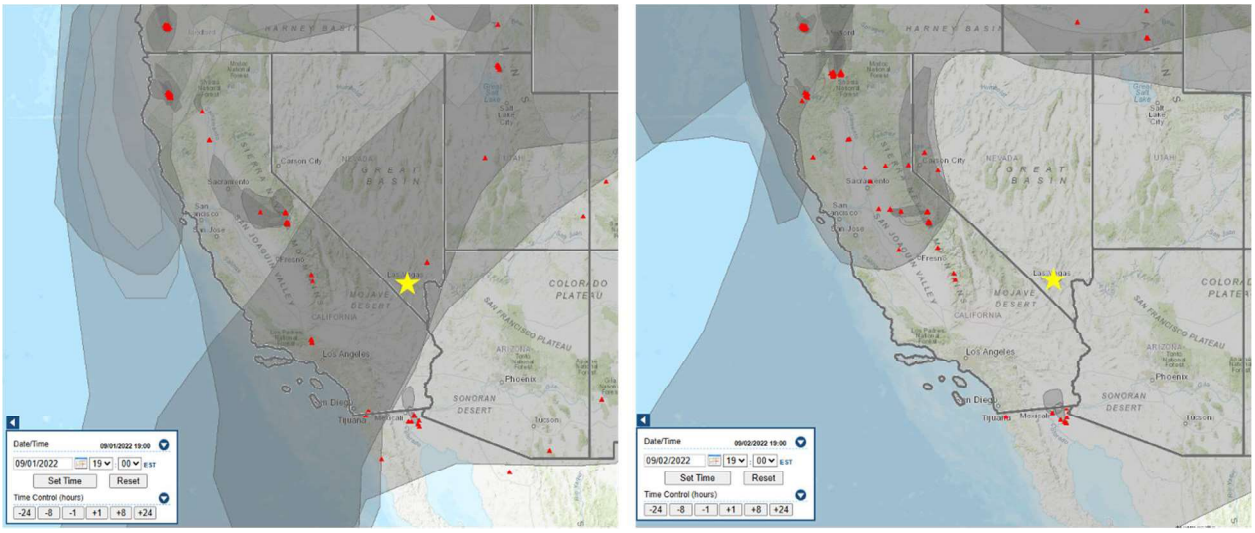

Figure 193. HMS smoke analysis from September 1, 2022 (left), and September 2 (right). The images show moderate density smoke over the Las Vegas region (star) on September 1, and light density smoke over Las Vegas on September 2. Source: AirNow-Tech

The HRRR smoke forecast product (Figure 194) agrees with the HYSPLIT dispersion and back trajectory analysis, showing vertically integrated smoke over the Clark County region on September 1-2, 2022.

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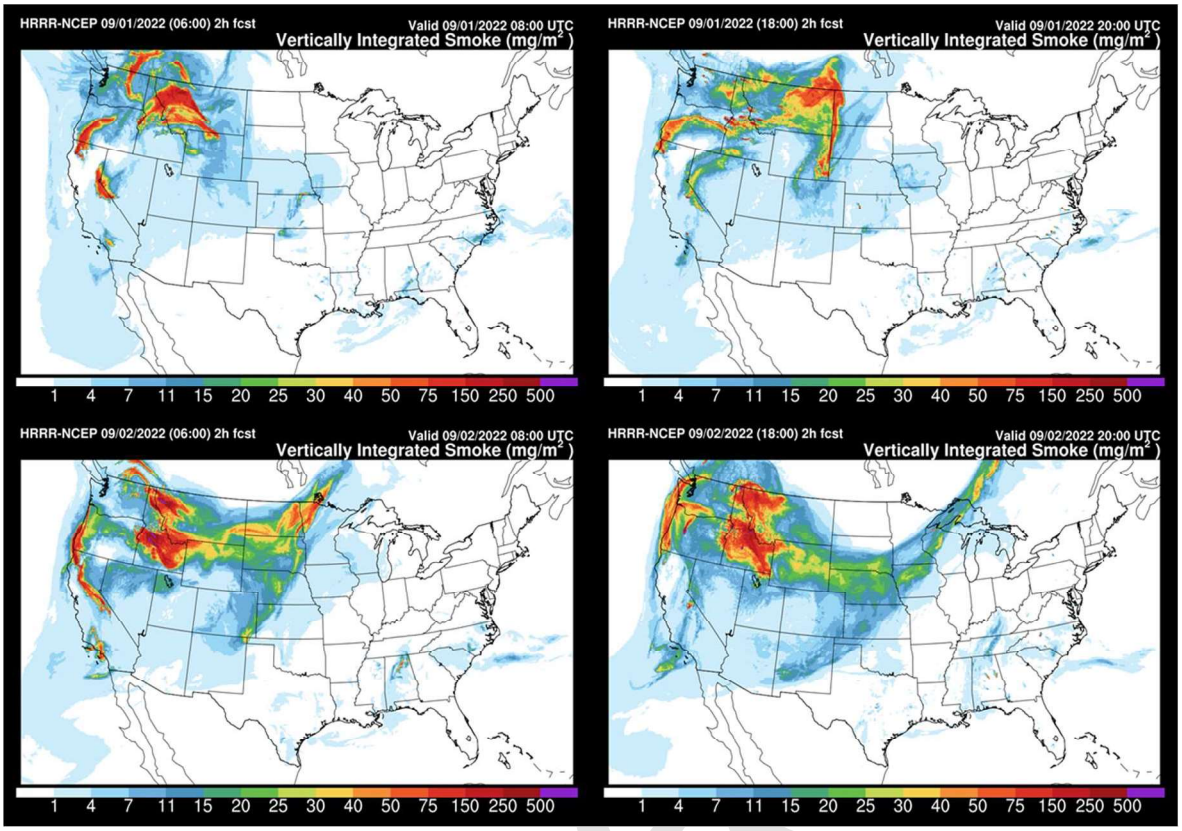

Figure 194. HRRR vertically integrated smoke forecast for September 1-2, 2022, at 00:00 PST and 12:00 PST.

In summary, the HMS maps, meteorological analysis, HYSPLIT analysis, and HRRR forecast products provide evidence that regional smoke from numerous fires across the northwestern United States was transported around a high-pressure system and into a well-mixed boundary layer in the Las Vegas Valley on September 1-2, 2022.

5.4.4 Impacts at the Surface

Figure 195 compares visibility conditions in the Las Vegas Valley before and during the exclusion event, showing visibility conditions at 12:00 on August 31, 2022 (the day before the event), and the event dates of September 1 and 2. The presence of regional wildfire smoke on the exclusion dates from fires identified in Section 5.4.2 may be indicated by some reduction in visibility conditions on September 1 and 2. The mountains in the north and northwestern views are somewhat obscured as the exclusion event continues, which may indicate the presence of increasing regional smoke on the exclusion event days in Clark County.

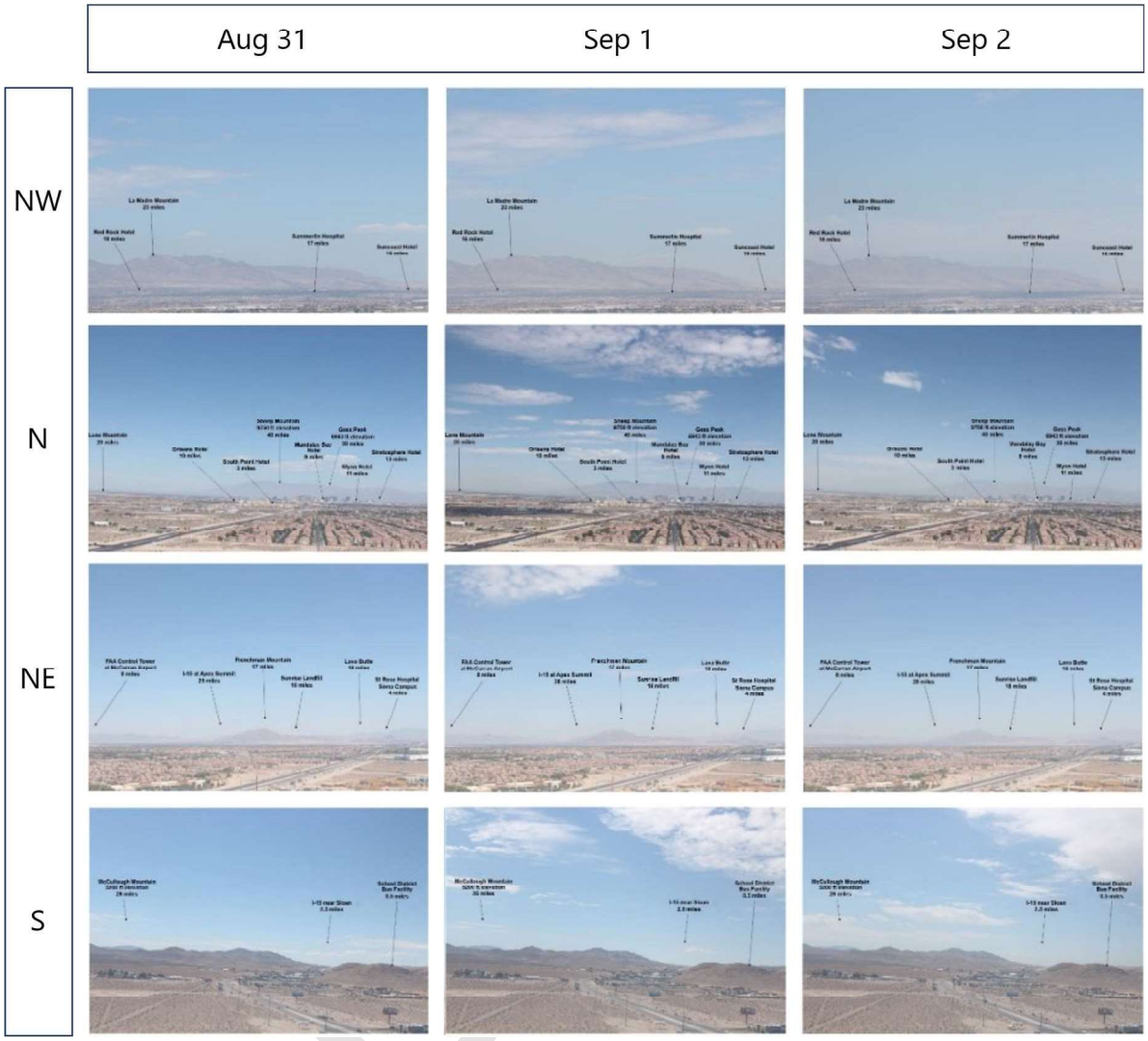

Figure 195. Camera images for August 31, 2022 (left column), September 1 (middle column), and September 2 (right column), taken at 12:00 PST each day from the M Resort Hotel in Las Vegas. These images face northwest (top row), north (second row), northeast (third row), and south (bottom row).

Figure 196 show the hourly $PM_{2.5}$ concentrations during the event period, compared to the diurnal 10th-90th percentile $PM_{2.5}$ concentration (calculated from May-October 2017-2022), at the Paul Meyer site and all other regional supporting sites that measure $PM_{2.5}$ concentrations. Hourly $PM_{2.5}$ concentrations shown in Figure 196 for the exclusion period met or exceeded the diurnal 90th percentile $PM_{2.5}$ concentrations at multiple sites in the Las Vegas Valley on September 1 and 2. However, none of the spikes in $PM_{2.5}$ concentrations are particularly enhanced or coincide with multiple other sites to indicate an injection of a large amount of smoke. Concentrations do trend upward between September 1 and 2, consistent with the somewhat decreased visibility in the camera images shown in Figure 195.

Figure 197 shows the hourly CO concentrations alongside the 10th-90th percentile diurnal concentrations, calculated from May-October 2017-2022, recorded at the sites that measure CO concentrations. There was an uptick in CO concentrations early on September 1, and concentrations exceeded the 90th percentile at each site at some point during the event period.

Figure 198 shows the hourly NO_2 concentrations alongside the median and 10th-90th percentile diurnal concentrations, calculated from May-October 2017-2022, recorded at the sites that measure NO_2 concentrations. NO_2 concentrations at the Jerome Mack-NCore, Sunrise Acres, and Walnut Community Center sites met or exceeded the 90th percentile during max the hours of typical maximum concentration on September 1 and into September 2.

NO_z (i.e., NO_y-NO_x) includes reservoir species such as nitric acid (HNO_3), peroxyacetylnitrates (PANs), and other nitrates that can store NO_x during transport and release this ozone precursor to enhance ozone production downwind of a source (e.g., wildfires). For the September 1-2 dates, we find that NO_z concentrations are enhanced and increasing in the day before the wildfire event (Figure 199). We also see NO_z concentrations well above the 90th percentile late in the day on September 1 and into September 2. Unfortunately, the NO_y and NO_x data were unavailable (meaning NO_z data were also unavailable) between the mid-morning on August 31 through the mid-day on September 1. Despite this lapse in data, we note that this enhancement of NO_z is likely to enhance concentrations of ozone precursors and contribute to enhanced ozone production. This is confirmed through the enhanced NO_2 concentrations seen on September 1 and 2.

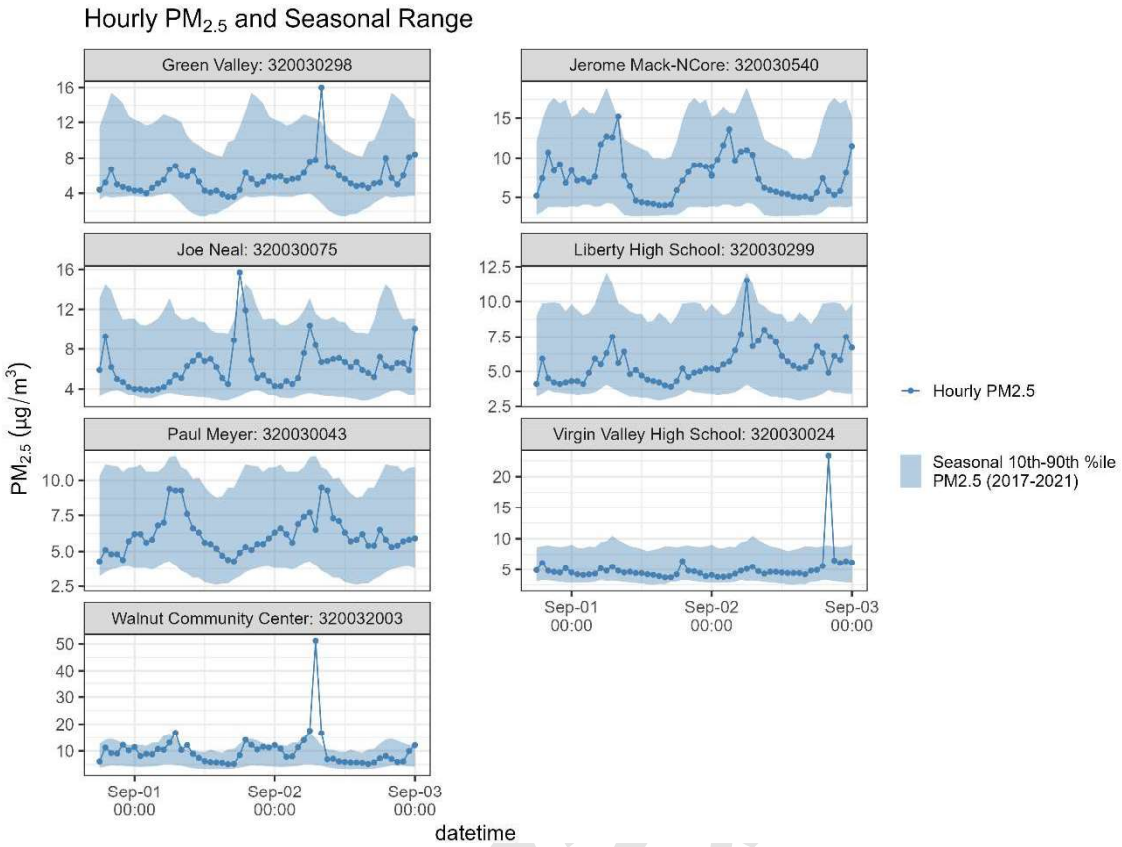

Figure 196. Hourly $PM_{2.5}$ measurements overlaid on the 10th-90th percentile diurnal concentrations recorded at the event-affected measurement sites and supporting sites that measure $PM_{2.5}$ concentrations. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2022.

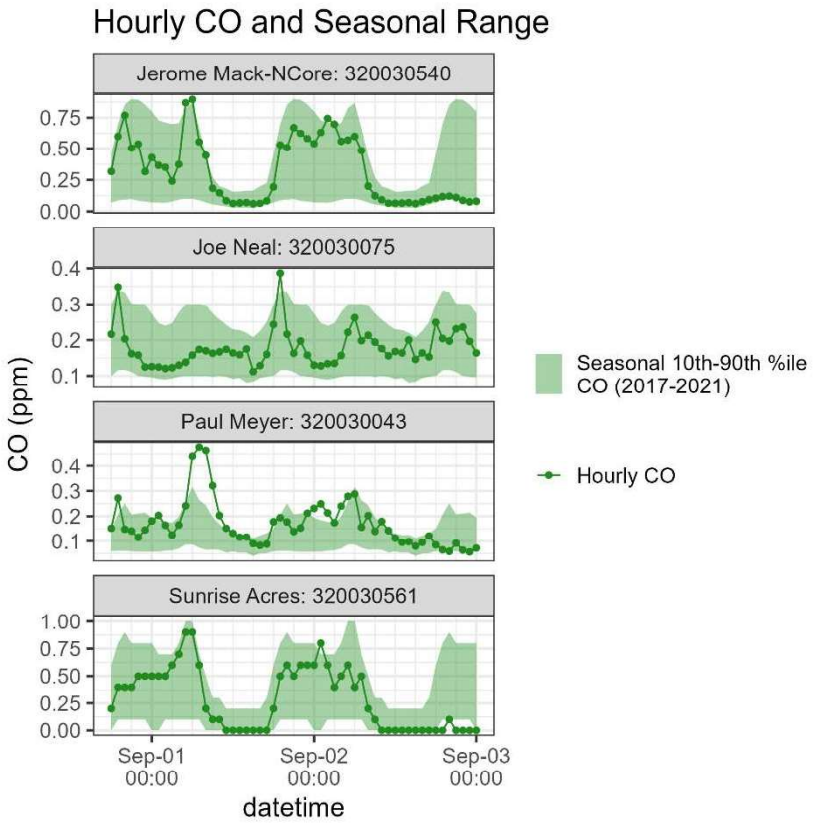

Figure 197. Hourly CO measurements overlaid on the 10th-90th percentile diurnal concentrations at each event-affected measurement site and supporting sites that measure CO concentrations. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2022.

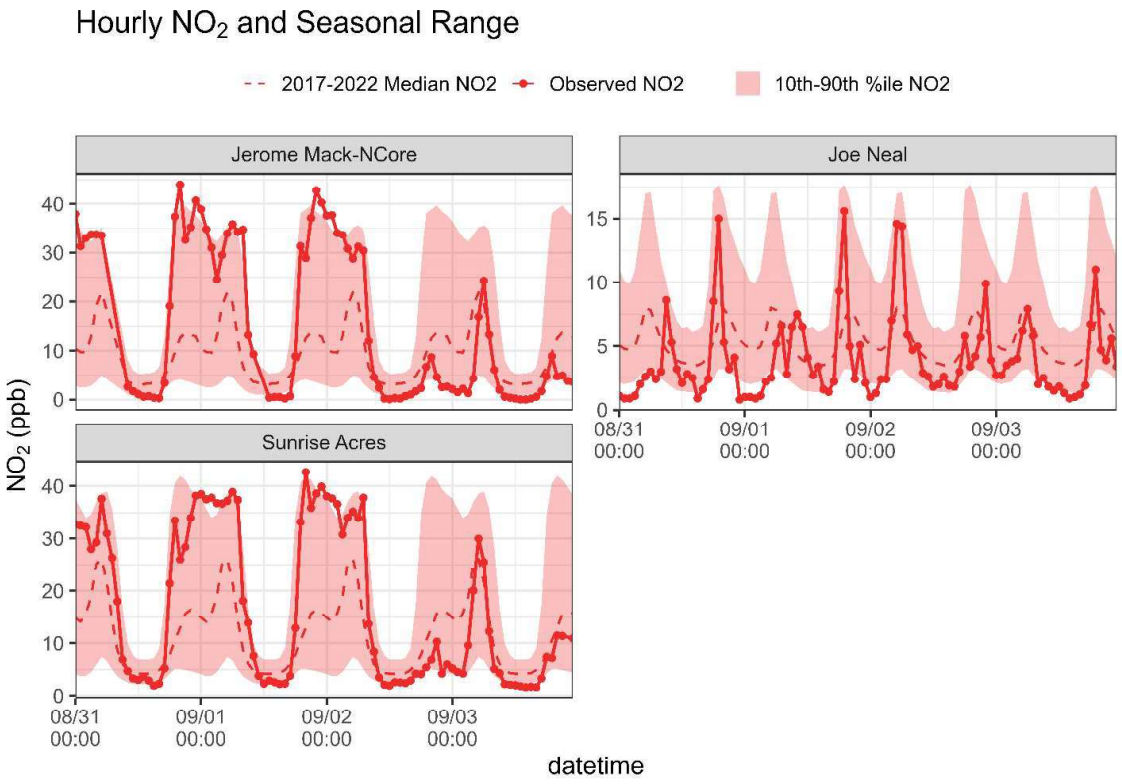

Figure 198. Hourly NO_2 measurements overlaid on the 10th-90th percentile diurnal concentrations at each event-affected measurement site and supporting sites that measure NO_2 concentrations. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2022.

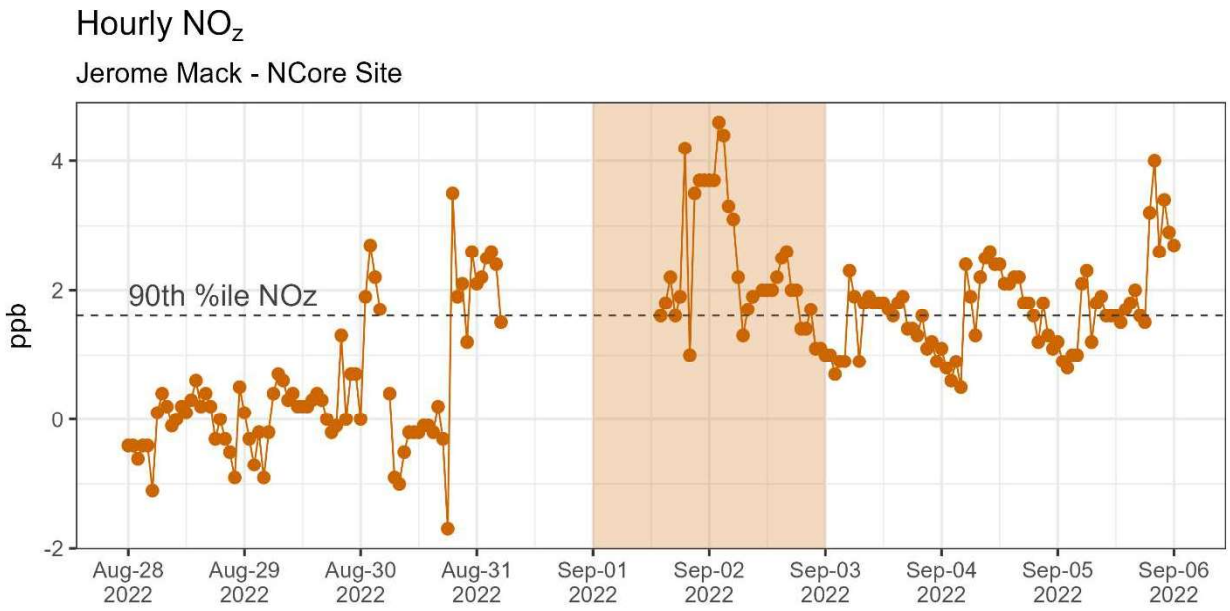

Figure 199. Hourly NO_z (i.e., NO_y-NO_x) concentrations at the Jerome Mack site for the September 1-2 event days and three days before and after the event. The 90th percentile of 2017-2022 NO_z concentrations is shown as the dashed line. The event day is highlighted in orange.

5.4.5 Matching Date Analysis

Local meteorological conditions have a strong influence on day-to-day ozone production. Similar local meteorological conditions are expected to yield similar levels of local ozone production, barring any atypical influence on a given date. This section compares ozone concentrations between the exclusion date and dates that are meteorologically similar. If an external source of ozone or ozone precursors were present in the Las Vegas region on the exclusion date, the ozone concentrations are likely to be statistically different from the meteorologically similar dates. Days between 2017-2022 with similar meteorological conditions as the exclusion date were identified according to four key meteorological measurements: maximum daily wind speed, maximum daily temperature, mixing height at 16:00 LST (00:00 UTC), and average daily relative humidity. Table 46 shows the source of each meteorological parameter and the threshold used to define a "similar" measurement. Note that mixing height data is unavailable from NOAA's NCEI IGRA at Las Vegas between August 31 – September 4, 2022. Mixing heights were derived manually for the exclusion dates of September 1 and September 2, 2022, based on the same parcel method (i.e., Holzworth method) used by NCEI to derive mixing heights. Other atypical event dates identified in this document were omitted from the pool of potential similar dates.

Five dates were identified as similar to September 1, 2022 (Table 47), and four dates were identified as similar to September 2, 2022 (Table 48). The variable that limited the number of meteorologically similar dates for both exclusion dates is mixing height, despite the similarity threshold spanning

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1,500 m. The mixing height on September 1 is higher than previously recorded by NCEI at 5,156 m AGL, likely due to an extremely high afternoon temperature of 113°F. Maximum hourly wind speed is 3.3 kts, and average hourly relative humidity is 12.96%. The mixing height on September 2 is 2,467 m AGL, lower than most other dates with a similar maximum hourly temperature (111°F), maximum hourly wind speed (8.8 kts), and average hourly relative humidity (18.54%). Despite the extremes of these days, we were able to find five dates for comparison with September 1 and four dates for comparison with September 2.

Table 46. Meteorological parameters used to identify dates with similar meteorological conditions to the exclusion date. The threshold used to define a "similar" measurement to the observed measurement during the exclusion period is listed per parameter.

Parameter	Data Source	"Similar" threshold
Hourly Wind Speed measured at Jerome Mack – NCore AQS site	U.S. EPA Air Quality System Data Mart	+/- 2.5 kts
Hourly Temperature measured at Jerome Mack – NCore AQS site	U.S. EPA Air Quality System Data Mart	+/- 5 °F
Hourly Relative Humidity measured at Jerome Mack – NCore AQS site	U.S. EPA Air Quality System Data Mart	+/- 20%
Mixing Height AGL at 16:00 LST (00 UTC) at NWS Forecast Office Las Vegas, NV	• NOAA NCEI IGRA • Manually derived from Skew-T diagrams available from the University of Wyoming Department of Atmospheric Science for September 1 – 2, 2022.	+/- 750 m

Table 47. Dates between 2017-2022 identified as meteorologically similar to the exclusion date September 1, 2022 based on the thresholds listed in Table 46. Measurements on September 1, 2022, are listed for reference in the first row (bold). Maximum Site MDA8 Ozone is the maximum concentration across the Paul Meyer and Walter Johnson measurement sites.

Date	Max. Hourly Wind Speed (kts)	Mixing Height at 16:00 LST (m AGL)	Max. Hourly Temperature (°F)	Average Hourly RH (%)	Maximum Site MDA8 Ozone (ppb)
09/01/2022	**3.3**	**5156**	**113**	**12.96**	**74**
08/01/2018	5.6	4554	110	19.00	68

08/19/2018	5.6	4629	112	16.50	64
07/28/2019	4.3	4585	112	15.29	63
08/03/2019	5.6	4474	111	13.96	62
08/27/2019	4.1	4649	110	19.04	62

Table 48. Dates between 2017-2022 identified as meteorologically similar to the exclusion date September 2, 2022 based on the thresholds listed in Table 46. Measurements on September 2, 2022, are listed for reference in the first row (bold). Maximum Site MDA8 Ozone is the maximum concentration across the Paul Meyer and Walter Johnson measurement sites.

Date	Max. Hourly Wind Speed (kts)	Mixing Height at 16:00 LST (m AGL)	Max. Hourly Temperature (°F)	Average Hourly RH (%)	Maximum Site MDA8 Ozone (ppb)
09/02/2022	**8.8**	**2467**	**111**	**18.54**	**73**
07/30/2017	8.3	2813	108	21.92	62
08/05/2018	8.5	2969	110	6.12	68
08/30/2019	9.6	2564	109	11.08	51
08/26/2020	10.1	3168	109	10.08	61

Figure 200 shows the comparison of MDA8 ozone concentrations between the exclusion period and on meteorologically similar dates at the Paul Meyer and Walter Johnson measurement sites. Each date in the exclusion period is displayed separately alongside similar dates listed in Table 47 (September 1, 2022) or Table 48 (September 2, 2022). The MDA8 ozone concentration is elevated during the exclusion period compared to the meteorologically similar dates. Higher-than-expected ozone concentrations measured during the exclusion period compared to meteorologically similar dates provide evidence of an external source of ozone and/or ozone precursors during the exclusion period.

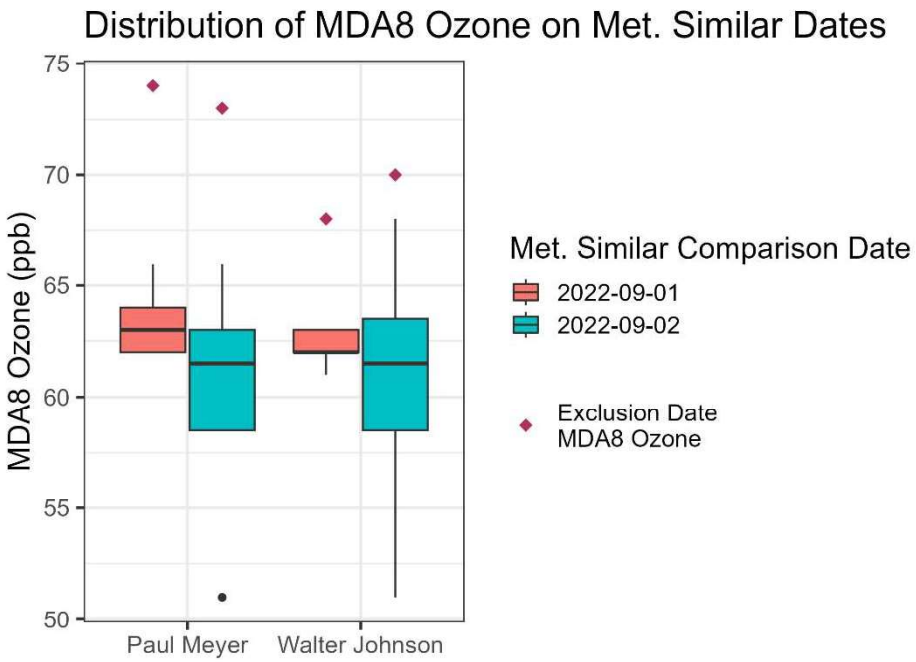

Figure 200. Distribution of MDA8 ozone concentrations on meteorologically similar days at the Paul Meyer and Walter Johnson measurement sites during the exclusion period, September 1, 2022 (pink boxes) and September 2, 2022 (green boxes). MDA8 ozone concentrations measured per site on each exclusion date are plotted as red diamonds.

5.4.6 Event Statistics

Table 49 summarizes the daily measurements of ozone, $PM_{2.5}$, CO, and NO_2 concentrations on the exclusion event days of September 1-2, 2022, as well as the percentile rank of the observations compared to the previous five years of ozone season data (May 1-October 31 of 2018-2022). On both September 1 and 2, ozone MDA8 measurements were above the 97th percentile at the Paul Meyer monitoring site and were above the 89th percentile at the Walter Johnson site. 24-hr average $PM_{2.5}$ concentrations at Paul Meyer and Walter Johnson ranged from the 52nd - 63rd percentile on September 1 and 2. CO 1-hr daily maximum concentrations at Paul Meyer were above the 99th percentile on September 1 and in the 77th percentile on September 2. NO_2 1-hr daily maximum measurements (shown for the Jerome Mack-NCore site, because NO_2 measurements are not collected at the Paul Meyer or Walter Johnson sites) were in the 87th percentile on September 1 and in the 71st percentile on September 2.

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Table 49. Percentile of pollutant measurements on the September 1-2, 2022, exclusion days compared with most recent five years of pollutant concentration data (2018-2022).* The percentile rank is calculated across the ozone production season (May 1-October 31) of 2018-2022. Data from the Jerome Mack-NCore site (grey *italicized*) is included for regional NO_2 information because NO_2 measurements are not collected at the Paul Meyer or Walter Johnson sites.

Date	Site Name	Site Code	Ozone		$PM_{2.5}$		CO		NO_2	
			Ozone MDA8 (ppb)	Percent Rank	$PM_{2.5}$ 24-hr Avg ($\mu g/m^3$)	Percent Rank	CO 1-hr Daily Max (ppb)	Percent Rank	NO_2 1-hr Daily Max (ppb)	Percent Rank
9/1/2022	Paul Meyer	320030043	74	97.6	6.1	58.7	477	99.3*	--	--
9/1/2022	Walter Johnson	320030071	68	89.1	5.5	41.8	--	--	--	--
9/1/2022	*Jerome Mack-NCore*	*320030540*	*53*	*49.4*	*7.5*	*58.3*	*898*	*79.8**	*42.8*	*87*
9/2/2022	Paul Meyer	320030043	73	97	6.4	63.5	288	77.1*	--	--
9/2/2022	Walter Johnson	320030071	70	93.5	5.9	52.5	--	--	--	--
9/2/2022	*Jerome Mack-NCore*	*320030540*	*54*	*53.8*	*7.4*	*56.7*	*744*	*70**	*37.7*	*71.6*

*Sites that have less than five years of data available for a given parameter.

5.5 Request for Exclusion

The wildfire smoke events resulted in ozone measurements that are atypical, extreme, and nonrepresentative of past and future days for Clark County, NV. Appendix W to Part 51 states "control agencies have long expressed a need for consistency in the application of air quality models for regulatory purposes…the expanded requirements for models to cover even more complex problems have emphasized the need for period review and update of guidance on these techniques". Wildfire smoke events are one such complex problem, as wildfire season has extended and encompasses the summer months, also considered to be ozone production season. Wildfire occurrence is wildly considered to be a stochastic natural phenomenon and is therefore inconsistent year-to-year. Downstream smoke impacts, including ozone formation, are not typical nor representative of the ambient conditions of Clark County, Nevada. The four wildfire smoke events identified in this report are inconsistent with previous records and determined to be extreme, as indicated by:

- All site exceedances are above the 94th percentile of all ozone measurements.
- Multiple sites were affected during each event, including those that did not exceed regulatory standards.
- Significant smoke was identified from regional wildfire incidents.

Table 50 provides the evidence and exclusion narrative for each date.

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Table 50. Evidence provided for each exclusion date.

Exclusion Date(s)	Event Summary
June 16, 2022	Transport of smoke from fires in Baja California, Mexico, on the afternoon of June 16 enhanced ozone concentrations in Clark County, keeping ozone values high and affecting the MDA8 ozone concentrations at three sites. Smoke maps from NOAA's HMS, HYSPLIT forward trajectories, PBL analysis, and pollutant concentrations suggest that smoke entered the area in the afternoon on June 16, affecting the typical diurnal profiles of ozone and other pollutants. Statistics show ozone concentrations were atypical during this event.

Exclusion Date(s)	Event Summary
July 17, 2022	Regional transport of smoke from large wildfires in Canada mixed with smoke from wildfires in Nevada and California to enhanced ozone concentrations in the Las Vegas Valley on the exclusion day. HMS smoke maps, meteorological information, PBL analysis, HYSPLIT back trajectories, and HRRR data suggest that regional smoke was transported around a high-pressure system in the southwest U.S. and descended into the well-mixed boundary layer in the Las Vegas Valley on July 17. Statistics show ozone concentrations were atypical during this event.
July 28-29, 2022	Smoke from two fires in Idaho and California combined to create a light layer of regional smoke in the southwestern U.S. and impacted Clark County on July 28-29. HMS smoke maps, PBL analysis, HYSPLIT back trajectories, meteorological data, and HRRR data suggest that this regional smoke was transported and descended into the well-mixed boundary layer the Las Vegas Valley on July 28. Stagnant conditions on July 29 allowed smoke to linger. Statistics show ozone concentrations were atypical during this event.
September 1-2, 2022	Regional transport of smoke from large fires throughout the western U.S. was carried along a high-pressure system and descended into the well-mixed boundary layer within Clark County on September 1 and 2, which caused increasingly hazy and smoky conditions over the course of the exclusion days. HMS smoke maps, PBL analysis, HYSPLIT back trajectories, meteorological data, and HRRR data suggest that this light regional smoke was transported and descended into the Las Vegas Valley on September 1-2. Statistics show ozone concentrations were atypical during this event at the site most affected by the light regional smoke.

Based on the evidence provided, we formally request exclusion of the following dates in base and projected ozone design values.

6. 2023 Ozone Technical Supporting Documents

The U.S. Environmental Protection Agency (EPA) published the memo *Clarification Memo on Additional Methods, Determinations, and Analyses to Modify Air Quality Data Beyond Exceptional Events*[52] (the memo), which illustrates cases where air quality data may be modified for certain regulatory determinations, actions, and analysis. The document defines cases where a request to exclude data can be made through the Exceptional Events Rule, such as when a National Ambient Air Quality Standard (NAAQS) design value is recalculated in EPA's Air Quality System (AQS) using modified data to determine attainment. The document also defines additional analyses that are not covered in the Exceptional Events Rule, where submitting modified data may be appropriate. These additional cases that are not covered in the Exceptional Event Rule are defined as conditions where ambient air quality data may have been "influenced by an atypical, extreme or unrepresentative event." The Clark County Department of Environment & Sustainability (DES) is submitting a request to exclude data on this basis for the following case explicitly defined in the document: "Estimating base and future-year design values ozone SIP attainment demonstrations" as a part of their State Implementation Plan (SIP).

The EPA document states that monitoring data could qualify for exclusion if "[A]mbient data are not representative to characterize background or base period concentrations in accordance with the *Guideline,*" in reference to *Guideline on Air Quality Models*, 40 CFR Part 51, Appendix W.[53] Extreme wildfire events are increasingly prevalent in the western United States (U.S.), resulting in increased smoke impacts. Clark County, Nevada, was impacted by wildfire smoke from local and regional sources in the summer of 2023 (Table 51). Following an atypical smoke intrusion, high ozone concentrations were measured because of direct transport and secondary photochemical processes.

As stated in the memorandum, EPA or the appropriate reviewing authority will determine whether the air agency, in this case, Clark County DES, has appropriately documented and justified the data exclusion and/or adjustment when it acts on a SIP submission. The following documentation is provided to demonstrate that one local and regional wildfire smoke events in July 2023 meet the criteria as defined in the document and guidance. This evidence is included as part of Clark County's request to exclude these data from base and future-year design values for ozone SIP attainment demonstrations as a part of their SIP.

[52] https://www.epa.gov/sites/default/files/2019-04/documents/clarification_memo_on_data_modification_methods.pdf

[53] https://www.epa.gov/scram/2024-appendix-w-final-rule

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Table 51. Summary of events requested for exclusion from ozone SIP base and future-year design values.

Event Date	Event Ozone Concentration Percentile	Sites Exceeded During Event	Type of Event
July 5-8, 2023	95th – 99th	11 sites: Green Valley, Indian Springs, Jean, Jerome Mack, Joe Neal, Liberty, Mountain's Edge, Palo Verde, Paul Meyer, Walnut Community Center, and Walter Johnson	Regional Smoke

6.1 July 5-8, 2023

6.1.1 Event Summary

An unrepresentative ozone event took place across July 5-8, 2023, in Clark County, NV within the jurisdiction of Clark County Department of Environment and Sustainability (CCDES), and affected two monitoring sites (Indian Springs and Walter Johnson) on July 5, eleven (Green Valley, Indian Springs, Jean, Jerome Mack, Joe Neal, Liberty High School, Mountain's Edge, Palo Verde, Paul Meyer, Walnut Rec, and Walter Johnson) on July 6, six (Indian Springs, Joe Neal, Mountain's Edge, Palo Verde, Paul Meyer, and Walter Johnson) on July 7, and eight (Green Valley, Indian Springs, Jean, Joe Neal, Mountain's Edge, Palo Verde, Paul Meyer, and Walter Johson) on July 8. The Indian Springs and Jean monitoring sites are outside of HA 212 and are not significant for the design value assessments. However, these sites indicate a wide-spread regional ozone event. Regional wildfire smoke and transport of ozone precursor pollutants contributed to the NAAQS exceedances. The data presented in this document shows there was smoke from northwestern Mexico during the ozone event. Additionally, accumulation of ozone precursor pollutants during low-speed upslope winds from the east produced higher ozone impacts in the western Las Vegas Valley.

Table 52 shows a summary table of the ozone exceedances that occurred during the July 5-8, 2023, event. The two sites exceeding the NAAQS on July 5, 2023, had 8-hour maximum (MDA8) ozone concentrations of 71 and 72 ppb. Sites exceeding the NAAQS on July 6, 2023, had MDA8 ozone concentrations ranging from 72 to 76 ppb. The MDA8 ozone concentrations at sites exceeding the NAAQS on July 7, 2023, ranged from 71 to 76 ppb and the sites on July 8, 2023, ranged from 71 to 73 ppb.

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Table 52. Sites with MDA8 ozone levels (ppb) exceeding the NAAQS across July 5-8, 2023. *Not in HA 212

Date	Site Name	Full AQS ID	Concentration (ppb)
7/5/2023	Indian Springs*	320037772	72
7/5/2023	Walter Johnson	320030071	71
7/6/2023	Green Valley	320030298	72
7/6/2023	Indian Springs*	320037772	71
7/6/2023	Jean*	320031019	72
7/6/2023	Jerome Mack	320030540	71
7/6/2023	Joe Neal	320030075	74
7/6/2023	Liberty High School	320030299	72
7/6/2023	Mountain's Edge	320030044	76
7/6/2023	Palo Verde	320030073	73
7/6/2023	Paul Meyer	320030043	71
7/6/2023	Walnut Rec	320032003	71
7/6/2023	Walter Johnson	320030071	71
7/7/2023	Indian Springs*	320037772	76
7/7/2023	Joe Neal	320030075	77
7/7/2023	Mountain's Edge	320030044	72
7/7/2023	Palo Verde	320030073	71
7/7/2023	Paul Meyer	320030043	71
7/7/2023	Walter Johnson	320030071	75
7/8/2023	Green Valley	320030298	71
7/8/2023	Indian Springs*	320037772	72
7/8/2023	Jean*	320031019	71
7/8/2023	Joe Neal	320030075	72
7/8/2023	Mountain's Edge	320030044	73
7/8/2023	Palo Verde	320030073	71
7/8/2023	Paul Meyer	320030043	71
7/8/2023	Walter Johnson	320030071	72

Figure 201 shows the time series graph for hourly ozone concentrations (top) and daily MDA8 (bottom) that exceeded the NAAQS. Figure 202 shows the 5-year historical hourly ozone (ppm) norms within ± 50 days of the event and 5th-95th percentiles (top) and 5-year historical MDA8

ozone (ppm) norms within ± 50 days of the event and 5th and 95th percentiles (bottom). The low MDA8 value at Joe Neal on July 5 is the result of the power being out at the site until 14:00 PST.

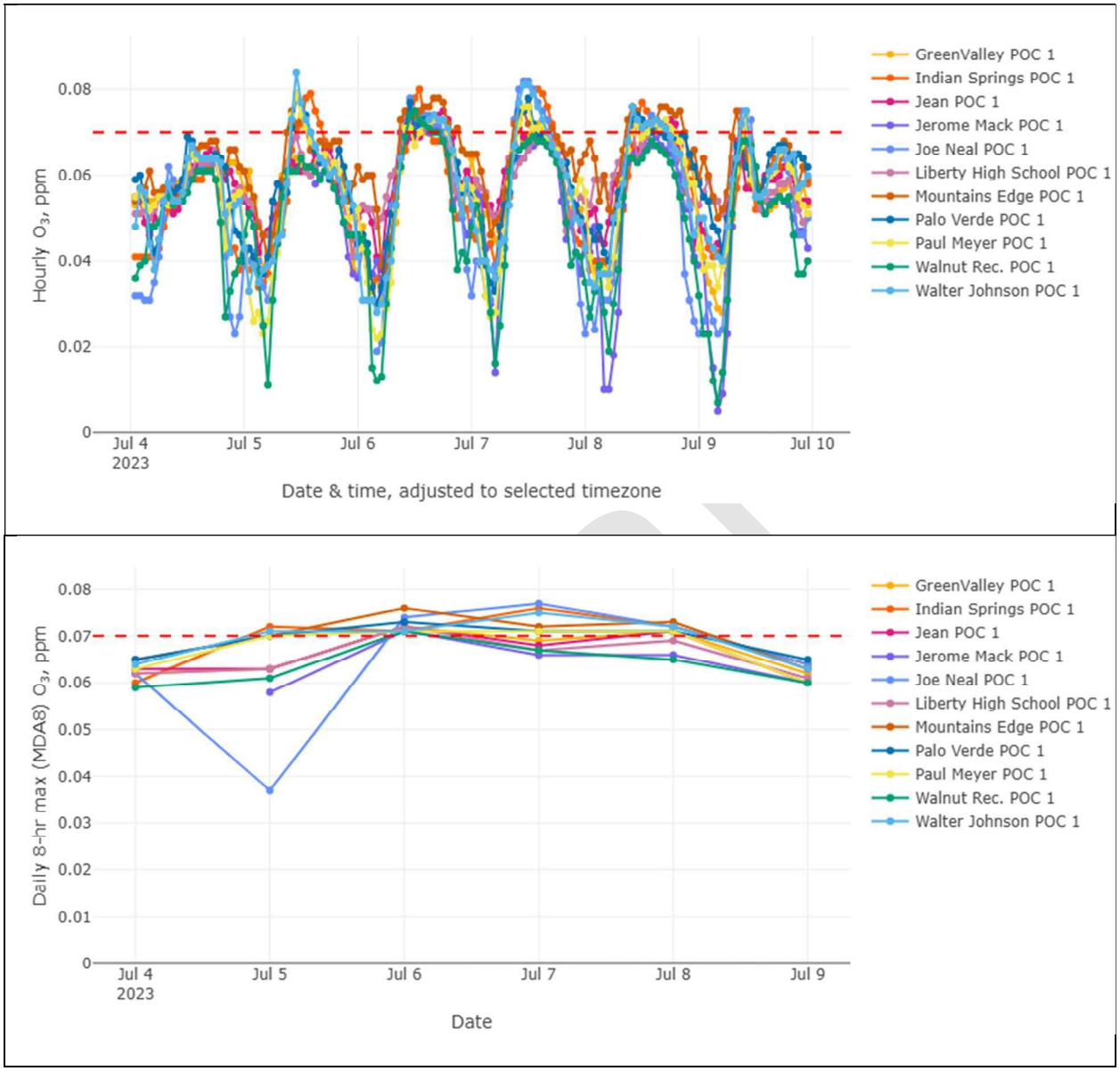
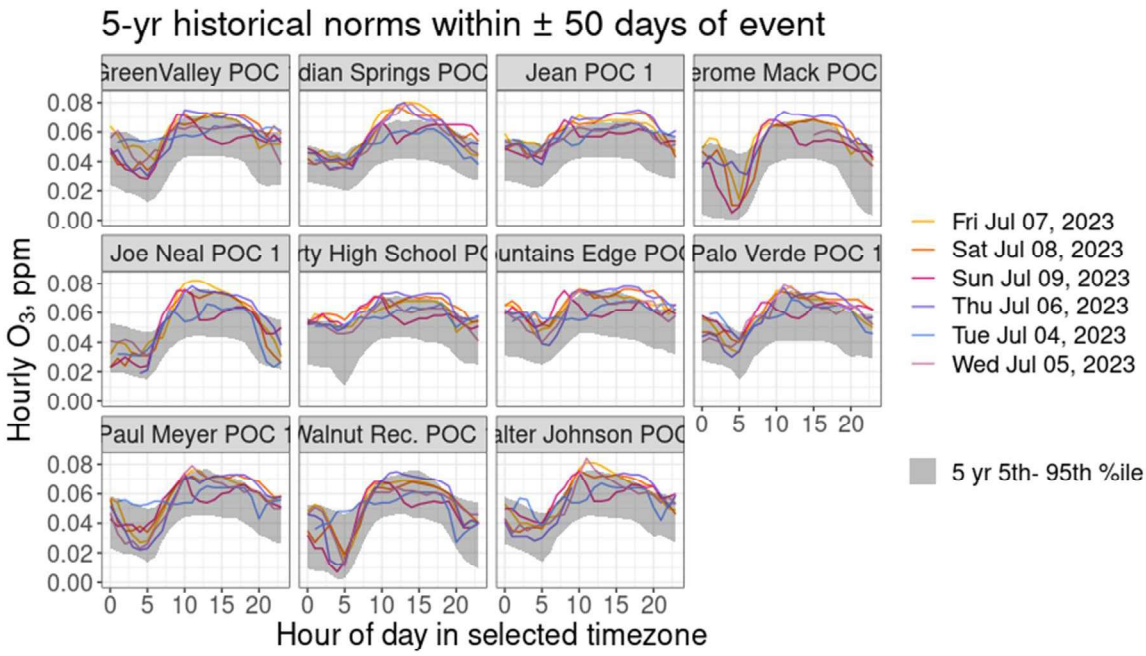


Figure 201. Top: Hourly ozone concentrations (ppm) across July 4-10, 2023. Bottom: Daily 8-hour maximums (ppm) that exceeded the NAAQS across July 4-10, 2023.


5-yr historical norms within ± 50 days of event
GreenValley POC
dian Springs POC
Jean POC 1
erome Mack POC
Joe Neal POC 1
ty High School PC
untains Edge POC
Palo Verde POC 1
Paul Meyer POC 1
Walnut Rec. POC
alter Johnson POC
Hourly O3, ppm
0.08
0.06
0.04
0.02
0.00
0 5 10 15 20
Hour of day in selected timezone
Fri Jul 07, 2023
Sat Jul 08, 2023
Sun Jul 09, 2023
Thu Jul 06, 2023
Tue Jul 04, 2023
Wed Jul 05, 2023
5 yr 5th- 95th %ile

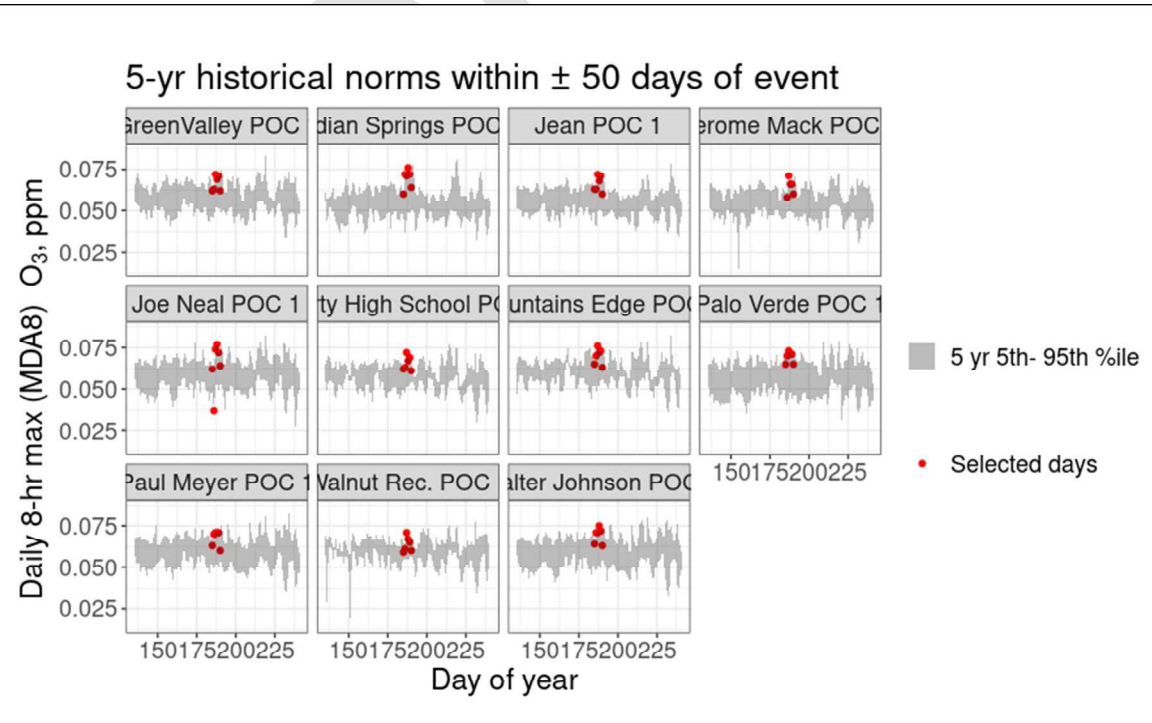

5-yr historical norms within ± 50 days of event
GreenValley POC
dian Springs POC
Jean POC 1
erome Mack POC
Joe Neal POC 1
ty High School PC
untains Edge POC
Palo Verde POC 1
Paul Meyer POC 1
Walnut Rec. POC
alter Johnson POC
Daily 8-hr max (MDA8) O3, ppm
0.075
0.050
0.025
150175200225
Day of year
5 yr 5th- 95th %ile
Selected days

Figure 202. 5-year historical hourly ozone (ppm) norms within ± 50 days of the event (top) and 5-year historical MDA8 ozone (ppm) norms within ± 50 days of the event (bottom). *Data collection at the Liberty High School, Mountain's Edge, and Walnut Recreation sites did not begin until 2021.

Time series graphs showing hourly ozone concentrations on July 5-8, the points that exceeded the 5th-95th percentiles at each site are shown in Figure 202 (top). After the typical diurnal peak near 12:00 PST, hourly ozone concentrations remained enhanced during the typical diurnal minimum exceeding the 95th percentile between 14:00 to 20:00 PST and not returning to typical concentrations overnight.

The Green Valley site exceeded on July 6 and 8, 2023 (Figure 203). Afternoon ozone concentrations show significant enhancement, exceeding the 95th percentile. Overnight and early-morning ozone concentrations were persistently higher than the expected diurnal pattern. The diurnal amplitude was flattened, showing minimal nighttime decline and inflated daytime levels, remaining near or above the 95th percentile boundary.

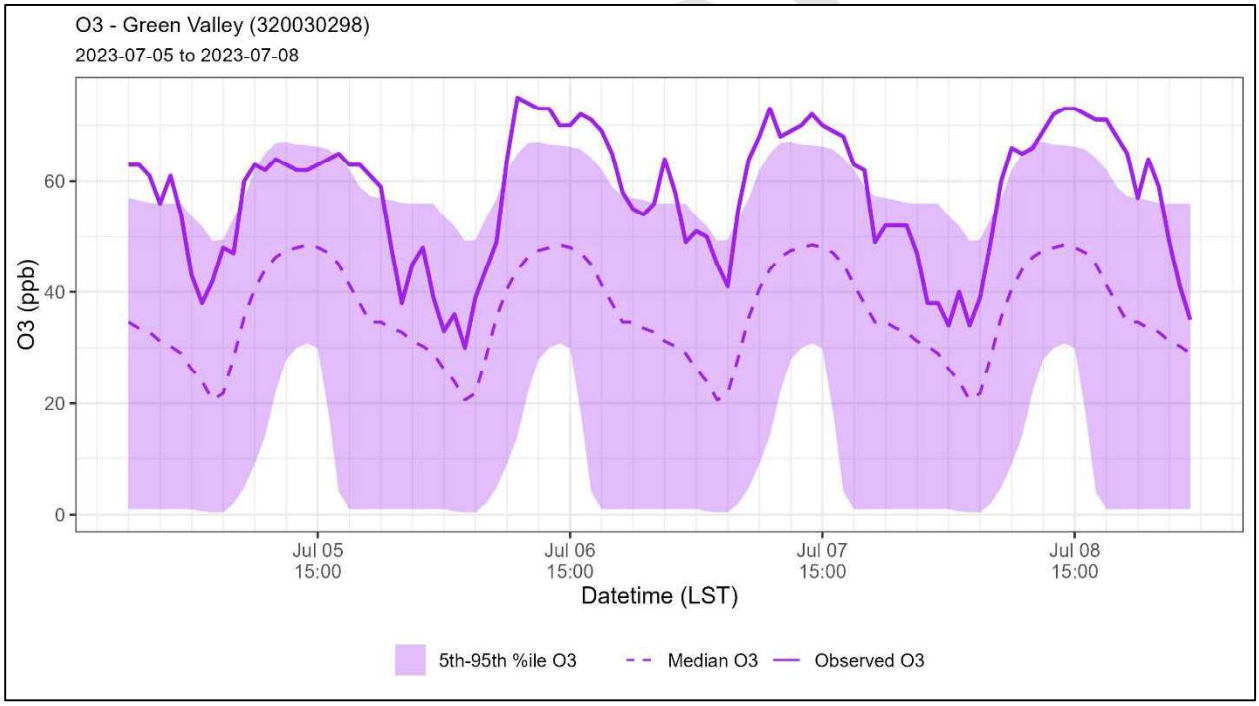


Figure 203. Hourly O_3 measurements overlaid on the 5th to 95th percentile diurnal concentration at Green Valley (AQS site code 320030298). The 5th to 95th percentile concentration is calculated across the ozone production season (April-September) for 2018-2023.

The Indian Springs site exceeded on July 5-8 (Figure 204). Afternoon ozone concentrations show significant enhancement, exceeding the 95th percentile. Overnight and early-morning ozone

concentrations remained above the expected diurnal minimum. While Indian Springs is not a part of HA212, the amplified afternoon peaks, elevated baseline and exceedances of the historical percentile range indicate a widespread event.

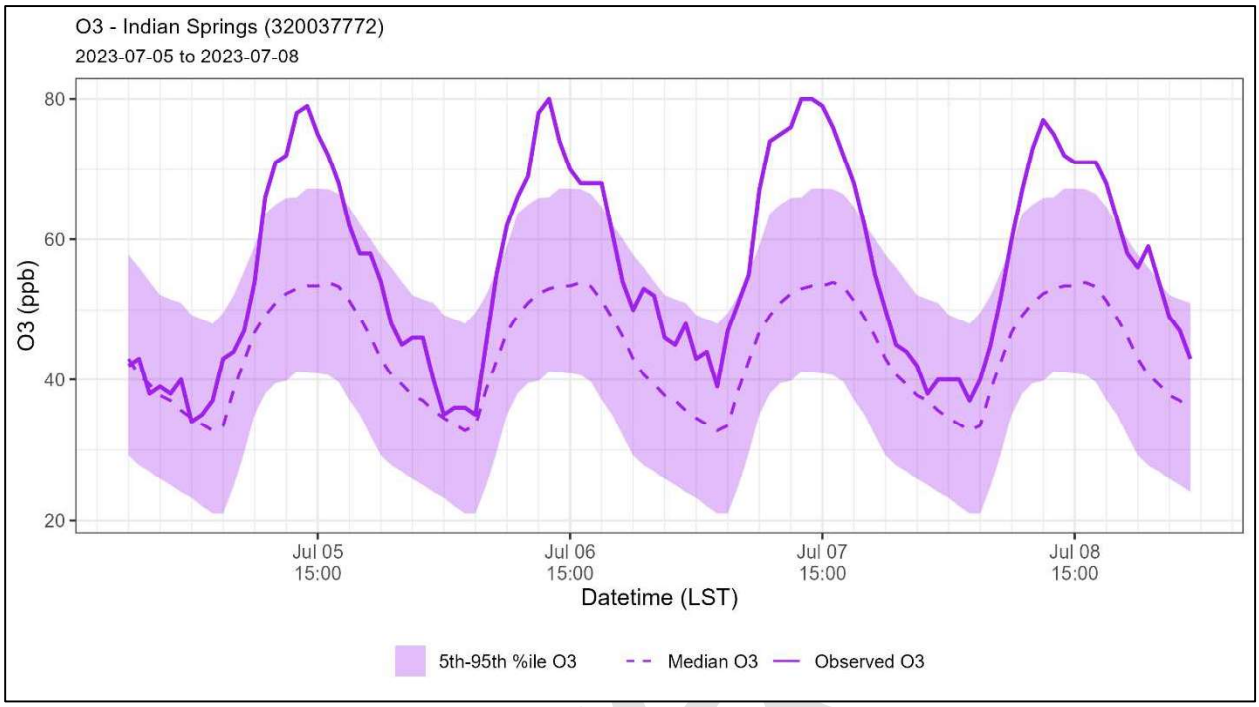


Figure 204. Hourly O_3 measurements overlaid on the 5th to 95th percentile diurnal concentration at Indian Springs (AQS site code 320037772). The 5th to 95th percentile concentration is calculated across the ozone production season (April-September) for 2018-2023.

The Jean site exceeded on July 6 and 8 (**Figure 205**). Afternoon ozone concentrations show significant enhancement, exceeding the 95th percentile. Overnight and early-morning ozone concentrations were persistently higher than the expected diurnal pattern. Overnight ozone levels remained high, staying above the 95th percentile, never returning to low values typical for this site. Afternoon peaks were higher and occurred earlier on July 8. The diurnal amplitude was flattened, showing minimal nighttime decline and inflated daytime levels, remaining near or above the 95th percentile boundary. While the Jean site is not a part of HA212, the amplified afternoon peaks, elevated baseline and exceedances of the historical percentile range indicate a widespread event.

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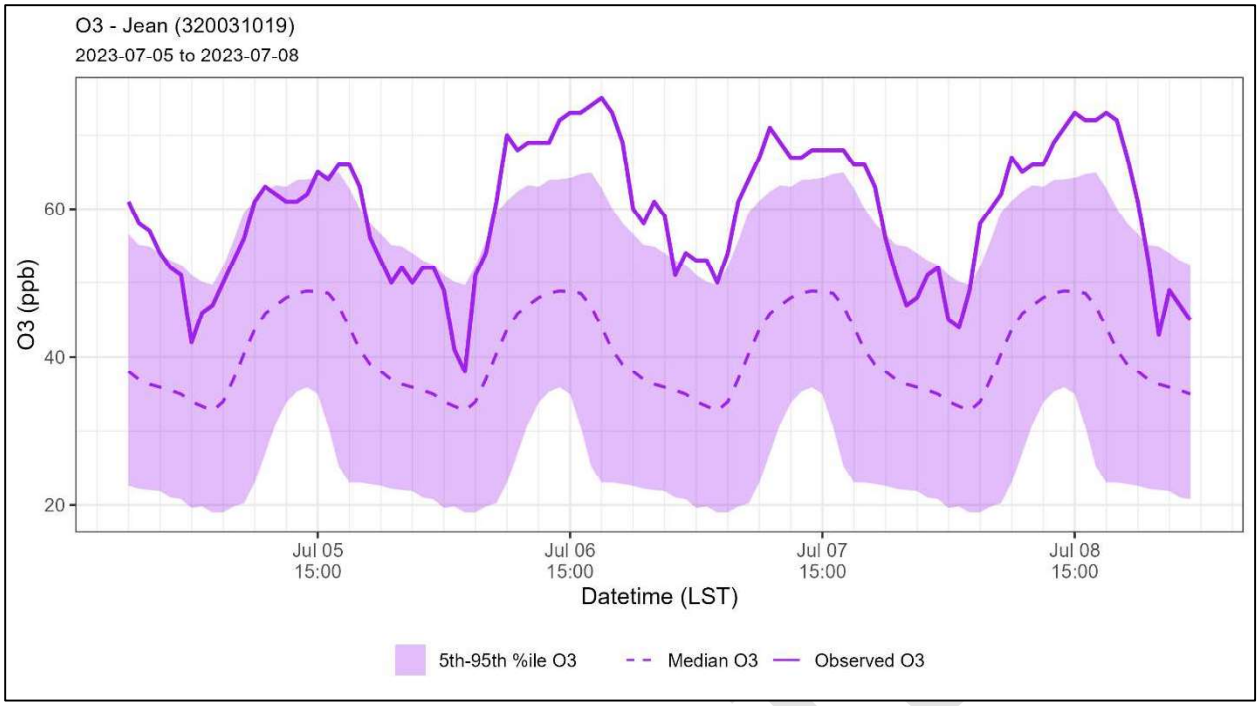


Figure 205. Hourly O_3 measurements overlaid on the 5th to 95th percentile diurnal concentration at Jean (AQS site code 320031019). The 5th to 95th percentile concentration is calculated across the ozone production season (April-September) for 2018-2023.

The Jerome Mack site exceeded on July 6 (Figure 206). Afternoon ozone concentrations show significant enhancement, exceeding the 95th percentile. Overnight and early-morning ozone concentrations were persistently higher than the expected diurnal pattern. The diurnal amplitude was flattened, showing a decrease in the length of overnight decline and inflated daytime levels, remaining near or above the 95th percentile boundary.

Draft

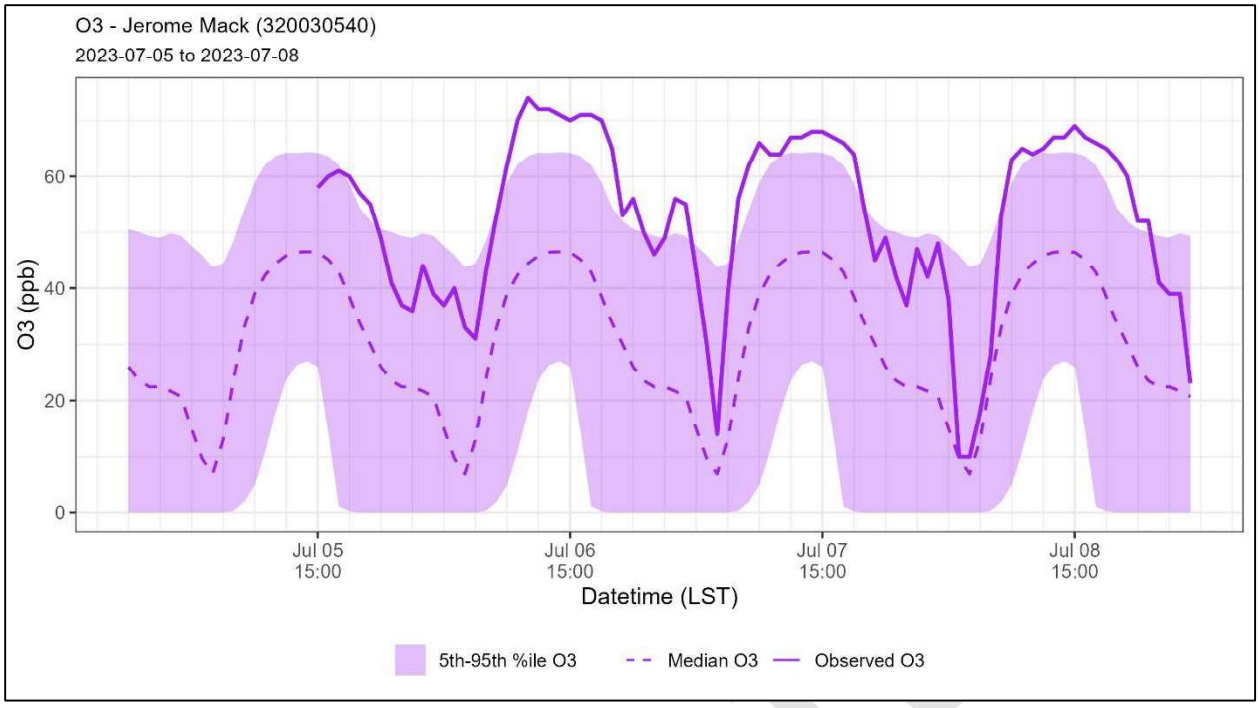


Figure 206. Hourly O_3 measurements overlaid on the 5th to 95th percentile diurnal concentration at Jerome Mack (AQS site code 320030540). The 5th to 95th percentile concentration is calculated across the ozone production season (April-September) for 2018-2023.

The Joe Neal site exceeded on July 6-8 (Figure 207). Afternoon ozone concentrations show significant enhancement, exceeding the 95th percentile from approximately 07:00 until 21:00 PST. Overall, there was reduced nighttime depletion and persistently higher-than-expected daytime concentrations, indicating a clear shift from the typical ozone pattern at the site during this smoke-impacted period.

Draft

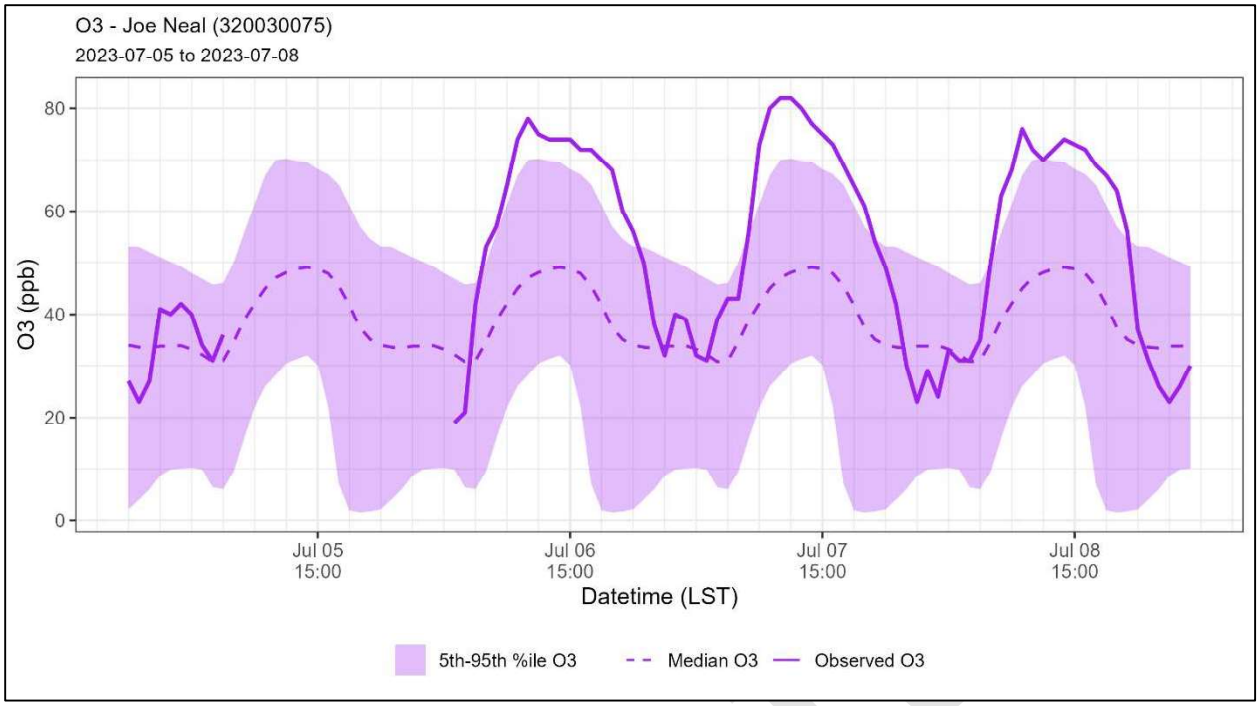


Figure 207. Hourly O_3 measurements overlaid on the 5th to 95th percentile diurnal concentration at Joe Neal (AQS site code 320030075). The 5th to 95th percentile concentration is calculated across the ozone production season (April-September) for 2018-2023.

The Liberty site exceeded on July 6 (Figure 208). Observed ozone was persistently higher than both the median and 95th percentile, showing a clear shift from the typical ozone pattern. On July 6, ozone concentrations remained above the 95th percentile from approximately 05:00 until 06:00 PST the following day. Overnight ozone levels remained high, staying above the 95th percentile, never returning to low values typical for this site.

Draft

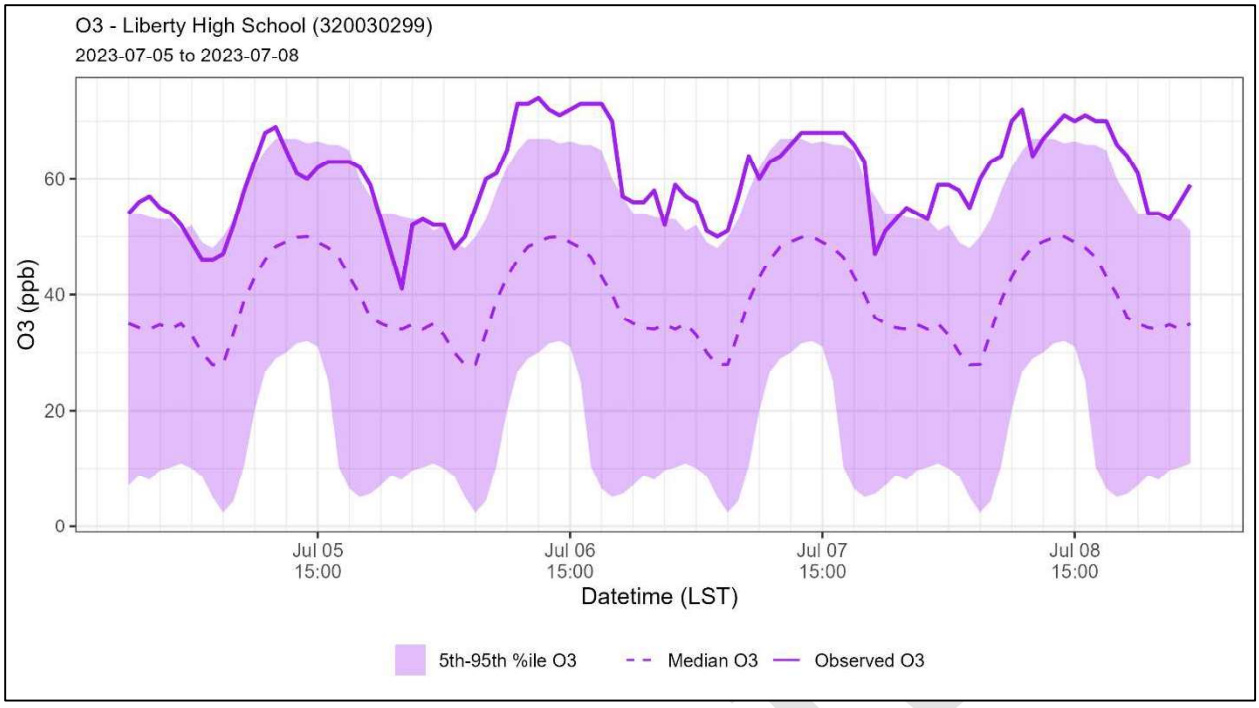


Figure 208. Hourly O_3 measurements overlaid on the 5th to 95th percentile diurnal concentration at Liberty (AQS site code 320030299). The 5th to 95th percentile concentration is calculated across the ozone production season (April-September) for 2018-2023. Note: Liberty includes data starting May 1, 2021, and onwards.

The Mountain's Edge site exceeded on July 6-8 (Figure 209). Observed ozone remained elevated throughout the period, with nighttime and early-morning concentrations substantially higher than the 95th percentile. Ozone concentration peaks occurred earlier than the typical pattern and consistently exceeded both the median and 95th percentile. On July 6, ozone concentrations remained above the 95th percentile from approximately 03:00 until 09:00 on July 7. Ozone concentrations dipped just below the 95th for approximately 3 hours on July 7 from 09:00-12:00. PST and 2 hours from 20:00-22:00 PST. On July 8, ozone concentrations remained above the 95th percentile except for 1 hour at 11:00 PST. The diurnal amplitude was flattened, showing minimal nighttime decline and inflated daytime levels, remaining near or above the 95th percentile boundary. The time series also shows multiple short-duration spikes associated with shifting smoke plumes and variable mixing conditions, behavior not characteristic of local photochemical production.

Draft

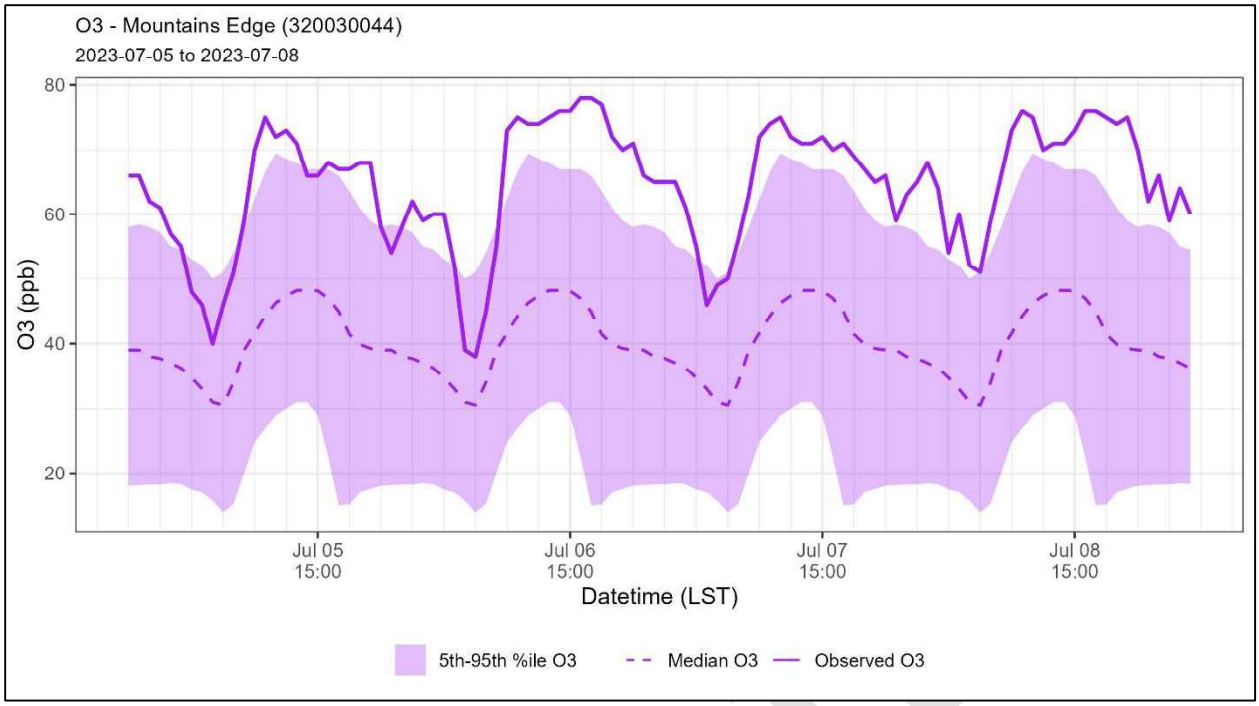


Figure 209. Hourly O_3 measurements overlaid on the 5th to 95th percentile diurnal concentration at Mountain's Edge (AQS site code 320030044). The 5th to 95th percentile concentration is calculated across the ozone production season (April-September) for 2018-2023. Note: Mountain's Edge includes data starting October 1, 2020, and onwards.

The Palo Verde site exceeded on July 6-8 (Figure 210). Observed ozone was persistently higher than both the median and 95th percentile, showing a clear shift from the typical ozone pattern. Overnight ozone levels remained high, staying above the 95th percentile, never returning to low values typical for this site. On July 6, ozone concentrations remained above the 95th percentile from 09:00 until 01:00 PST the following day. On July 7, ozone concentrations remained above the 95th percentile from 06:00 until 21:00. July 8 ozone concentrations remained above the 95th percentile from approximately 06:00 until after 03:00 the following day. The diurnal amplitude was flattened, showing minimal nighttime decline and inflated daytime levels, remaining near or above the 95th percentile boundary.

Draft

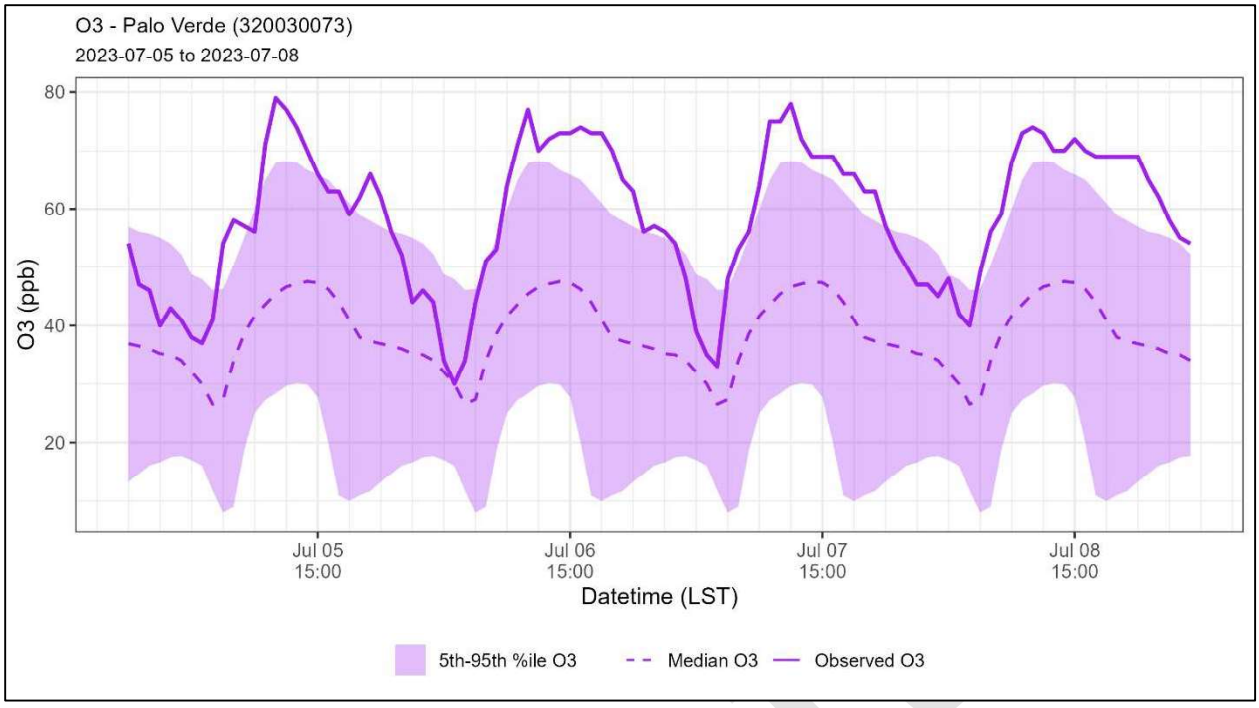


Figure 210. Hourly O_3 measurements overlaid on the 5th to 95th percentile diurnal concentration at Palo Verde (AQS site code 320030073). The 5th to 95th percentile concentration is calculated across the ozone production season (April-September) for 2018-2023.

The Paul Meyer site exceeded on July 6-8 (Figure 211). Observed ozone was persistently higher than both the median and 95th percentile, showing a clear shift from the typical diurnal pattern. Afternoon ozone concentrations show significant enhancement, exceeding the 95th percentile. On July 6, ozone concentrations remained above the 95th percentile from 09:00 until 01:00 PST the following day. On July 7 and 8, ozone concentrations were above the 95th percentile from approximately 08:00 until midnight PST.

Draft

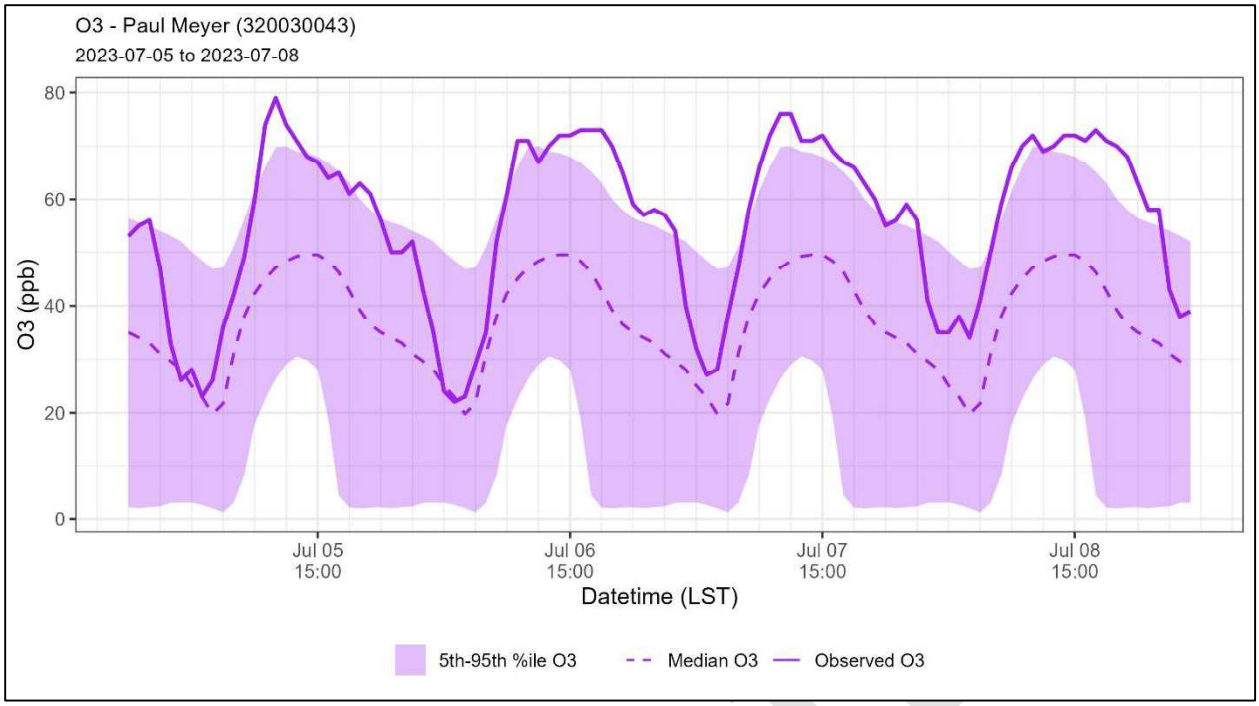


Figure 211. Hourly O_3 measurements overlaid on the 5th to 95th percentile diurnal concentration at Paul Meyer (AQS site code 320030043). The 5th to 95th percentile concentration is calculated across the ozone production season (April-September) for 2018-2023.

The Walnut Rec site exceeded on July 6 (Figure 212). The afternoon ozone concentration shows significant enhancement, exceeding the 95th percentile. Ozone concentrations were above the 95th percentile from 09:00-19:00 PST. Overnight ozone levels remained high, staying above the median and never returned to low values typical for this site.

Draft

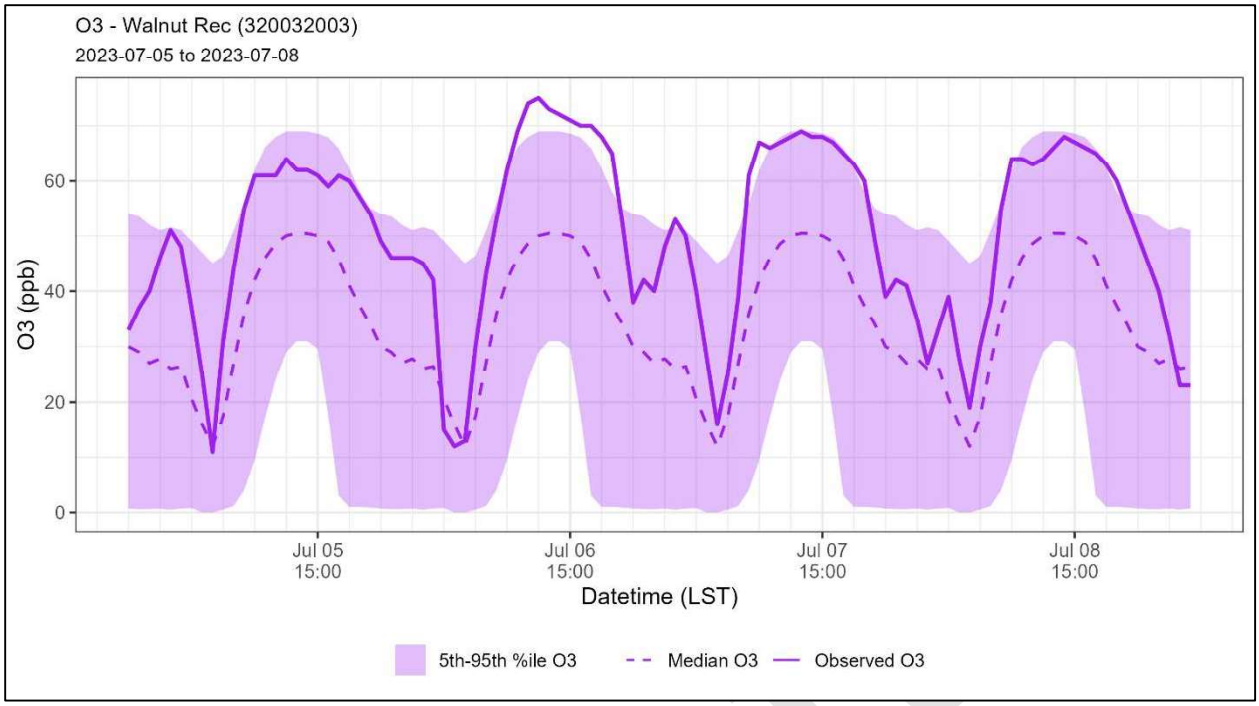


Figure 212. Hourly O_3 measurements overlaid on the 5th to 95th percentile diurnal concentration at Walnut Rec (AQS site code 320032003). The 5th to 95th percentile concentration is calculated across the ozone production season (April-September) for 2018-2023. Note: Walnut Rec includes data starting June 1, 2021, and onwards.

The Walter Johnson site exceeded on July 5-8 (Figure 213). Afternoon ozone concentrations show significant enhancement, exceeding the 95th percentile. Overnight and early-morning ozone concentrations were persistently higher than the expected diurnal pattern. On July 6 and 7, ozone concentrations were above the 95th percentile from 09:00-21:00 PST. On July 8, ozone concentrations remained above the 95th percentile from 06:00-21:00 PST.

Draft

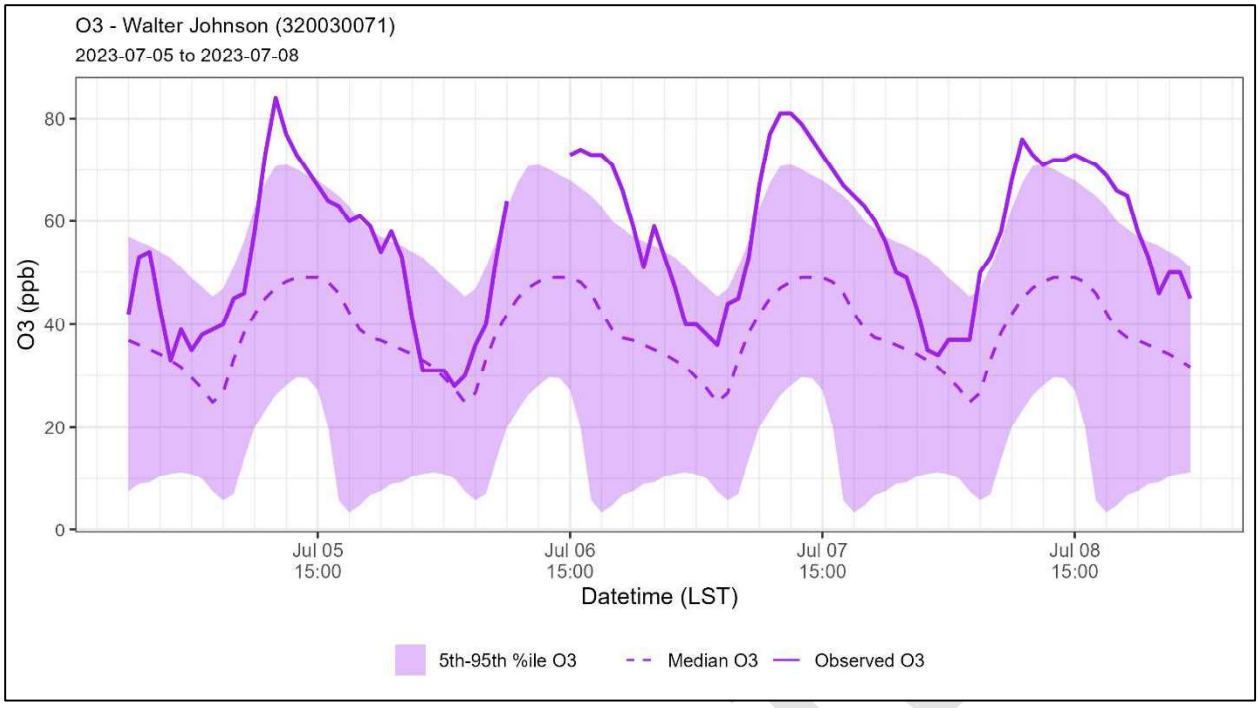


Figure 213. Hourly O_3 measurements overlaid on the 5th to 95th percentile diurnal concentration at Walter Johnson (AQS site code 320030071). The 5th to 95th percentile concentration is calculated across the ozone production season (April-September) for 2018-2023.

6.2 Identification of Wildfire(s)

Fires east and southeast of Clark County in Arizona and southwest in northwestern Mexico were active during the days before and during the July 5-8 ozone event (**Figure 214 through Figure 217**). To the southeast, the Pilot Fire in the Mohon Mountains near Wikieup, AZ burned more than 34,000 acres from July 1 until July 14, 2023.[54] To the east, the Ridge Fire in Coconino County seven miles southeast of Tusayan, AZ started via lightning and started on June 4 and as of July 11, 2023, 10,210 acres burned.[55] The Three Lakes Fire in Kaibab National Forest 6 miles south of the Jacob Lake area between forest road 217 and state route 67, started on June 16 and as of July 7, 2023, 5,146 acres had burned.[56] Over a dozen fires were actively burning in northwestern Mexico. Figure 214 through Figure 217 show Hazard Mapping System (HMS) maps that display smoke across the United States between July 5 and July 8, 2023. HMS smoke maps are created using visible satellite imagery from Geostationary Operational Environmental Satellites (GOES). Visible imagery is only available during the sunlit part of the GOES orbit; therefore, smoke movement during nighttime hours is inferred

[54] https://www.abc15.com/news/state/pilot-fire-burning-near-wikieup-at-more-than-32-000-acres
[55] https://inciweb.wildfire.gov/incident-information/azknf-ridge-fire
[56] https://inciweb.wildfire.gov/incident-publication/azknf-three-lakes-fire/crews-make-steady-progress-on-kaibab-nf-fires

between the daylight-generated smoke maps. The HMS maps show notable smoke plumes in northwestern Mexico and significant smoke from extremely large Canadian wildfires is also visible on July 4, 2023. On July 5, 2023, the smoke dispersed over wider areas blanketing the western United States, including Clark County. Notable smoke plumes in the surrounding areas from northwestern Mexico and Arizona were visible from July 6-8, 2023. In addition, significant smoke from Canadian wildfires continued to blanket much of the United States, including northern Nevada.

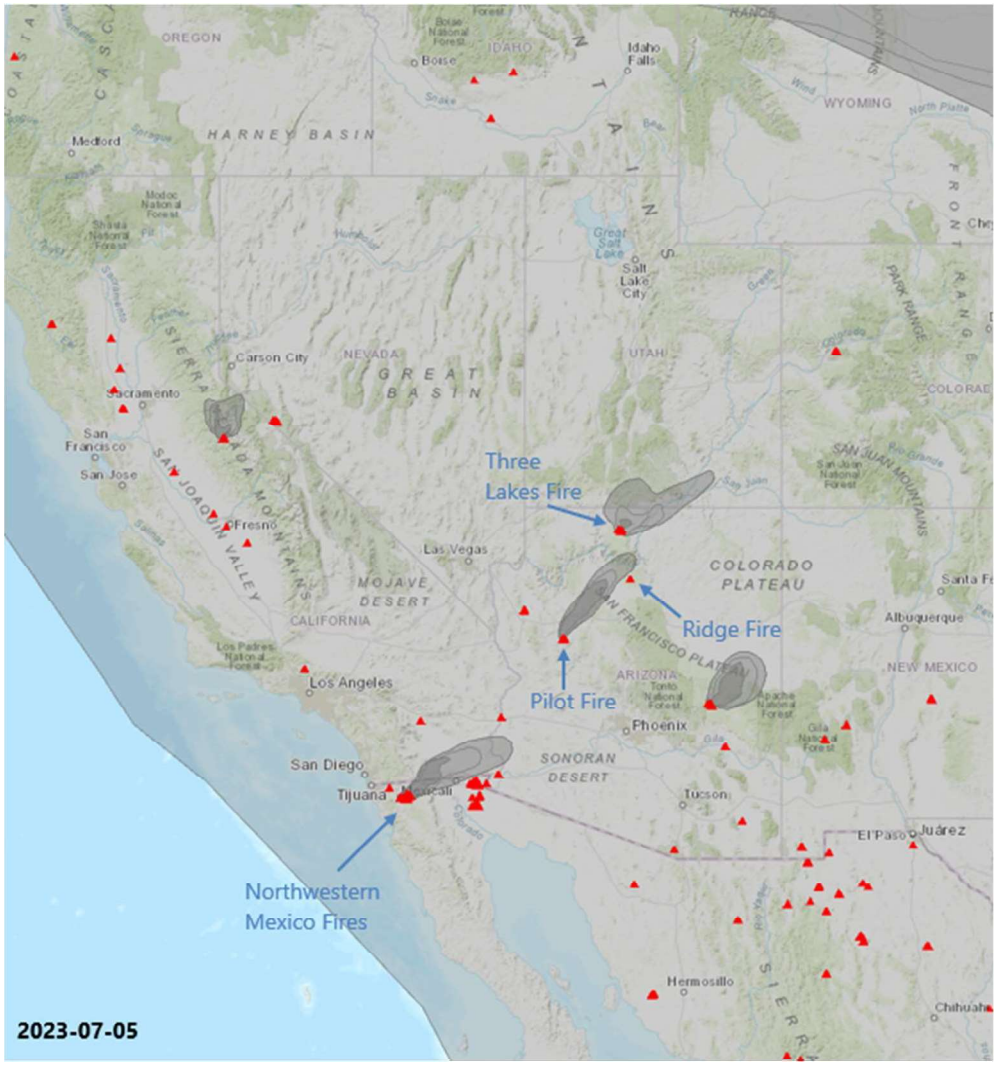


Figure 214. NOAA HMS smoke analysis (grey contours) and satellite fire detections (red triangles) for July 5, 2023. Source: AirNow-Tech.

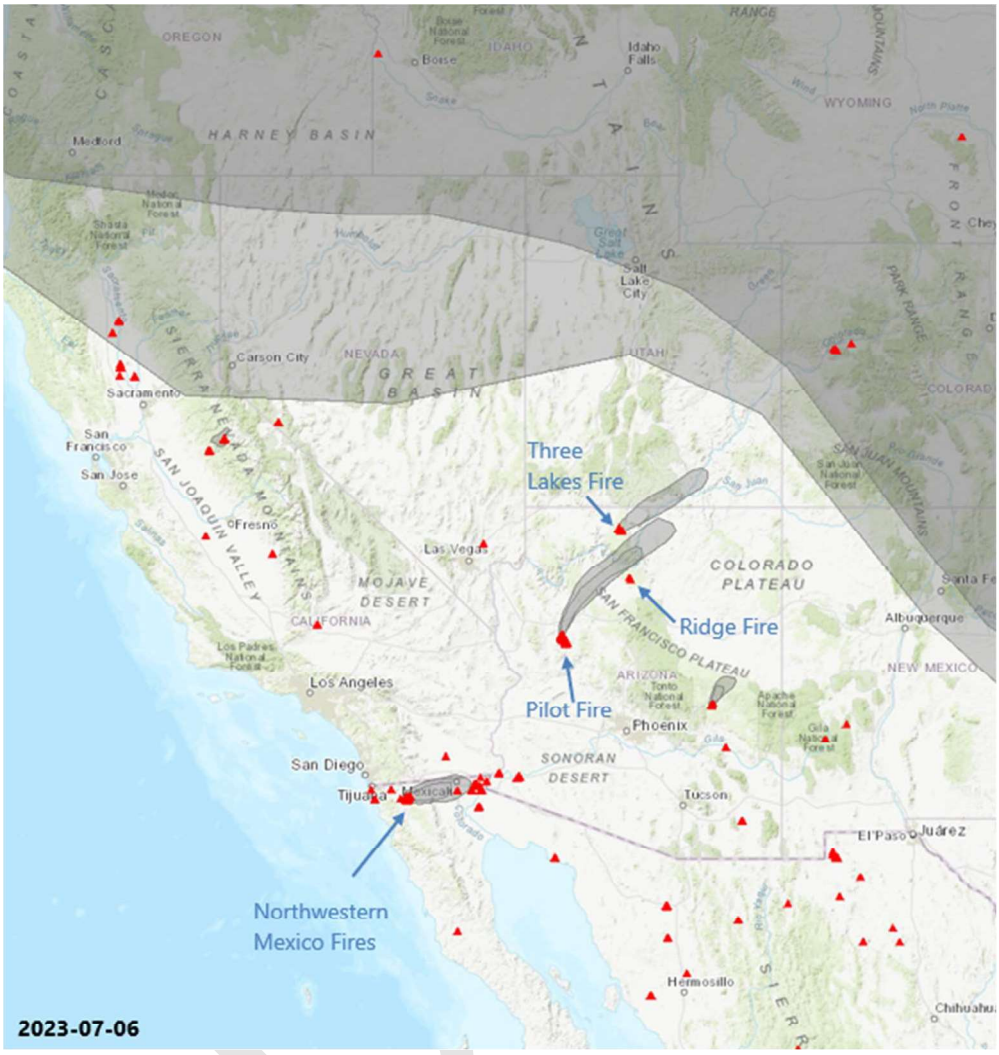


Figure 215. NOAA HMS smoke analysis (grey contours) and satellite fire detections (red triangles) for July 6, 2023. Source: AirNow-Tech.

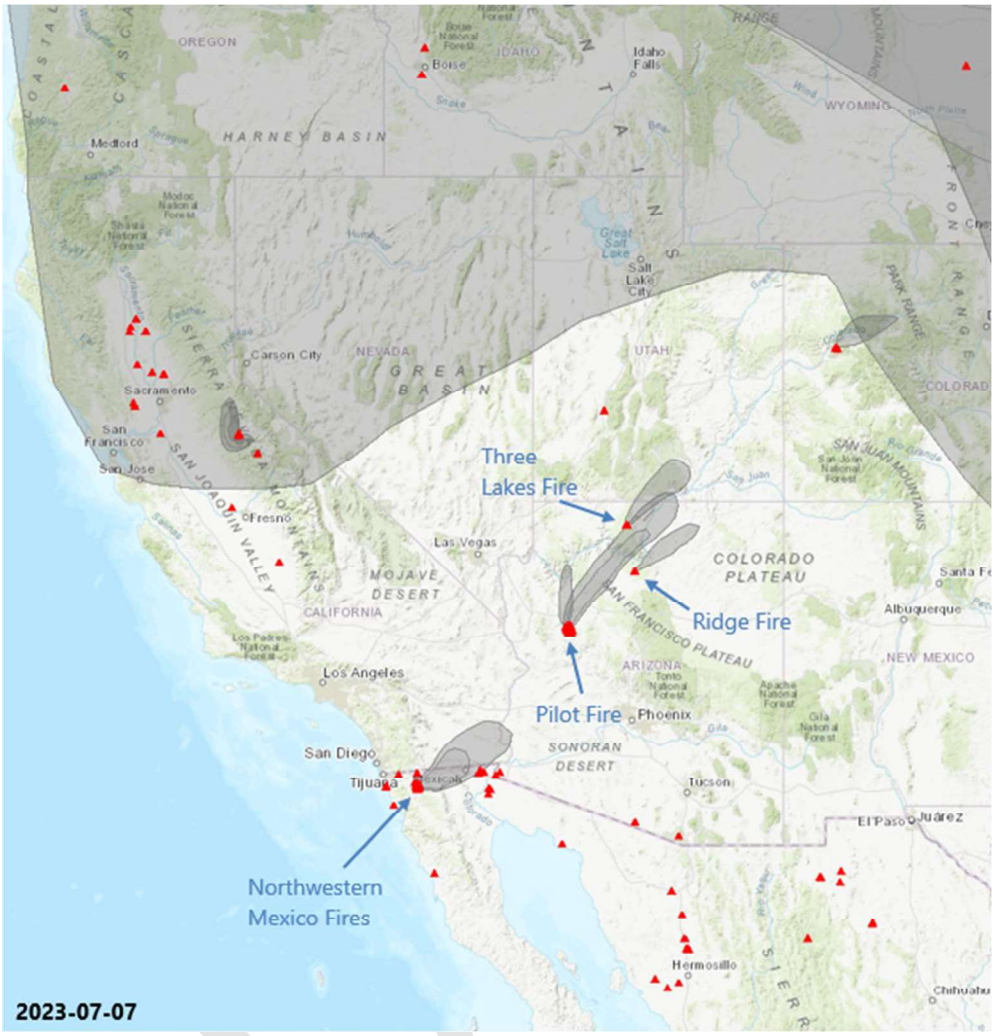


Figure 216. NOAA HMS smoke analysis (grey contours) and satellite fire detections (red triangles) for July 7, 2023. Source: AirNow-Tech.

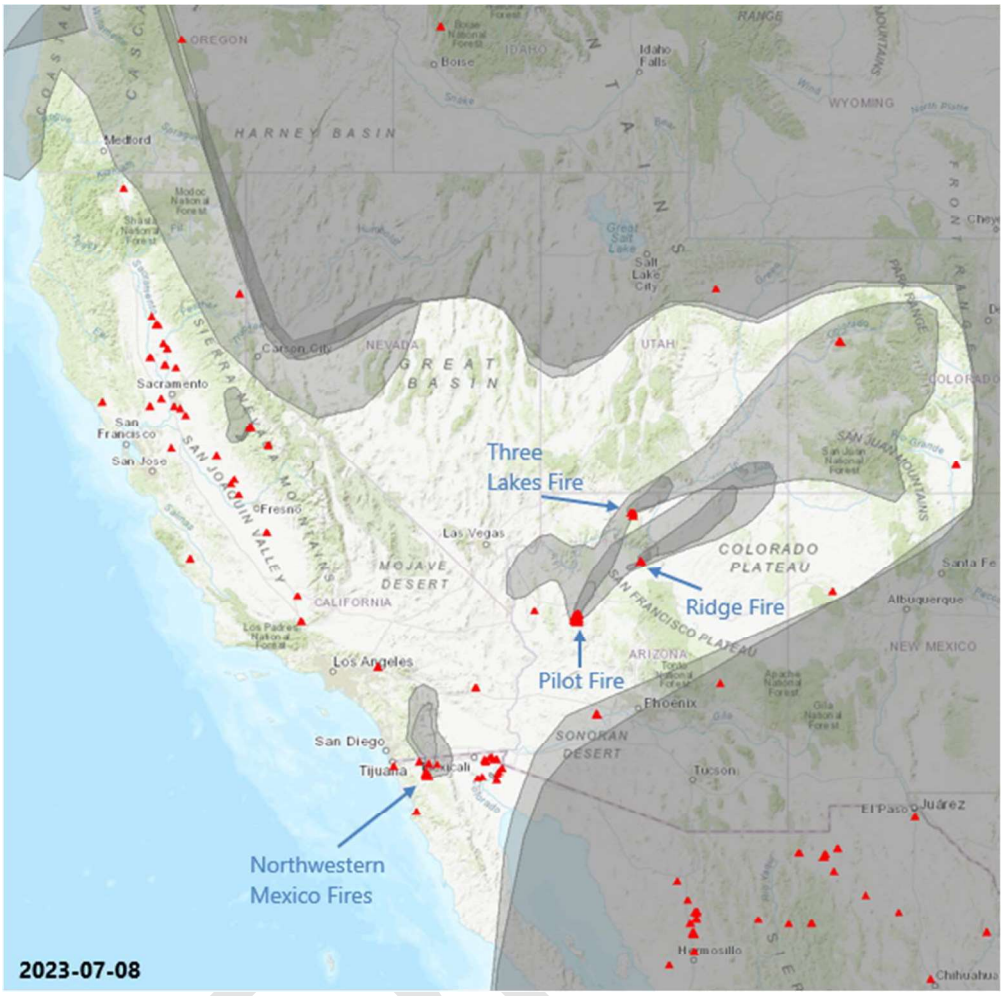


Figure 217. NOAA HMS smoke analysis (grey contours) and satellite fire detections (red triangles) for July 8, 2023. Source: AirNow-Tech.

Wildfires in Arizona and northwestern Mexico were active during the days leading up to and including the exclusion dates, which contributed to regional smoke as shown in the HMS images. Table 53 presents the state location, total acres within the fire perimeter, and the start and containment dates for each fire based on data from InciWeb and Wikipedia. For the northwestern fire in Mexico, the fire size was estimated using satellite imagery from the Fire Information for Resource Management System.

Table 53. Wildfires affecting Clark County on July 5-8.

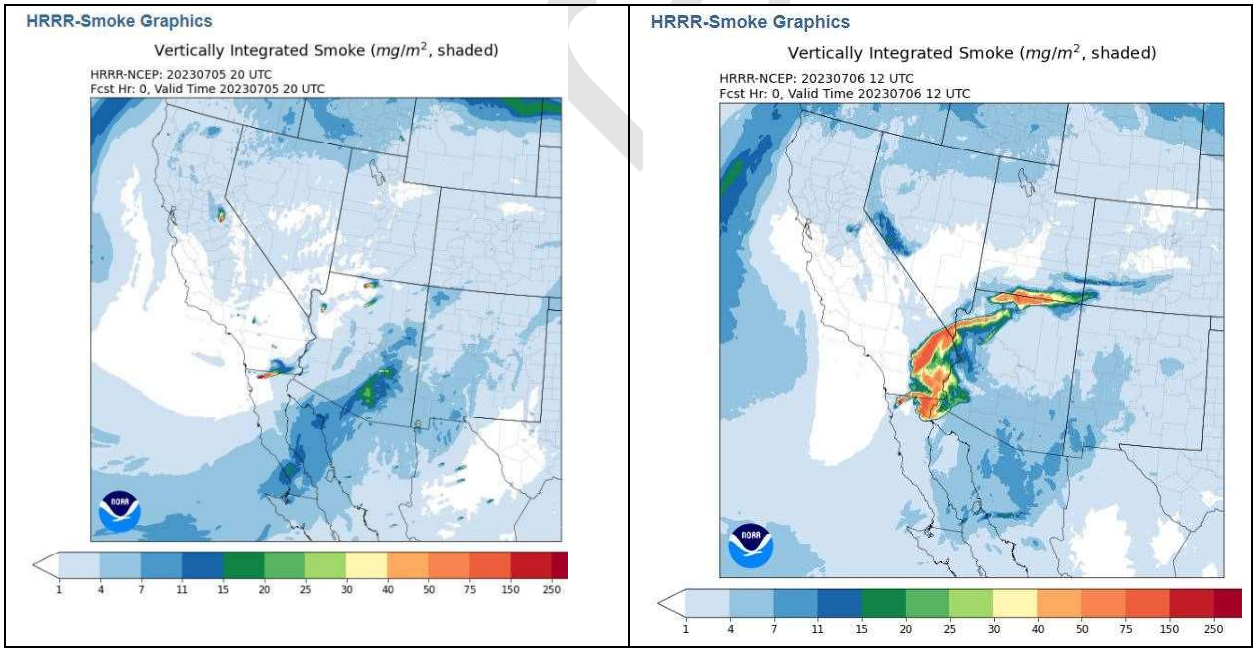
Wildfire Name	State	Total Acres	Start Date	Containment Date
Pilot Fire	Arizona	34,810	July 1	August 3
Ridge Fire	Arizona	10,210	June 4	August 22

Three Lakes Fire	Arizona	6,914	June 16	July 21
Northwestern Mexico Fires	Mexico	9,607	July 1	July 17

6.3 Meteorological Analysis

6.3.1 HRRR Smoke Model Output

Figure 218 shows the levels of vertically integrated smoke over the Clark County region from July 5-8, 2023. The HRRR data is shown for July 5, 2023, at 13:00 PST, July 6, 2023, at 05:00 and 13:00 PST, July 7, 2023, at 05:00 and 13:00 PST, and July 8, 2023, at 05:00 and 13:00 PST. The HRRR data shows heavy levels of smoke being emitted from the northwestern Mexico and Arizona fires that were mixed into a regional plume of smoke. The plume of smoke over southern California can be traced back to the fires in northwestern Mexico, which is shown to be directly impacting Clark County on the exclusion dates of July 5-8, 2023. The HYSPLIT trajectories indicate nearly direct transport from the fire in northwestern Mexico to Clark County on July 5, 2023. Overall, the HRRR data shows light to heavy levels of vertically integrated smoke from the fires in northwestern Mexico and Arizona over the Clark County region during the exclusion days during the MDA8 ozone periods.



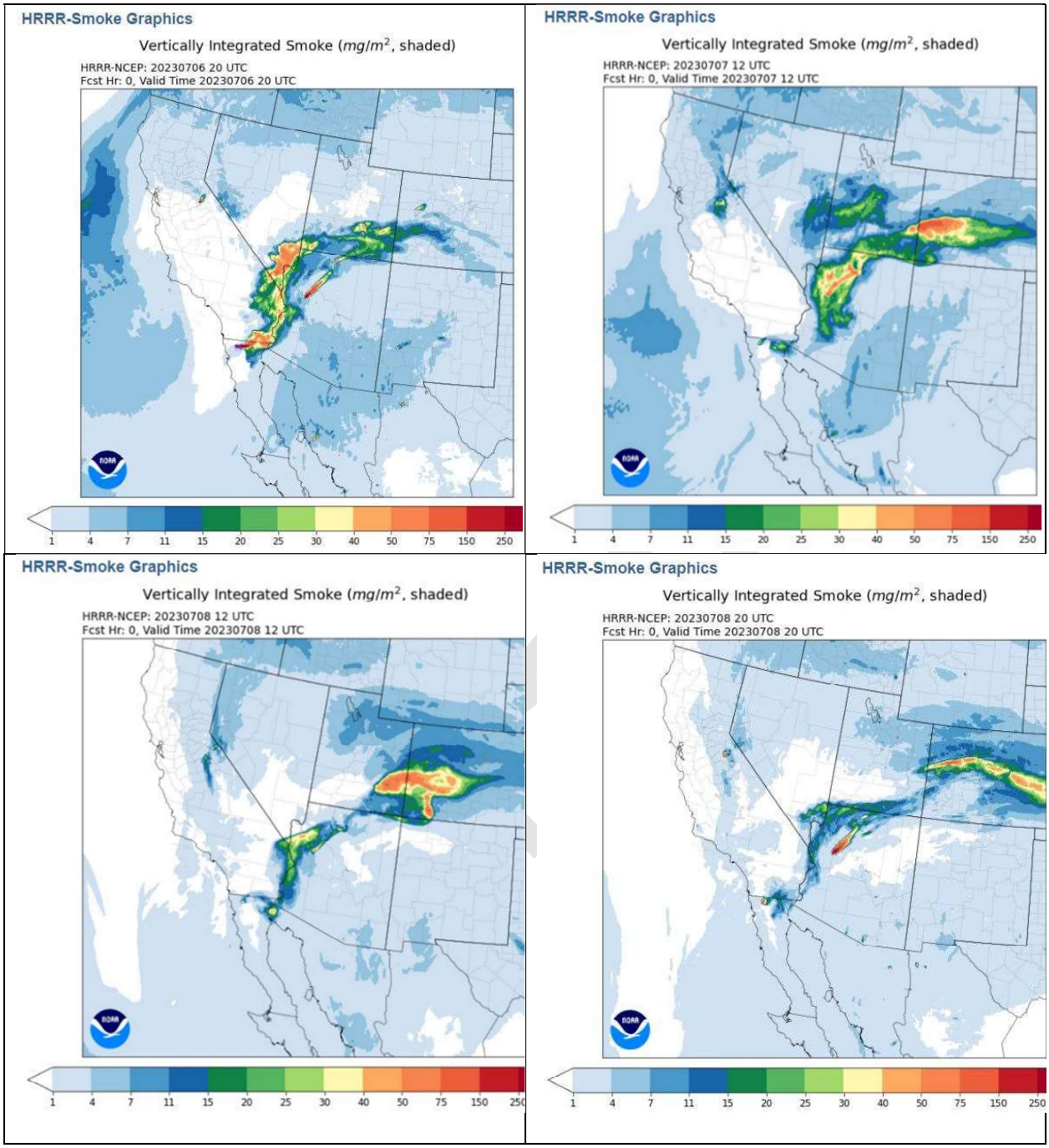


Figure 218. HRRR vertically integrated smoke forecast for July 5-8, 2023, at 05:00 and 13:00 PST.

6.3.2 Upper-Level Analysis

The height of the 500-millibar (mb) pressure level AGL as well as the curvature of the 500-mb height field can be useful in discerning the potential for ozone production on the synoptic (large) scale. Areas of low pressure are generally conducive to cloud development and precipitation, as cool

temperatures in the mid-levels promote atmospheric mixing and instability. Low pressure areas generally coincide with decreased ozone development. Alternatively, areas of high pressure are normally indicative of a warm, dry air mass in the mid-levels of the atmosphere. Those warm and dry mid-level conditions often promote sunny skies and increase the potential for ozone development.

The contour plots of geopotential height at 500 mb (approximately 18,000 feet) from July 5-8, 2023, shown in Figure 219 through Figure 222 show a persistent broad ridge of upper-level high pressure over southern Nevada. The pronounced upper-level high pressure produced mostly sunny skies and hot temperatures in the Clark County region on each of these days, providing the ultraviolet radiation needed for the photochemical reactions that produce ozone. Additionally, this upper-level ridge confined smoke from regional fires to the mid- and lower-levels of the atmosphere.

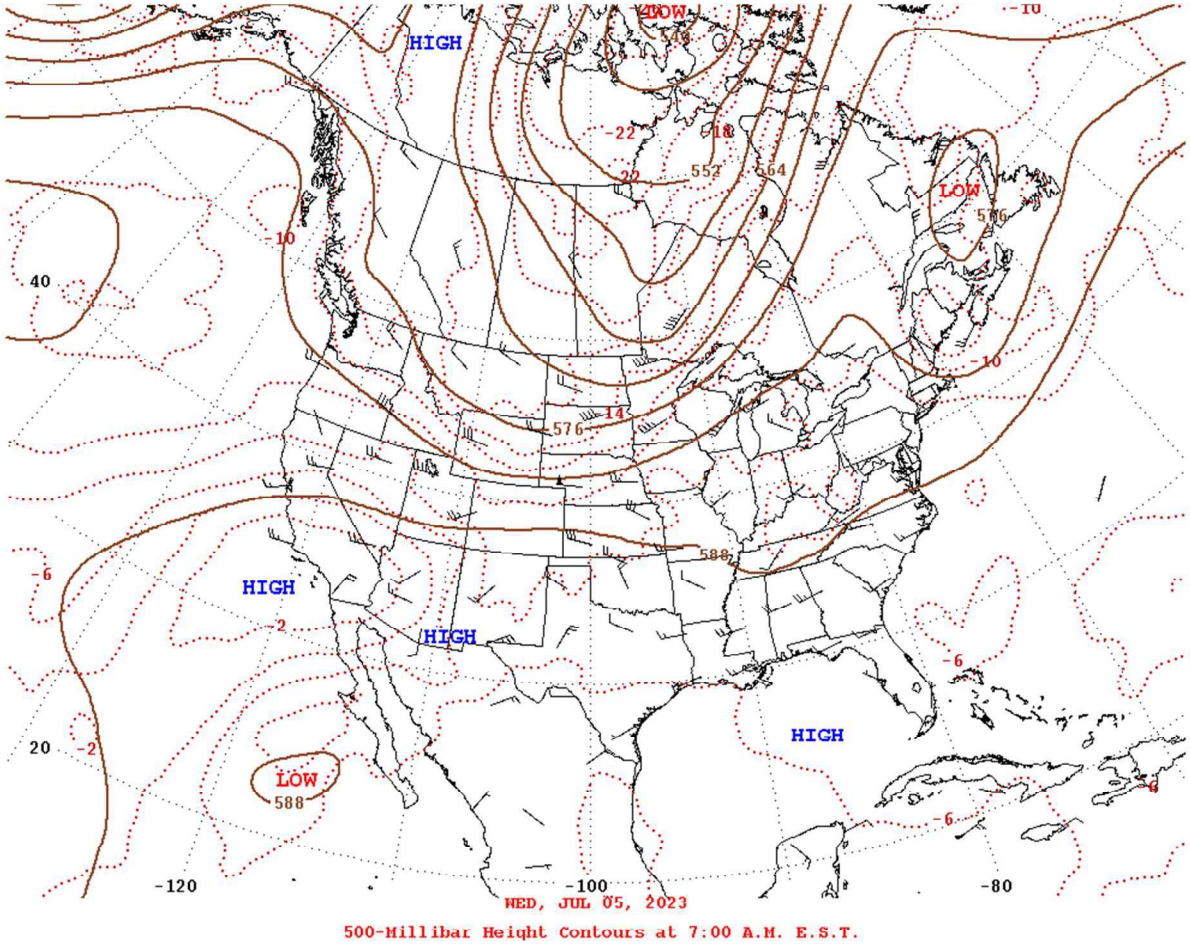


Figure 219. 500-mb heights, winds, and temperatures at 04:00 PST on July 5, 2024. Source: NOAA Weather Prediction Center.

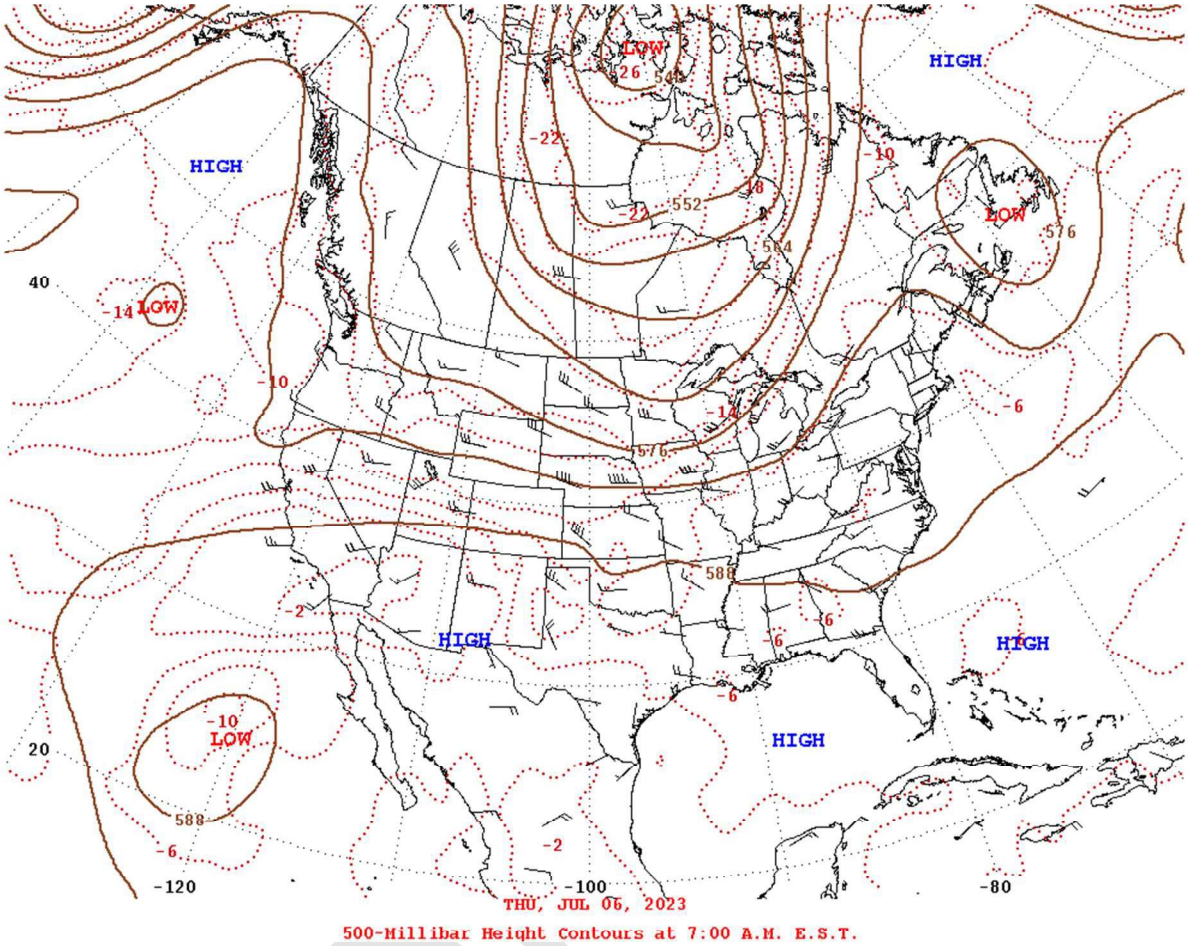


Figure 220. 500-mb heights, winds, and temperatures at 04:00 PST on July 6, 2024. Source: NOAA Weather Prediction Center.

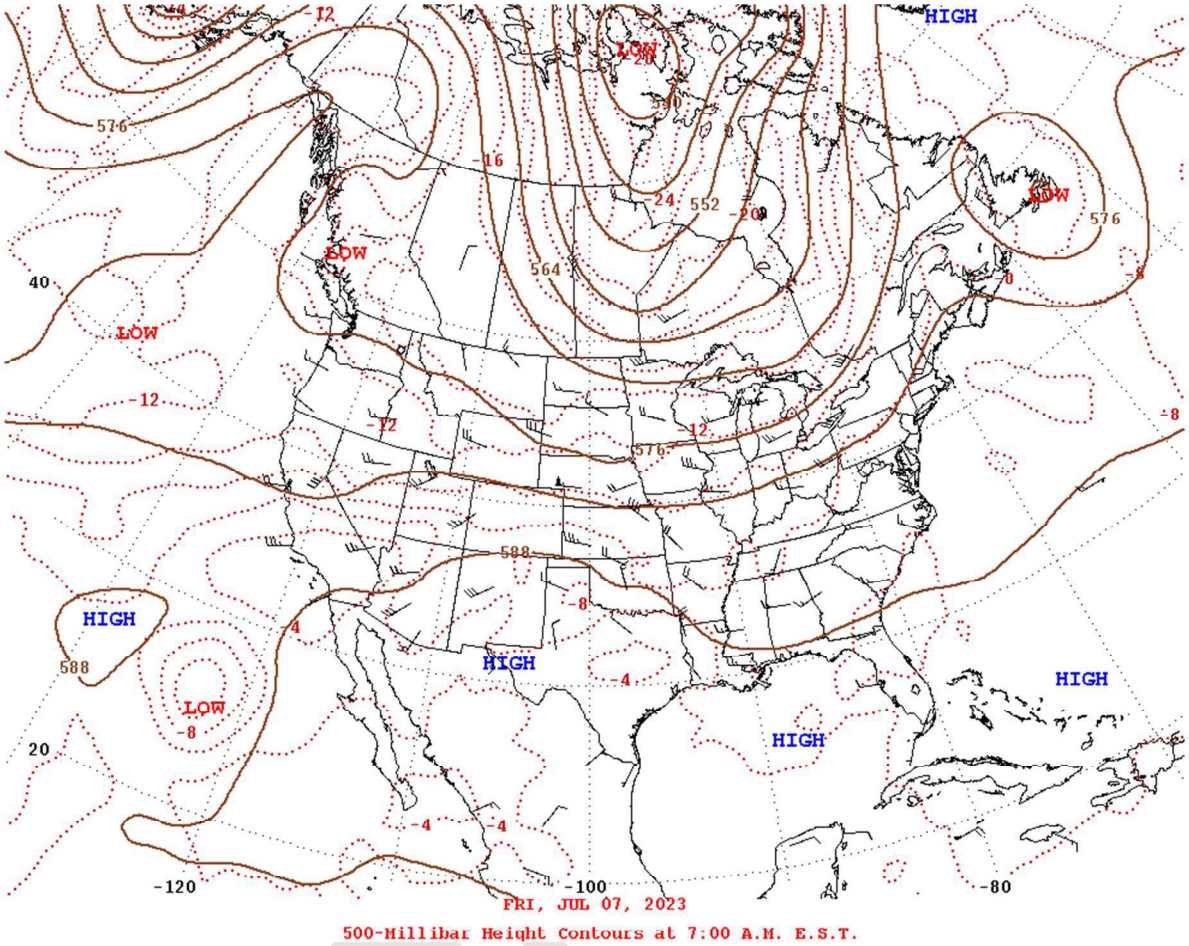


Figure 221. 500-mb heights, winds, and temperatures at 04:00 PST on July 7, 2024. Source: NOAA Weather Prediction Center.

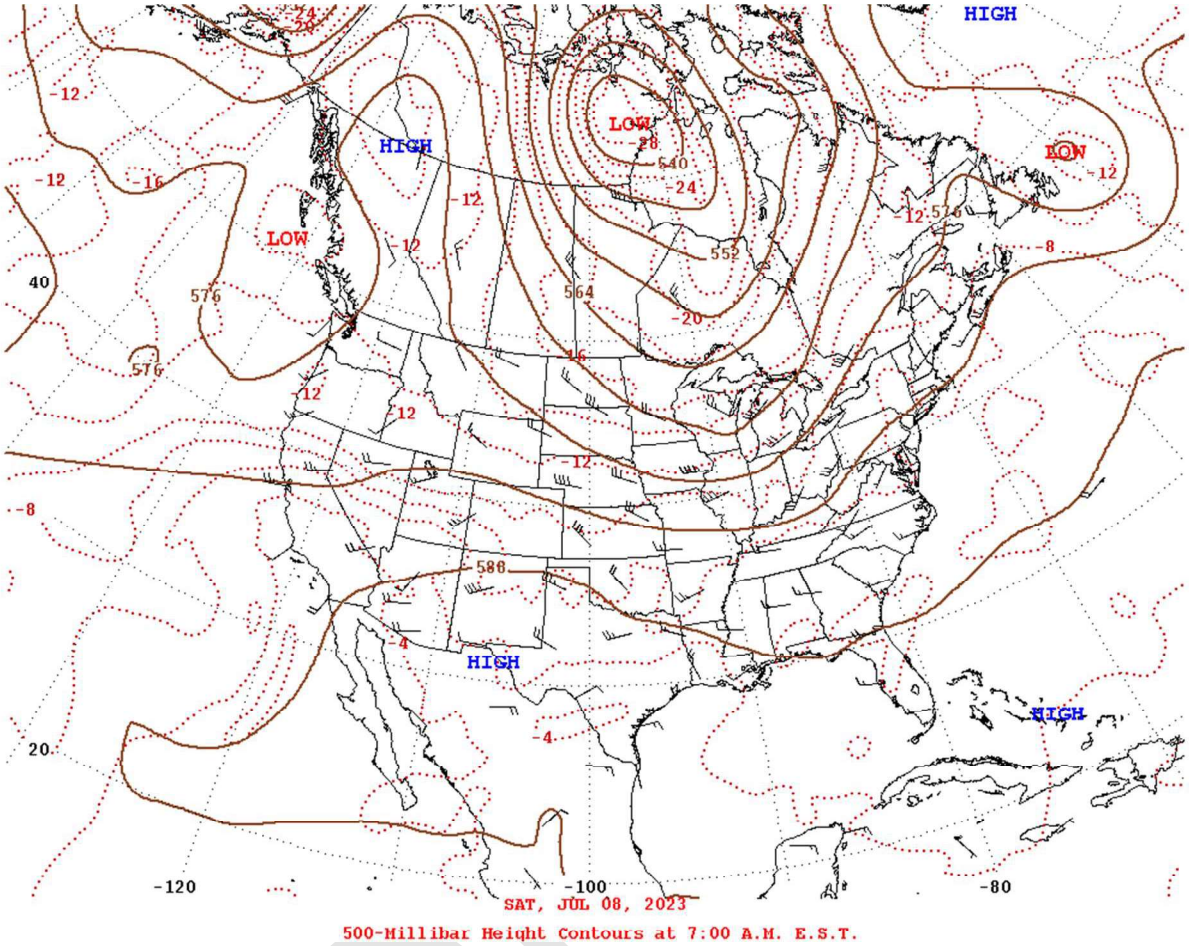


Figure 222. 500-mb heights, winds, and temperatures at 04:00 PST on July 8, 2024. Source: NOAA Weather Prediction Center.

6.3.3 Surface Weather Patterns

Table 54 provides meteorological reports (METAR) that show stagnant morning conditions and moderate evening winds on July 5-8. Stagnant morning conditions limit dispersion, allowing wildfire smoke products to remain in the area and impact ozone production. Evening wind speeds above 8 knots made conditions suitable for regional wildfire smoke transport into the area. Smoke was identified in the KLAS (Las Vegas) METAR report (reported as "FU," meaning smoke) on July 5 at 3:56 and 4:56, July 6 at 7:56, 8:56, and 12:56, and July 8 at 14:56 confirming that smoke was observed at the surface in Clark County. Wind speeds were low (0-7 knots) during these periods, except for 12:56 on July 6 when winds reached 8 knots, creating predominately stagnant conditions favorable to smoke-influenced ozone production.

Table 54. METAR report at the Las Vegas International Airport (KLAS) for July 5-8, 2023. VRB is variable wind direction.

Date/ Time (PST/PDT)	Temperature (C°)	Dew Point (C°)	Wind Direction	Wind Speed (knots)	Pressure (hPa)	Visibility	Sky Conditions
7/5/2023 00:56	31.11	-0.61	190	5	1006.2	10SM	
7/5/2023 01:56	30.00	-1.72	170	5	1006.4	10SM	
7/5/2023 02:56	28.89	-1.11	180	10	1006.8	10SM	
7/5/2023 03:56	28.33	-1.11	200	6	1007.2	10SM	Haze (HZ), Smoke (FU), Distant (DSNT) SW NW
7/5/2023 04:56	26.27	-1.11	0	0	1008.0	10SM	Smoke (FU)
7/5/2023 05:56	26.11	-0.61	210	4	1008.4	10SM	
7/5/2023 06:56	27.22	1.11	160	4	1008.8	10SM	
7/5/2023 07:56	29.44	0.00	250	3	1009.3	10SM	
7/5/2023 08:56	31.11	0.56	0	0	1009.7	10SM	
7/5/2023 09:56	32.22	0.56	0	0	1009.8	10SM	
7/5/2023 10:56	34.44	0.00	VRB	5	1009.8	10SM	
7/5/2023 11:56	36.11	0.56	0	0	1009.4	10SM	
7/5/2023 12:56	37.78	-3.89	100	5	1008.7	10SM	
7/5/2023 13:56	38.89	-6.11	VRB	6	1008.2	10SM	
7/5/2023 14:56	39.44	-7.22	70	6	1007.3	10SM	
7/5/2023 15:56	40.00	-7.22	40	8	1006.3	10SM	
7/5/2023 16:56	39.44	-7.22	VRB	5	1005.5	10SM	
7/5/2023 17:56	39.44	-6.72	VRB	4	1005.0	10SM	

Date/ Time (PST/PDT)	Temperature (C°)	Dew Point (C°)	Wind Direction	Wind Speed (knots)	Pressure (hPa)	Visibility	Sky Conditions
7/5/2023 18:56	38.33	-6.11	100	11	1005.0	10SM	
7/5/2023 19:56	37.22	-5.00	150	12	1005.0	10SM	
7/5/2023 20:56	35.56	-4.39	170	9	1005.7	10SM	
7/5/2023 21:56	34.44	-5.00	170	7	1006.5	10SM	
7/5/2023 22:56	32.78	-6.11	180	6	1006.7	10SM	
7/5/2023 23:56	32.22	-6.11	180	6	1006.6	10SM	
7/6/2023 00:56	31.70	-7.22	200	8	1006.5	10SM	
7/6/2023 01:56	30.00	-7.22	190	8	1006.2	10SM	
7/6/2023 02:56	29.44	-5.61	190	6	1006.4	10SM	
7/6/2023 03:56	28.33	-4.39	190	4	1006.6	10SM	
7/6/2023 04:56	27.22	-2.22	0	0	1007.0	10SM	
7/6/2023 05:56	27.22	-2.22	0	0	1007.3	10SM	
7/6/2023 06:56	27.22	-2.22	290	3	1007.6	10SM	
7/6/2023 07:56	28.89	-1.72	0	0	1008.0	10SM	Smoke (FU)
7/6/2023 08:56	31.67	-0.61	60	4	1008.4	10SM	Smoke (FU)
7/6/2023 09:56	33.33	-4.39	30	7	1008.3	10SM	
7/6/2023 10:59	34.33	-5.00	360	3	1008.0	10SM	
7/6/2023 11:56	36.67	-6.11	180	9	1007.1	10SM	
7/6/2023 12:56	38.33	-6.72	200	8	1005.9	10SM	Smoke (FU)
7/6/2023 13:56	38.89	-5.61	210	9	1005.5	10SM	

Date/ Time (PST/PDT)	Temperature (C°)	Dew Point (C°)	Wind Direction	Wind Speed (knots)	Pressure (hPa)	Visibility	Sky Conditions
7/6/2023 14:56	39.44	-6.11	VRB	6	1004.4	10SM	
7/6/2023 15:58	38.89	-7.78	190	5	1003.5	10SM	
7/6/2023 16:56	39.44	-8.28	230	10	1003.0	10SM	
7/6/2023 17:56	38.89	-7.78	230	11	1002.4	10SM	
7/6/2023 18:56	37.78	-7.22	240	10	1002.5	10SM	
7/6/2023 19:56	36.67	-6.72	230	11	1002.7	10SM	
7/6/2023 20:56	35.00	-5.61	200	3	1002.8	10SM	
7/6/2023 21:56	33.33	-4.39	170	4	1003.3	10SM	
7/6/2023 22:56	32.22	-3.89	190	4	1003.2	10SM	
7/6/2023 23:56	31.11	-3.28	200	5	1002.9	10SM	
7/7/2023 00:56	30.56	-3.28	200	6	1002.8	10SM	
7/7/2023 01:56	29.44	-2.22	190	6	1003.0	10SM	
7/7/2023 02:56	27.78	-1.11	190	5	1003.0	10SM	
7/7/2023 03:56	27.22	0.00	180	4	1003.3	10SM	
7/7/2023 04:56	26.11	0.00	180	3	1003.7	10SM	
7/7/2023 05:56	26.11	0.56	200	4	1004.1	10SM	
7/7/2023 06:56	27.22	0.56	220	4	1004.8	10SM	
7/7/2023 07:56	28.89	1.67	VRB	3	1005.5	10SM	
7/7/2023 08:56	30.56	0.56	170	3	1005.8	10SM	
7/7/2023 09:56	32.78	0.00	VRB	3	1005.5	10SM	

Date/ Time (PST/PDT)	Temperature (C°)	Dew Point (C°)	Wind Direction	Wind Speed (knots)	Pressure (hPa)	Visibility	Sky Conditions
7/7/2023 10:56	33.33	0.56	110	3	1005.5	10SM	
7/7/2023 11:56	35.00	0.00	80	5	1004.9	10SM	
7/7/2023 12:56	36.67	-0.61	VRB	3	1004.3	10SM	
7/7/2023 13:56	37.78	-1.11	310	4	1003.3	10SM	
7/7/2023 14:56	38.33	-0.61	VRB	5	1002.7	10SM	
7/7/2023 15:56	38.89	-0.61	70	15	1001.8	10SM	
7/7/2023 16:56	39.44	-1.72	80	16	1001.3	10SM	
7/7/2023 17:56	38.89	-4.39	230	11	1000.8	10SM	
7/7/2023 18:56	38.33	-3.89	240	10	1001.0	10SM	
7/7/2023 19:56	36.67	-5.00	230	11	1001.6	10SM	
7/7/2023 20:56	34.44	-4.39	220	7	1002.2	10SM	
7/7/2023 21:56	38.89	-5.00	190	4	1003.1	10SM	
7/7/2023 22:56	32.22	-5.61	190	5	1003.2	10SM	
7/7/2023 23:56	31.11	-6.72	200	6	1003.3	10SM	
7/8/2023 00:56	30.00	-5.61	220	8	1003.3	10SM	
7/8/2023 01:56	28.33	-5.00	250	4	1003.4	10SM	
7/8/2023 02:56	27.78	-3.28	220	3	1003.3	10SM	
7/8/2023 03:56	26.67	-2.78	200	4	1003.8	10SM	
7/8/2023 04:56	26.11	-1.72	0	0	1004.4	10SM	
7/8/2023 05:56	25.56	-1.11	240	3	1005.1	10SM	

Date/ Time (PST/PDT)	Temperature (C°)	Dew Point (C°)	Wind Direction	Wind Speed (knots)	Pressure (hPa)	Visibility	Sky Conditions
7/8/2023 06:56	26.67	-1.11	210	4	1005.6	10SM	
7/8/2023 07:56	28.33	-2.22	290	4	1006.5	10SM	
7/8/2023 08:56	30.56	-2.22	0	0	1006.9	10SM	
7/8/2023 09:56	32.78	-1.72	VRB	4	1006.8	10SM	
7/8/2023 10:56	34.44	-1.72	40	6	1006.8	10SM	
7/8/2023 11:56	35.56	-3.89	50	5	1006.3	10SM	
7/8/2023 12:56	36.67	-5.61	60	8	1005.7	10SM	
7/8/2023 13:56	38.89	-6.72	VRB	5	1004.7	10SM	
7/8/2023 14:56	38.89	-8.28	360	7	1004.0	10SM	Smoke (FU)
7/8/2023 15:56	39.44	-8.89	VRB	3	1003.2	10SM	
7/8/2023 16:56	40.00	-8.28	150	8	1002.6	10SM	
7/8/2023 17:56	39.44	-9.39	150	12	1002.2	10SM	
7/8/2023 18:56	38.89	-8.89	160	12	1002.3	10SM	
7/8/2023 19:56	37.22	-8.89	170	11	1002.5	10SM	
7/8/2023 20:56	36.11	-10.61	180	10	1003.2	10SM	
7/8/2023 21:56	35.00	-3.89	200	8	1004.2	10SM	
7/8/2023 22:56	32.78	-3.89	180	4	1004.5	10SM	
7/8/2023 23:56	31.67	-6.72	180	5	1004.6	10SM	

6.3.4 Vertical Temperature Profiles and Mixing Heights

To assess the effects of wildfire smoke in Clark County (as indicated by the HMS smoke maps shown in Section 6.2), we first evaluated the meteorological conditions leading up to and during the July 5-8 event. The analysis focused on the boundary layer dynamics, particularly the depth of vertical mixing and the potential of smoke mixing to the surface. This information was then applied to model smoke via HYSPLIT and compared with independent sources (including HMS and HRRR data).

The PBL denotes the atmospheric layer closest to the surface, and the height of the PBL describes the vertical extent of surface air characteristics. Atmospheric soundings provide visualizations of the extent of vertical mixing in the lower troposphere. Figure 223 presents nine skew-T diagrams showing vertical profiles of the atmosphere every 12 hours from July 5 at 00:00 UTC (July 4 at 16:00 PST) to July 9 at 00:00 UTC (July 8 at 16:00 PST). The soundings are characterized primarily by little change from morning to afternoon except for a very shallow layer at the surface in the soundings taken at 12:00 UTC (04:00 PST). The soundings taken at 00:00 UTC (16:00 PST) show an approximately dry-adiabatic temperature lapse rate, indicating that the lower troposphere was well mixed with a PBL of approximately 3,500 m AGL (~650 mb). During the 2023 wildfire-impacted ozone episode, PBL heights were notably lower than the 2018–2022 mean (Table 55). These conditions indicate strong mixing from the surface through the mid-troposphere for most of the day. Overall, the exclusion days are characterized by a deep, well-mixed boundary layer, supporting the potential for transported smoke to mix down to the surface.

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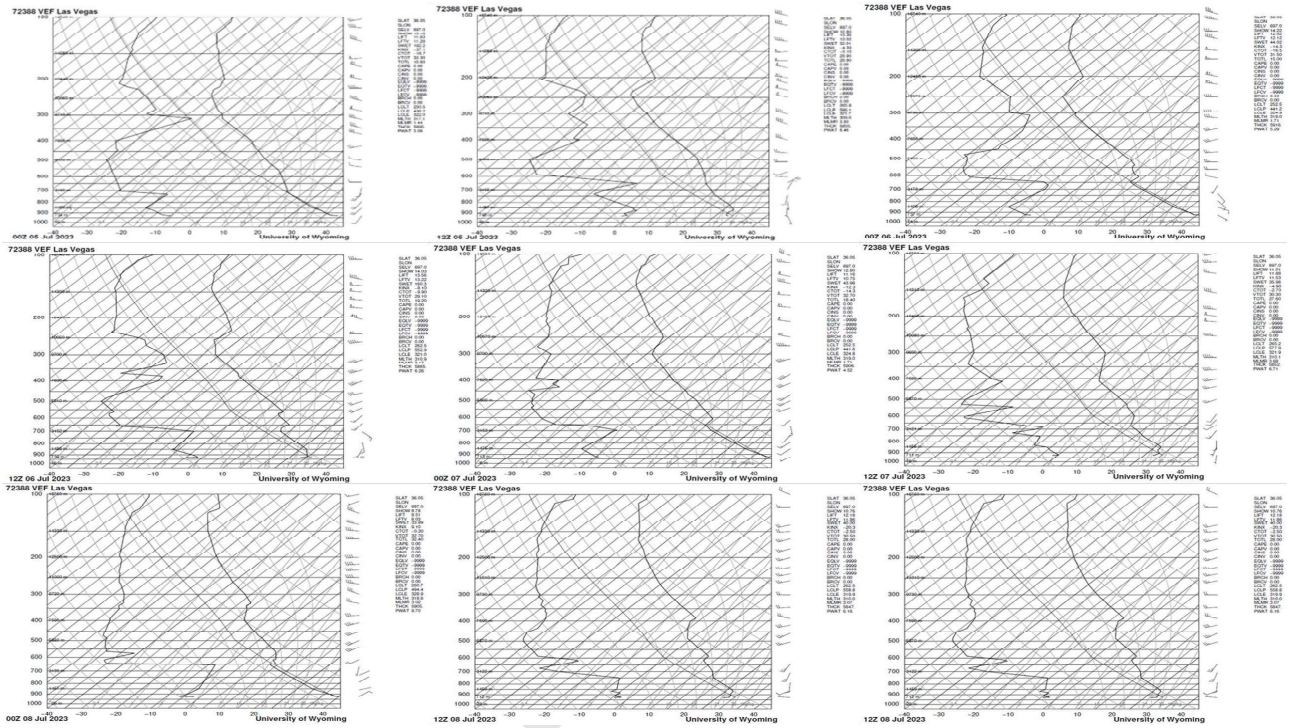

Figure 223. Skew-T soundings launched from the Las Vegas National Weather Service Office from July 5, 2023, at 00:00 UTC (July 4 at 16:00 PST) to July 9 at 00:00 UTC (July 8 at 16:00 PST).

Table 55. 5-year PBL averages for July 5-8. PBL heights are in meters.

Date	2018	2019	2020	2021	2022	2023	2018-2022 Mean
7/5/2023	3600	4200	4000	4800	3500	3200	4020
7/6/2023	5000	4200	4000	5100	3500	3200	4360
7/7/2023	4400	4100	3000	5300	3600	3500	4080
7/8/2023	3200	3800	3100	5700	3500	3500	3860

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6.3.5 Smoke Transport

Back trajectories ending in Las Vegas at 15:00 PST on July 5 are shown originating on July 4 (Figure 224). The HMS fire detections (red triangles) and smoke plumes (gray shading) correspond to the date of the trajectory origin. Date and time stamps indicate air parcel positions along those trajectories. As shown in Figure 224, the back trajectory ending in Las Vegas at 15:00 PST on July 5 at 100 m AGL (green line), indicates a transport path within a smoke plume and passed nearby fires observed in Northwestern Mexico, Southern California, and Arizona. Additionally, the back trajectories at 1,500 and 3,500 m AGL shows a transport path within a smoke plume over southern and central California.

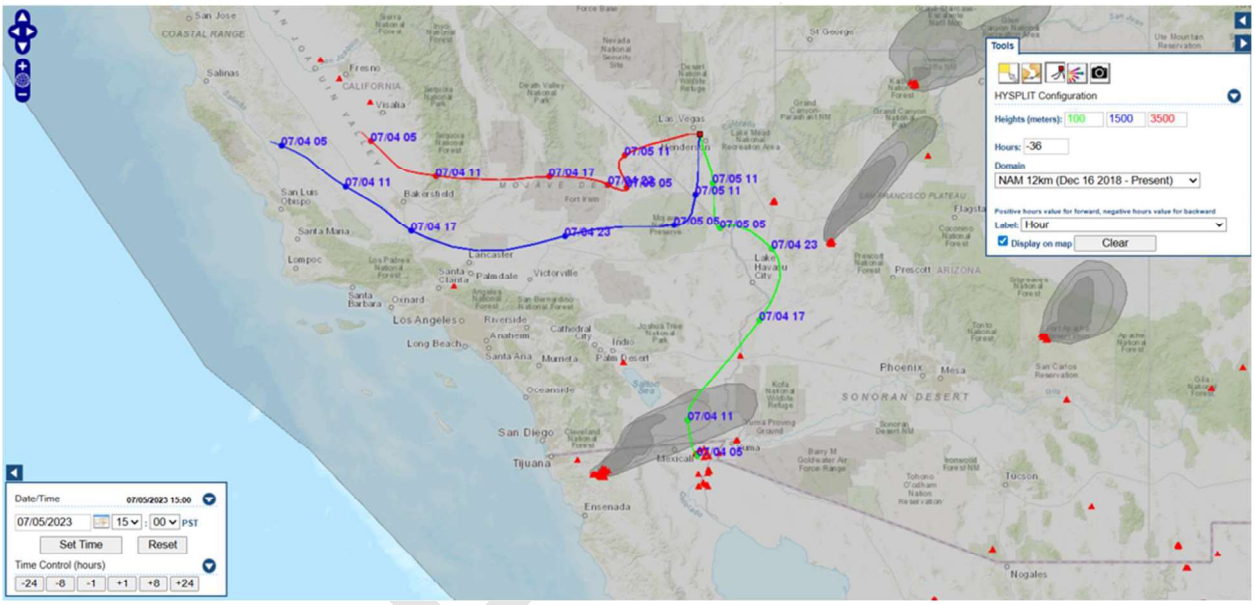

Figure 224. 36-hr back trajectory from the NAM model ending in Las Vegas on July 5, 2023, at 15:00 PST at 100 m (green line), 1,500 m (blue line), and 3,500 m (red line) HMS fires (triangles) and smoke (gray shading) on July 5 are also displayed. Image courtesy of EPA's AirNow-Tech.

Back trajectories ending in Las Vegas at 12:00 PST on July 6 are shown originating on July 4 (Figure 225). The HMS fire detections (red triangles) and smoke plumes (gray shading) correspond to July 5. Date and time stamps indicate air parcel positions along those trajectories. As shown in Figure 225, the back trajectories ending in Las Vegas at 12:00 PST on July 6 at 100 m AGL (green line) and at 1,500 m AGL (blue line), indicate a transport path within a smoke plume and passed nearby fires observed in Northwestern Mexico, Southern California, and Arizona. Additionally, the back trajectories at 3,500 m AGL show a transport path within a smoke plume over southern and central California.

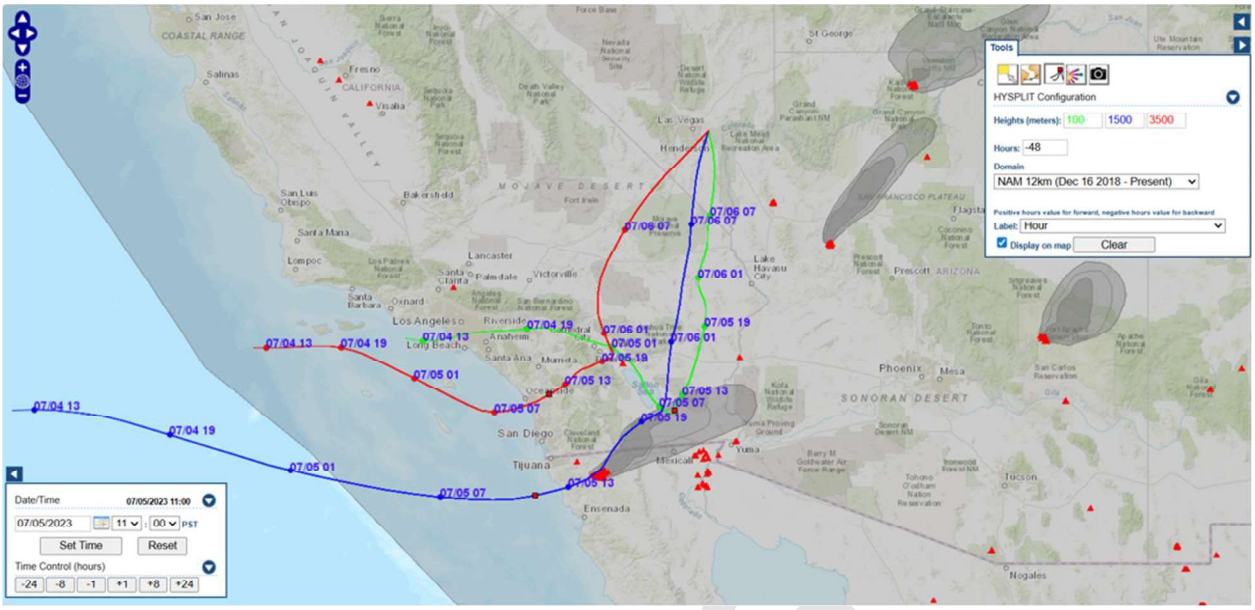

Figure 225. 48-hr back trajectory from the NAM model ending in Las Vegas on July 6, 2023, at 12:00 PST at 100 m (green line), 1,500 m (blue line), and 3,500 m (red line) HMS fires (triangles) and smoke (gray shading) on July 5 are also displayed. Image courtesy of EPA's AirNow-Tech.

Additional back trajectories at 100 m, 250 m, 500 m AGL (Figure 226) and at 50 m, 100 m, and 250 m AGL (Figure 227) were performed. The back trajectories ending in Las Vegas at 11:00 PST on July 6 are shown originating on July 4. The HMS fire detections (red triangles) and smoke plumes (gray shading) correspond to July 5. Date and time stamps indicate air parcel positions along those trajectories. As shown in Figure 226, the back trajectories ending in Las Vegas near the Joe Neal site at 11:00 PST on July 6 at 100 m AGL (green line) and at 250 m AGL (blue line) indicate a transport path within a smoke plume and passed nearby fires observed in northwestern Mexico, southern California, and Arizona. Additionally, the back trajectories at 500 m AGL (red line) show a transport path within a smoke plume over southern and central California. Back trajectories shown in Figure 227 ending in Las Vegas near the Joe Neal site at 11:00 PST on July 6 at 50 m AGL (green line), 100 m AGL (blue line), and 250 m AGL (red line) indicate a transport path within a smoke plume and passed nearby fires observed in northwestern Mexico, southern California, and Arizona.

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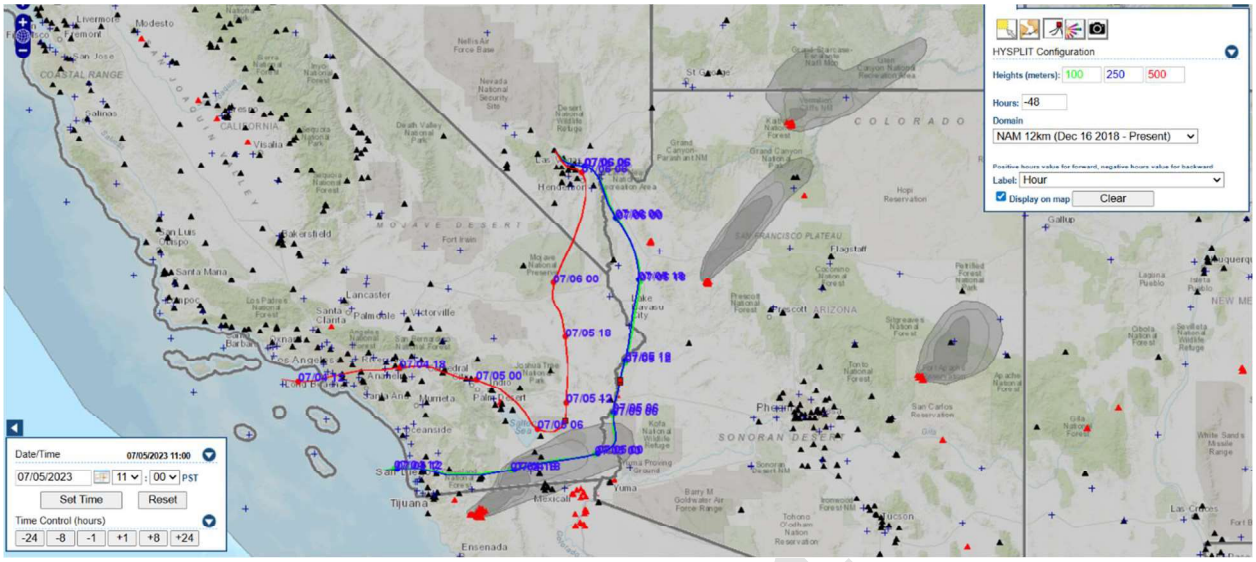

Figure 226. 36-hr back trajectory from the NAM model ending in Las Vegas on July 6, 2023, at 11:00 PST at 100 m (green line), 250 m (blue line), and 500 m (red line) HMS fires (triangles) and smoke (gray shading) on July 5 are also displayed. Image courtesy of EPA's AirNow-Tech.

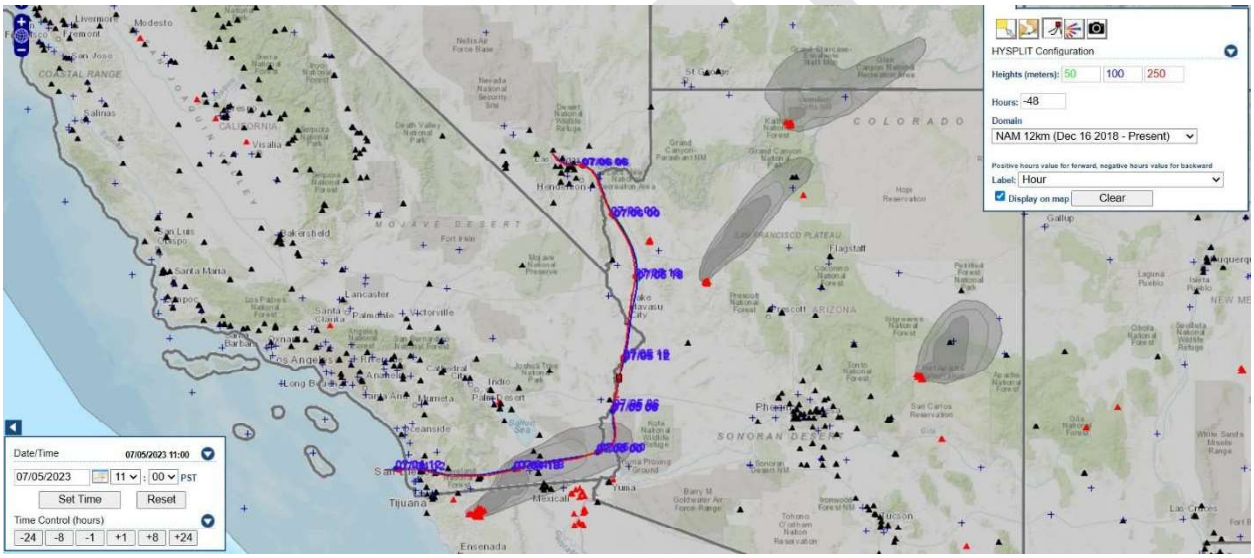

Figure 227. 48-hr back trajectory from the NAM model ending in Las Vegas on July 6, 2023, at 11:00 PST at 50 m (green line), 100 m (blue line), and 250 m (red line) HMS fires (triangles) and smoke (gray shading) on July 5 are also displayed. Image courtesy of EPA's AirNow-Tech.

Back trajectories ending in Las Vegas at 14:00 PST on July 7 are shown originating on July 6 (Figure 228). The HMS fire detections (red triangles) and smoke plumes (gray shading) correspond to the date of the trajectory origin. Date and time stamps indicate air parcel positions along those trajectories. As shown in Figure 228, the back trajectory ending in Las Vegas at 14:00 PST on July 7 at 100 m AGL (green line), indicates a transport path within a smoke plume and passed nearby fires observed in Northwestern Mexico and Arizona.

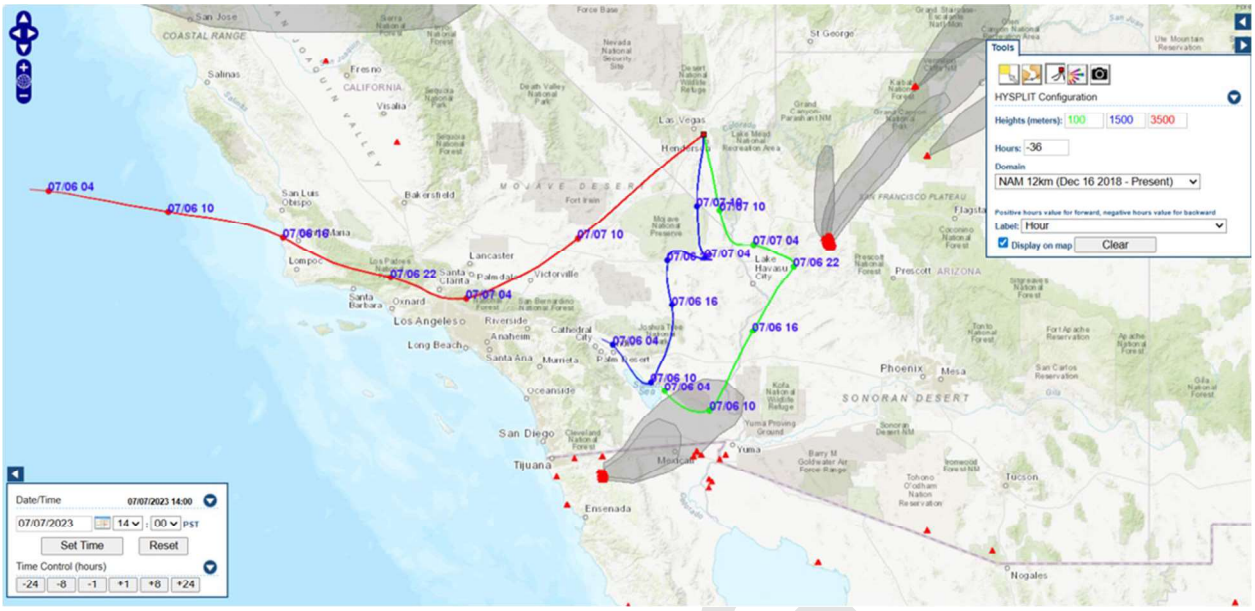

Figure 228. 36-hr back trajectory from the NAM model ending in Las Vegas on July 7, 2023, at 14:00 PST at 100 m (green line), 1,500 m (blue line), and 3,500 m (red line) HMS fires (triangles) and smoke (gray shading) on July 7 are also displayed. Image courtesy of EPA's AirNow-Tech.

Back trajectories ending in Las Vegas at 14:00 PST on July 8 are shown originating on July 7 (Figure 229). The HMS fire detections (red triangles) and smoke plumes (gray shading) correspond to the date of the trajectory origin. Date and time stamps indicate air parcel positions along those trajectories. As shown in Figure 229, the back trajectory ending in Las Vegas at 14:00 PST on July 8 at 100 m AGL (green line) and 1,500 m AGL (blue line), indicates a transport path within a smoke plume and passed nearby fires observed in Northwestern Mexico, Southern California and Arizona.

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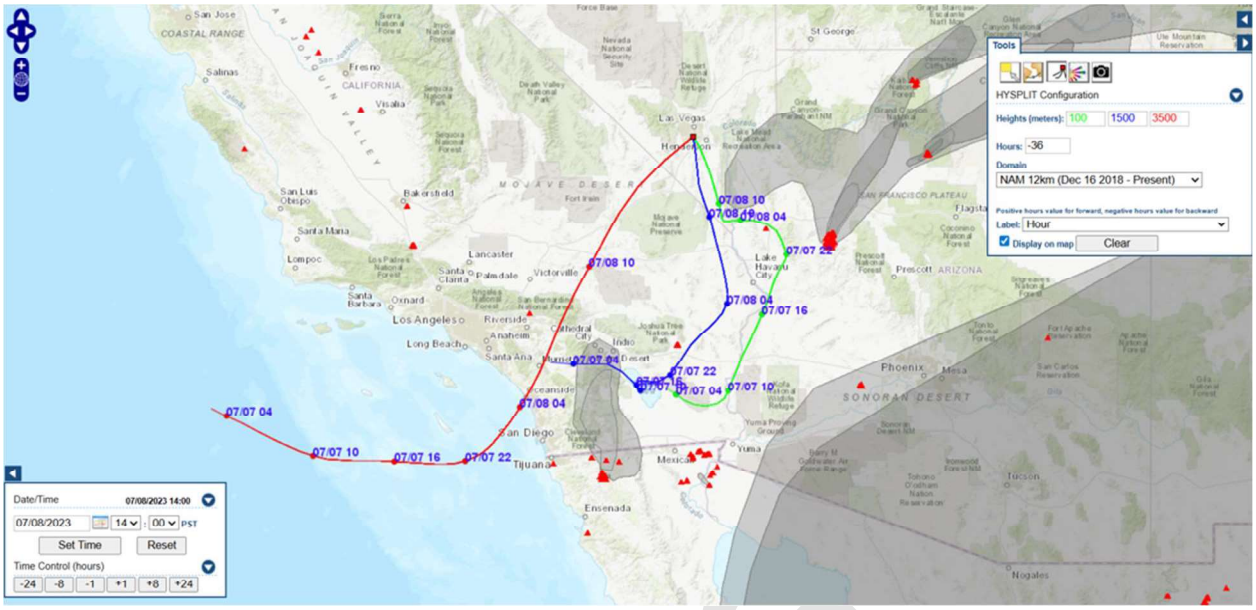

Figure 229. 36-hr back trajectory from the NAM model ending in Las Vegas on July 8, 2023, at 14:00 PST at 100 m (green line), 1,500 m (blue line), and 3,500 m (red line) HMS fires (triangles) and smoke (gray shading) on July 8 are also displayed. Image courtesy of EPA's AirNow-Tech.

Additional 48-hour back trajectories at 100 m, 250 m, 500 m AGL (Figure 230) were performed. The back trajectories ending in Las Vegas at 14:00 PST on July 8 are shown originating on July 6. The HMS fire detections (red triangles) and smoke plumes (gray shading) correspond to July 7. Date and time stamps indicate air parcel positions along those trajectories. As shown in Figure 230, the back trajectories ending in Las Vegas near the Mountain's Edge site at 14:00 PST on July 8 at 100 m AGL (green line), 250 m AGL (blue line), and 500 m AGL (red line) indicate a transport path within a smoke plume and passed nearby fires observed in northwestern Mexico and Arizona.

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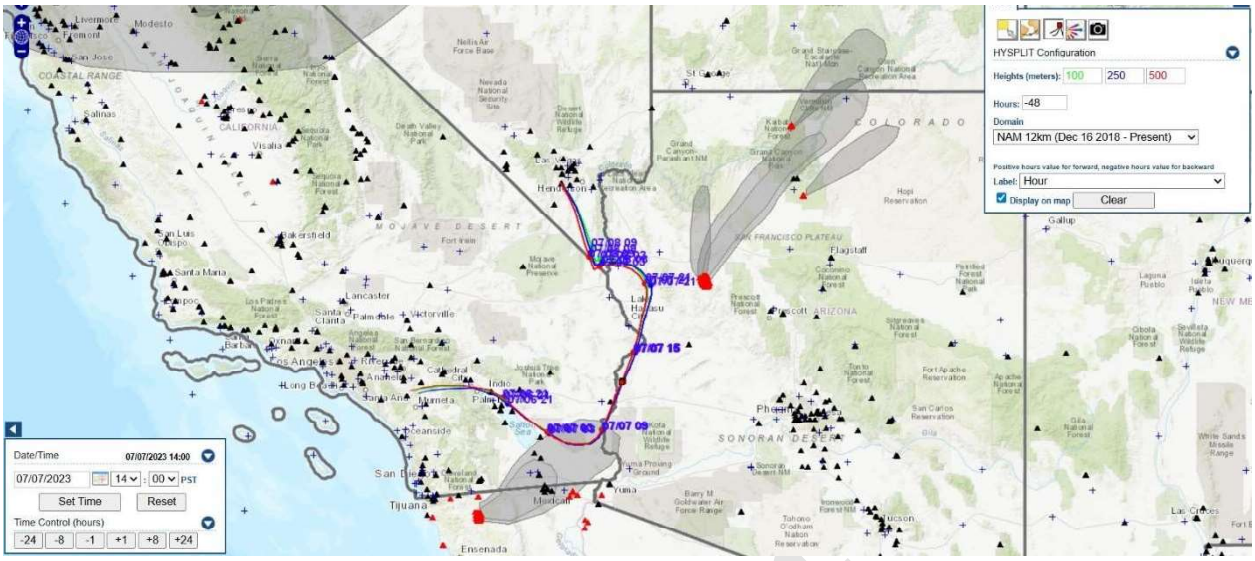

Figure 230. 48-hr back trajectory from the NAM model ending in Las Vegas on July 8, 2023, at 15:00 PST at 100 m (green line), 250 m (blue line), and 500 m (red line) HMS fires (triangles) and smoke (gray shading) on July 7 are also displayed. Image courtesy of EPA's AirNow-Tech.

A 42-hour forward trajectory originating from the northwestern Mexico fires at 03:00 PST on July 5 and arriving in the Las Vegas Valley at 14:00 PST on July 6 (Figure 231). The HMS fire detections (red triangles) and smoke plumes (gray shading) correspond to the date of the trajectory origin. Date and time stamps indicate air parcel positions along those trajectories. As shown in Figure 231, the forward trajectory arrives in Las Vegas near the southern sites of Green Valley, Liberty High, and Mountain's Edge at 14:00 PST on July 6 at 100 m AGL (green line), indicates a transport path originating at the northwestern Mexico fires, transports through the heavy smoke plumes observed in northwestern Mexico and Southern California. Additionally, the forward trajectory at 5,000 m AGL shows a transport path within a smoke plume over southern and central California and passes through the southern tip of Clark County, Nevada. The 500 m AGL shows a transport path within a smoke plume over southern California and through western Arizona.

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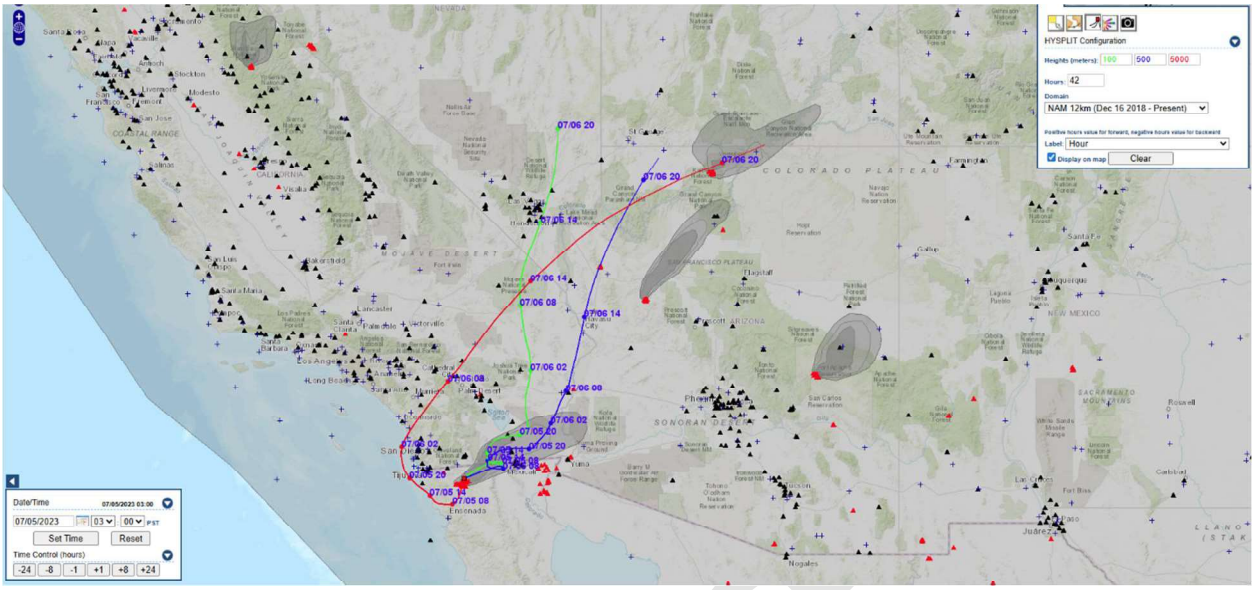

Figure 231. 42-hr forward trajectory from the NAM model arriving in Las Vegas on July 6, 2023, at 14:00 PST at 100 m (green line), 500 m (blue line) and 5,000 m (red line) AGL, HMS fires (triangles), and smoke (gray shading) on are also displayed. Image courtesy of EPA's AirNow-Tech.

A 42-hour forward trajectory originating from the northwestern Mexico fires at 03:00 PST on July 7 and arriving in the southeast Clark County at 14:00 PST on July 8 (Figure 232). The HMS fire detections (red triangles) and smoke plumes (gray shading) correspond to the date of the trajectory origin. Date and time stamps indicate air parcel positions along those trajectories. As shown in Figure 232, the forward trajectory arrives in southeast Clark County at 14:00 PST on July 6 at 1000 m AGL (green line), indicates a transport path originating at the northwestern Mexico fires, transports through the heavy smoke plumes observed in northwestern Mexico and Southern California. The forward trajectory at 100m AGL shows a transport path within a smoke plume over northwestern Mexico and stays within northwestern Mexico. The 6,000 m AGL shows a transport path within a smoke plume over southern California and through fires in western Arizona.

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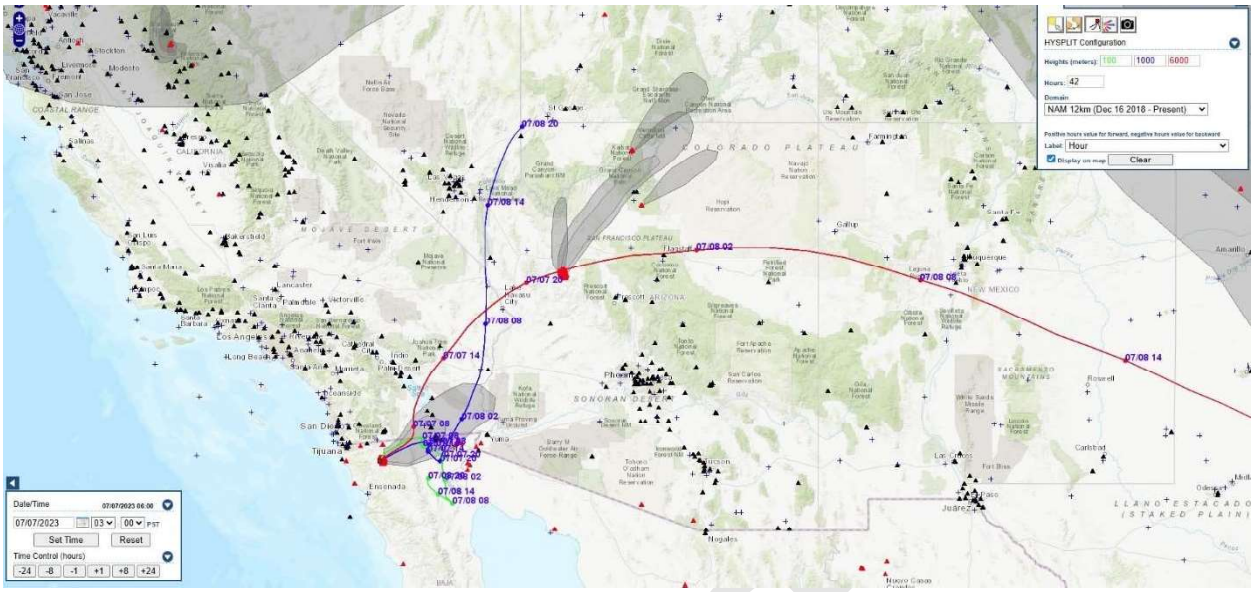

Figure 232. 42-hr forward trajectory from the NAM model arriving in southeast Clark County on July 8, 2023, at 14:00 PST at 1,000 m (blue line) AGL. 100 m (green line) and 6,000 m (red line) AGL, HMS fires (triangles), and smoke (gray shading) on are also displayed. Image courtesy of EPA's AirNow-Tech.

To assess the potential for smoke transport from the northwestern Mexico fire location, HYSPLIT dispersion modeling was performed from July 5 through July 8, 2023. Dispersion was initiated on July 5 at 08:00 UTC from the northwestern Mexico fires and modeled through the exclusion dates to simulate smoke transport. NAM 12 km was used for meteorological input. Output from the dispersion model is aggregated in 6-hr increments starting on July 5 at 20:00 UTC through July 8 at 20:00 UTC. This time period was chosen to correspond with the period of enhanced ozone measured in Clark County, NV. The accumulation of smoke in the boundary layer at 0-3,500 m is shown in Figure 233. The HYSPLIT dispersion modeling shows that smoke from the fires expanded over Clark County, NV from July 6 to July 8, 2023.

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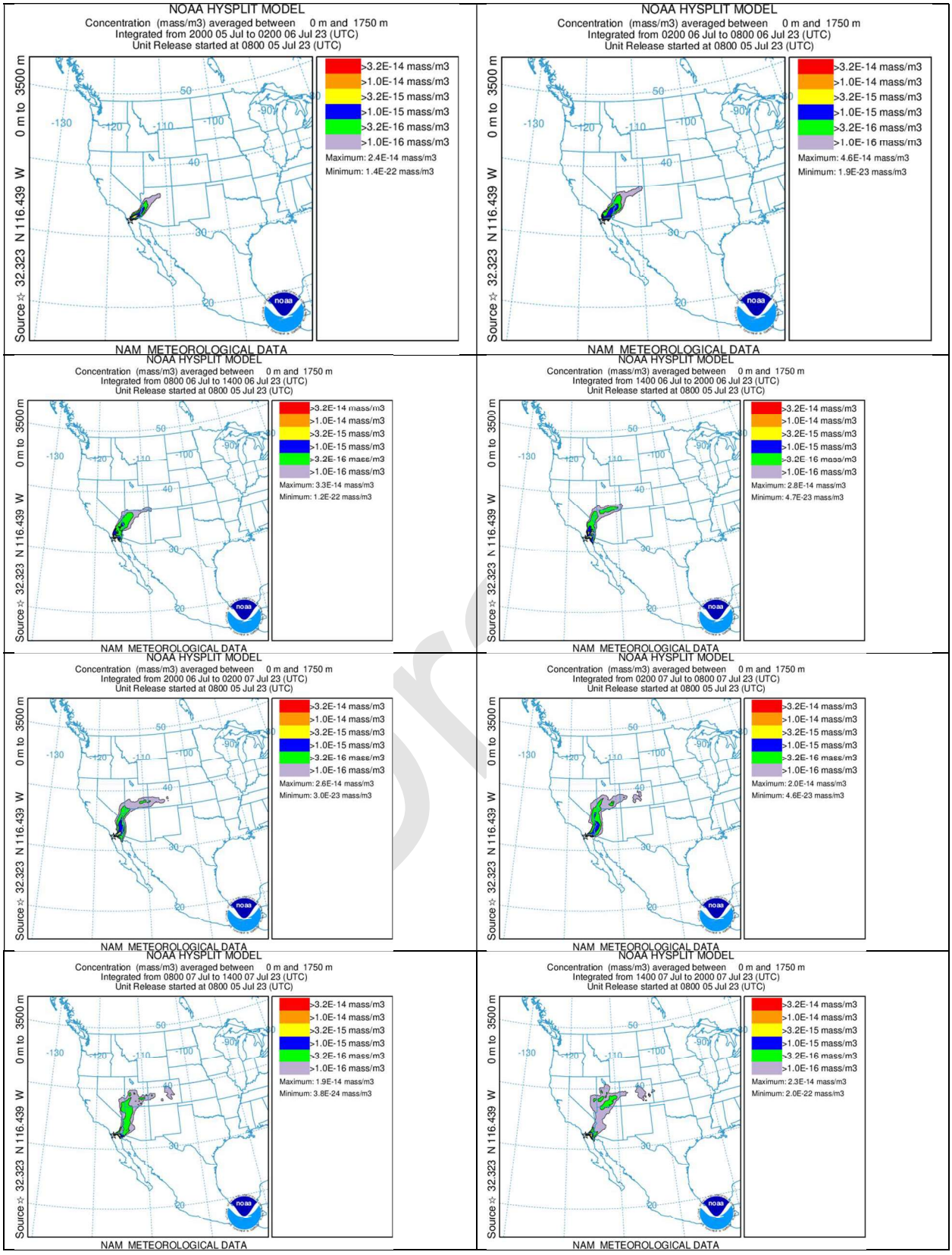
NOAA HYSPLIT MODEL
Concentration (mass/m3) averaged between 0 m and 1750 m
Integrated from 2000 05 Jul to 0200 06 Jul 23 (UTC)
Unit Release started at 0800 05 Jul 23 (UTC)
>3.2E-14 mass/m3
>1.0E-14 mass/m3
>3.2E-15 mass/m3
>1.0E-15 mass/m3
>3.2E-16 mass/m3
>1.0E-16 mass/m3
Maximum: 2.4E-14 mass/m3
Minimum: 1.4E-22 mass/m3
Source ☆ 32.323 N 116.439 W 0 m to 3500 m
NAM METEOROLOGICAL DATA
NOAA HYSPLIT MODEL
Concentration (mass/m3) averaged between 0 m and 1750 m
Integrated from 0200 06 Jul to 0800 06 Jul 23 (UTC)
Unit Release started at 0800 05 Jul 23 (UTC)
Maximum: 4.6E-14 mass/m3
Minimum: 1.9E-23 mass/m3
NAM METEOROLOGICAL DATA
NOAA HYSPLIT MODEL
Concentration (mass/m3) averaged between 0 m and 1750 m
Integrated from 0800 06 Jul to 1400 06 Jul 23 (UTC)
Unit Release started at 0800 05 Jul 23 (UTC)
Maximum: 3.3E-14 mass/m3
Minimum: 1.2E-22 mass/m3
NAM METEOROLOGICAL DATA
NOAA HYSPLIT MODEL
Concentration (mass/m3) averaged between 0 m and 1750 m
Integrated from 1400 06 Jul to 2000 06 Jul 23 (UTC)
Unit Release started at 0800 05 Jul 23 (UTC)
Maximum: 2.8E-14 mass/m3
Minimum: 4.7E-23 mass/m3
NAM METEOROLOGICAL DATA
NOAA HYSPLIT MODEL
Concentration (mass/m3) averaged between 0 m and 1750 m
Integrated from 2000 06 Jul to 0200 07 Jul 23 (UTC)
Unit Release started at 0800 05 Jul 23 (UTC)
Maximum: 2.6E-14 mass/m3
Minimum: 3.0E-23 mass/m3
NAM METEOROLOGICAL DATA
NOAA HYSPLIT MODEL
Concentration (mass/m3) averaged between 0 m and 1750 m
Integrated from 0200 07 Jul to 0800 07 Jul 23 (UTC)
Unit Release started at 0800 05 Jul 23 (UTC)
Maximum: 2.0E-14 mass/m3
Minimum: 4.6E-23 mass/m3
NAM METEOROLOGICAL DATA
NOAA HYSPLIT MODEL
Concentration (mass/m3) averaged between 0 m and 1750 m
Integrated from 0800 07 Jul to 1400 07 Jul 23 (UTC)
Unit Release started at 0800 05 Jul 23 (UTC)
Maximum: 1.9E-14 mass/m3
Minimum: 3.8E-24 mass/m3
NAM METEOROLOGICAL DATA
NOAA HYSPLIT MODEL
Concentration (mass/m3) averaged between 0 m and 1750 m
Integrated from 1400 07 Jul to 2000 07 Jul 23 (UTC)
Unit Release started at 0800 05 Jul 23 (UTC)
Maximum: 2.3E-14 mass/m3
Minimum: 2.0E-22 mass/m3
NAM METEOROLOGICAL DATA

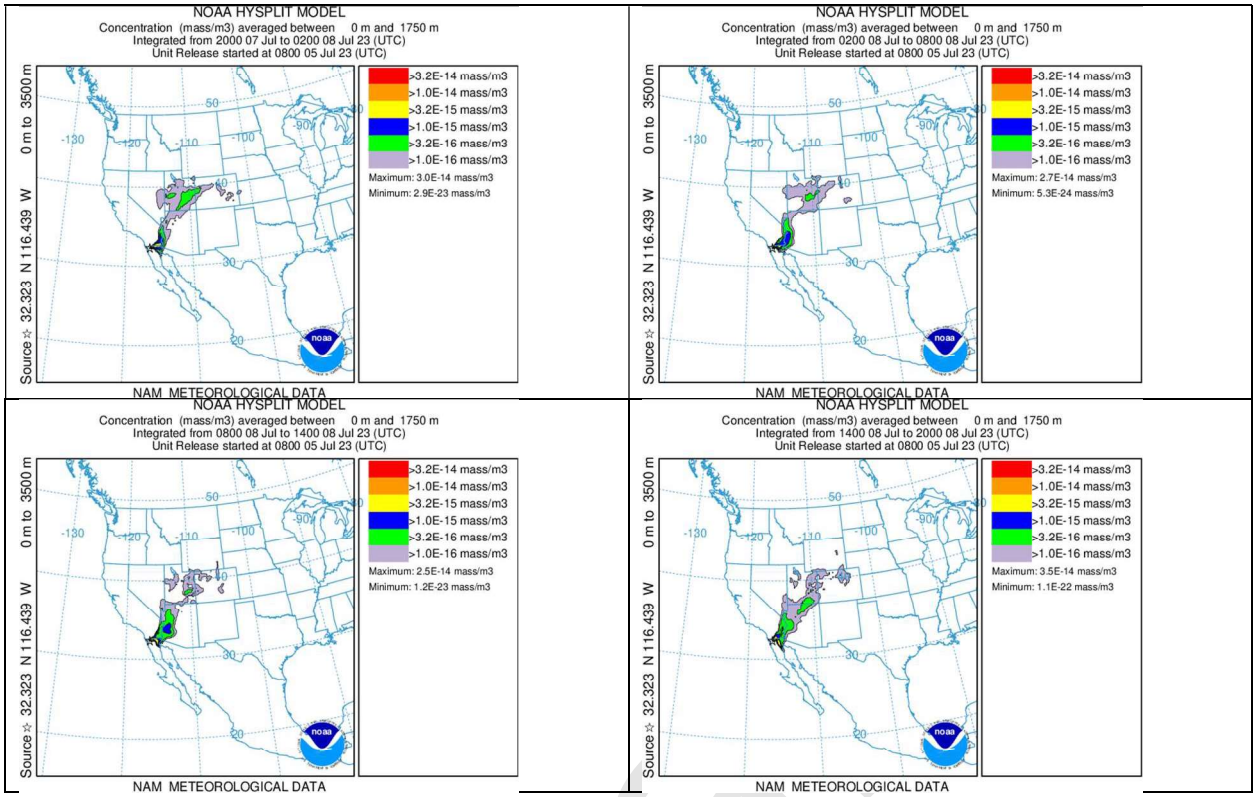

Figure 233. HYSPLIT dispersion modeling for the northwestern Mexico fires on or before the exclusion dates of July 5-8, 2023. NAM 12km meteorological data was used, and dispersion was initiated on July 5 at 08:00 UTC to model the regional smoke transport.

These trajectories and dispersion models provide evidence of direct smoke transport into the Clark County region during the July 5-8 exclusion days from multiple fires and smoke plumes.

6.4 Impacts at the Surface

Figure 234 through Figure 238 compare visibility conditions in the Las Vegas Valley before and during the exclusion dates. Figure 234 shows visibility conditions on July 4, 2023, at 12:00 PST, the day before the event. The images on July 4 show clearer visibility compared to the brown-tinted skies in the NW, N, and NE images on July 5-8. This is consistent with a well-mixed boundary layer with smoke. In Figure 234 through Figure 238, La Madre Mountain is on the top left, the Sheep Mountain Ranges is on the top right and Frenchman Mountain is on the bottom left. The mountain ranges are less visible on the exclusion days of July 5-8 than on July 4. The brown-tinted haze throughout the column, shown in the July 5-8 images compared to the July 4 images, is consistent with the narrative that smoke from the fires entered the Las Vegas area on July 5 and remained through July 8 and was well mixed in the column.

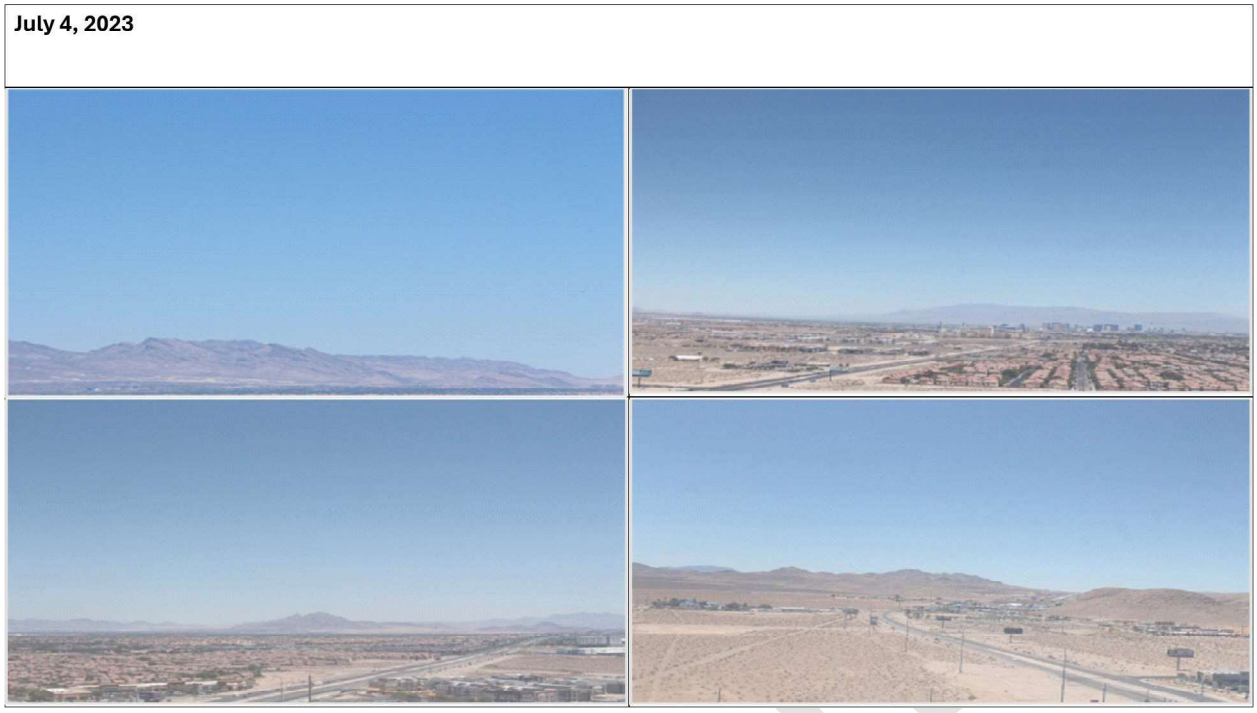

Figure 234. Camera images showing the NW (top left), N (top right), NE (bottom left), SSW (bottom right) coordinal directions, taken from the M Resort Hotel in Clark County, NV on July 4, 2023, at 13:15 PST.

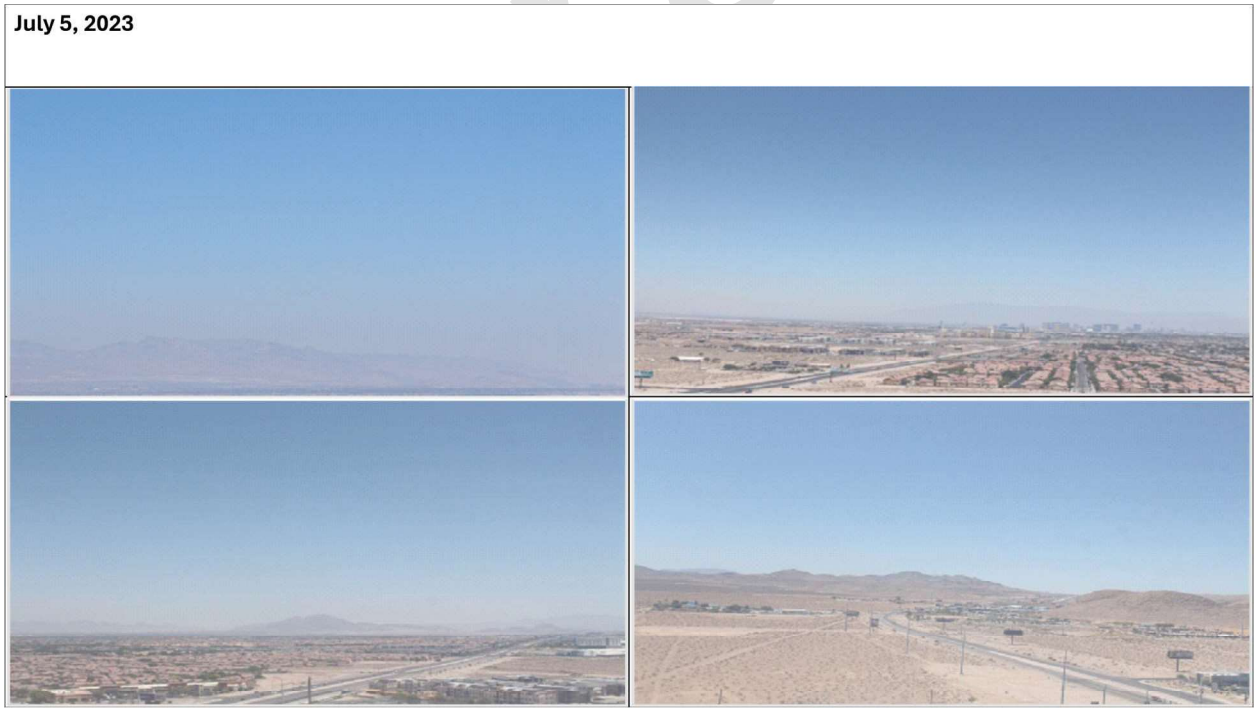

Figure 235. Camera images showing the NW (top left), N (top right), NE (bottom left), SSW (bottom right) coordinal directions, taken from the M Resort Hotel in Clark County, NV on July 5, 2023, at 15:30 PST.

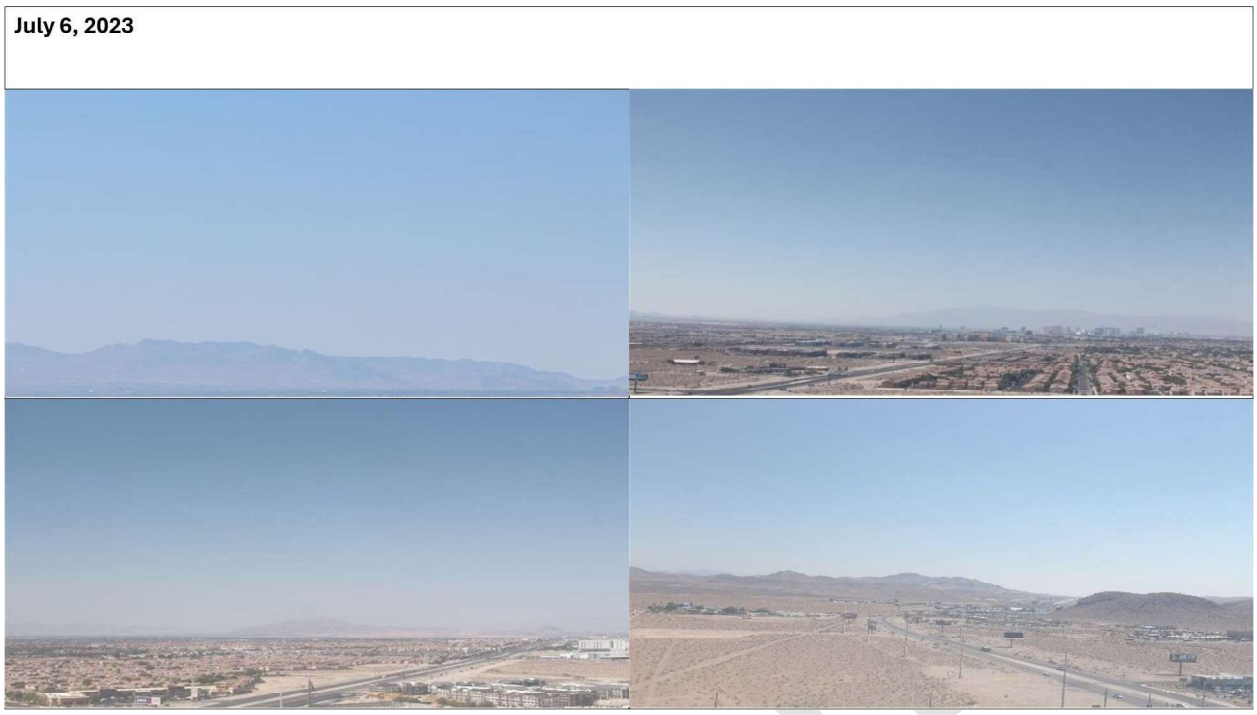

Figure 236. Camera images showing the NW (top left), N (top right), NE (bottom left), SSW (bottom right) coordinal directions, taken from the M Resort Hotel in Clark County, NV on July 6, 2023, at 15:00 PST.

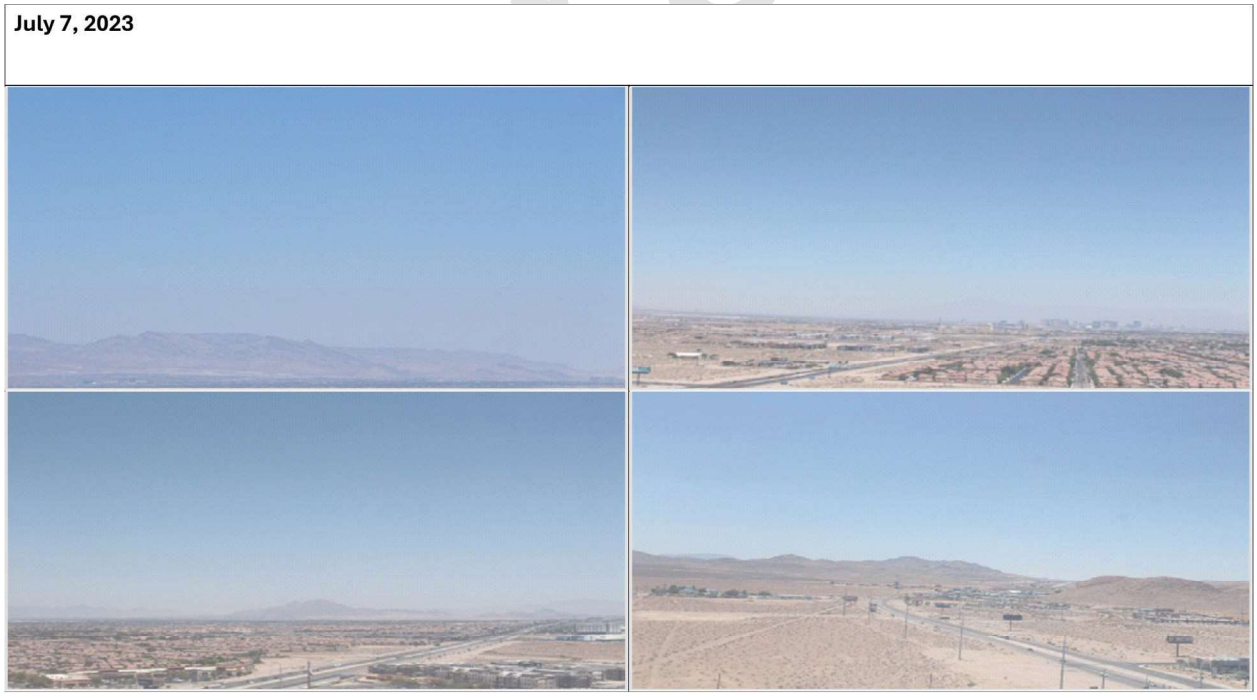

Figure 237. Camera images showing the NW (top left), N (top right), NE (bottom left), SSW (bottom right) coordinal directions, taken from the M Resort Hotel in Clark County, NV on July 7, 2023, at 11:45 PST.

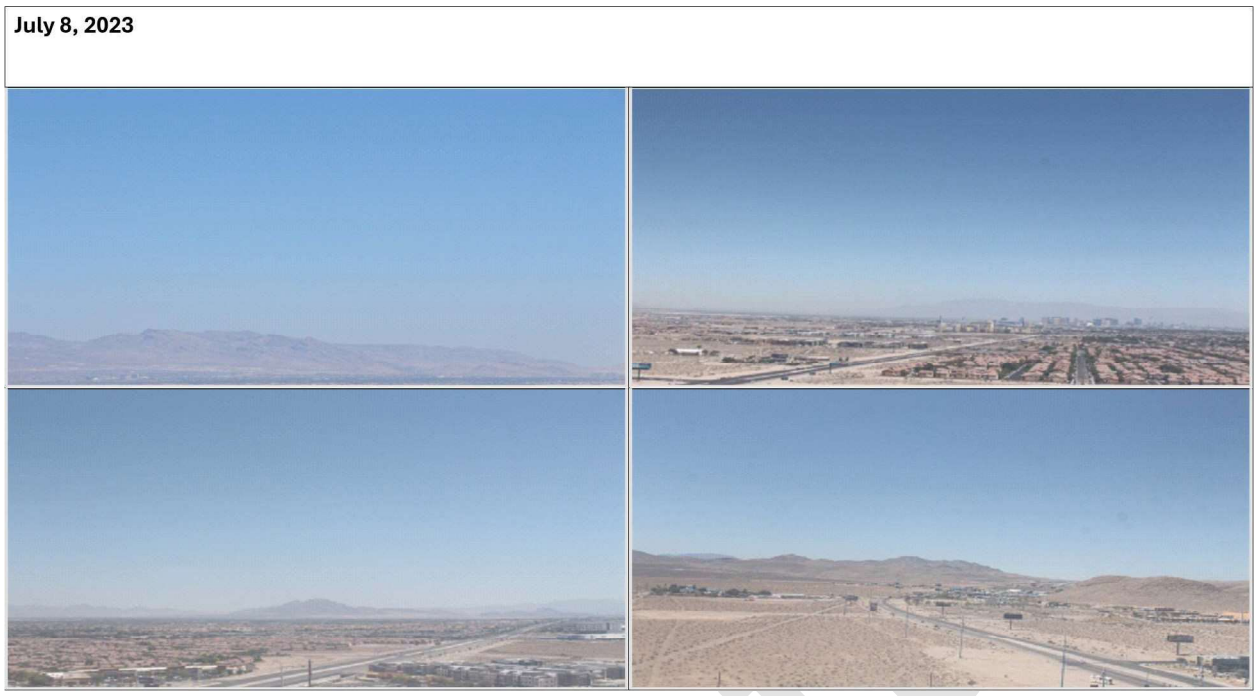

Figure 238. Camera images showing the NW (top left), N (top right), NE (bottom left), SSW (bottom right) coordinal directions, taken from the M Resort Hotel in Clark County, NV on July 8, 2023, at 10:15 PST.

Meteorologists at the National Weather Service (NWS) Las Vegas office observed a smoke plume originating from northern Baja Mexico moving into the region overnight on July 5. The 09:08 PDT NWS forecast discussion is shown in (Figure 239).

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026
FXUS65 KVEF 061608 AAA
AFDVEF

Area Forecast Discussion
National Weather Service Las Vegas NV
908 AM PDT Thu Jul 6 2023

.SYNOPSIS...Hot July afternoons and elevated breezes in the
afternoon and evenings can be expected through the weekend. The
hot and dry conditions will be favorable for enhanced fire danger,
especially in northwest Arizona. A warming trend is expected next
week with some signs of increasing moisture for the Desert
Southwest but confidence is very low for any potential for
precipitation at this point.

&&

.UPDATE...Only item of note this morning is a smoke plume moving
north across eastern Clark County, Lake Mead National Rec area.
Plume originated from northern Baja Mexico yesterday which drifted
north across eastern San Bernardino County overnight. Otherwise, no
updated needed this morning with seasonable temperatures and dry
conditions. South-southwest winds will increase this afternoon
leading to critical fire conditions in northwest Arizona due to dry
fuels, low RH and the wind. Similar conditions will exist Friday
with our Red Flag Warning going through Friday evening.
&&
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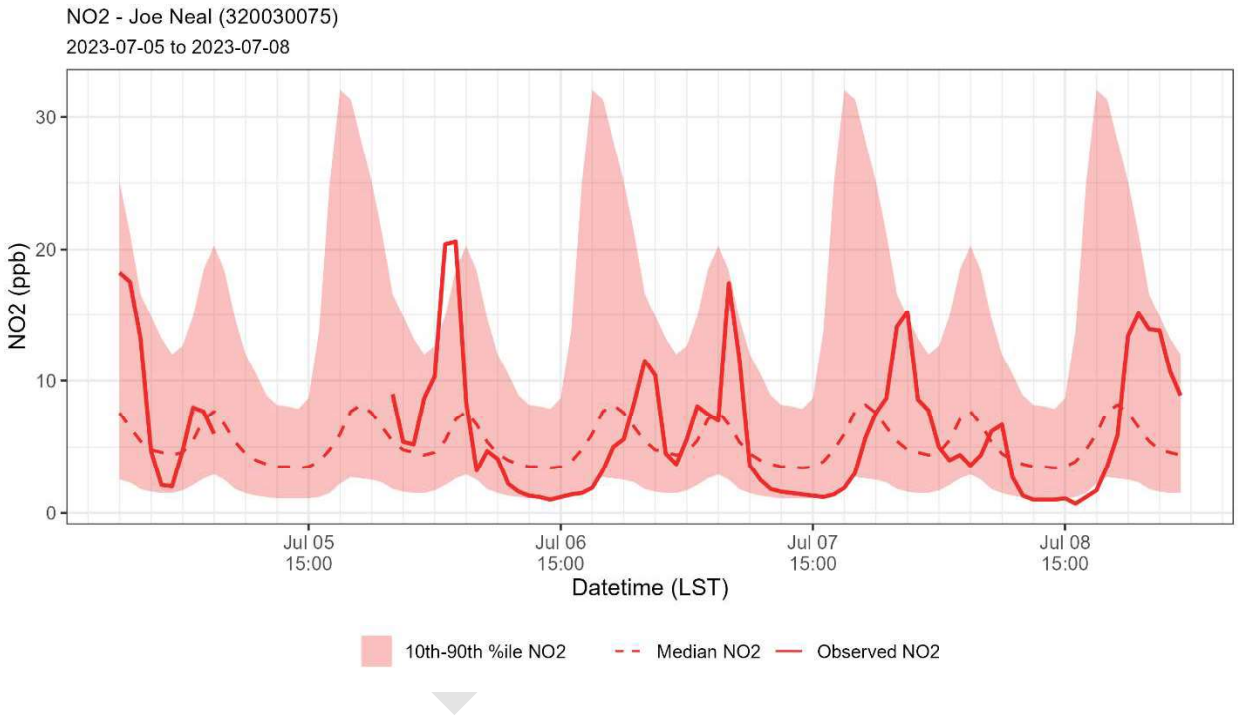
Figure 239. Area forecast discussion valid at 09:08 PDT on July 6, 2023. Meteorologists at the National Weather Service Las Vegas observed a smoke plume moving across the region.

$PM_{2.5}$, CO, and NO_2 concentrations were enhanced in Clark County from July 5-8 as smoke from northwestern Mexico entered the region and mixed towards the surface, providing further evidence that wildfire smoke was present as an atypical influence on ozone during the exclusion period.

NO_2 concentrations in Clark County showed elevated levels during the period of July 5-8, 2023, indicative of ozone precursor transport to the region. Figure 240 shows hourly NO_2 concentrations at Walnut Community Center alongside the multiyear seasonal 10th to 90th percentile range of diurnal concentration. NO_2 concentrations exhibited a pronounced diurnal pattern with peak concentrations occurring during overnight and early morning hours (approximately 21:00 to 06:00 PST) each day. These peak concentrations were substantially above the multiyear seasonal median, with multiple

exceedances of the 90th percentile threshold. Notably, on July 5 at approximately 06:00 PST, July 6 at approximately 06:00 PST, and July 7 at approximately 06:00 PST, concentrations were at or exceeded 35 ppb, well above the 90th percentile range. Similar patterns were observed at Jerome Mack and Joe Neal monitoring sites, where NO_2 concentrations peaked during early morning hours on July 7 and July 8, with concentrations at Jerome Mack reaching approximately 32 ppb nearing the 90th percentile on July 7 at approximately 06:00 PST and 27 ppb exceeding the 6-year seasonal median on July 8 at 06:00 PST. There was no data for NO_2 at Jerome Mack on July 5-6 until 08:00 PST. At Joe Neal, NO_2 concentrations showed peaks on July 5-6 and July 7-8, with maximum concentrations reaching approximately 20 ppb which neared the 90th percentile during those hours and exceeded the multiyear average median.



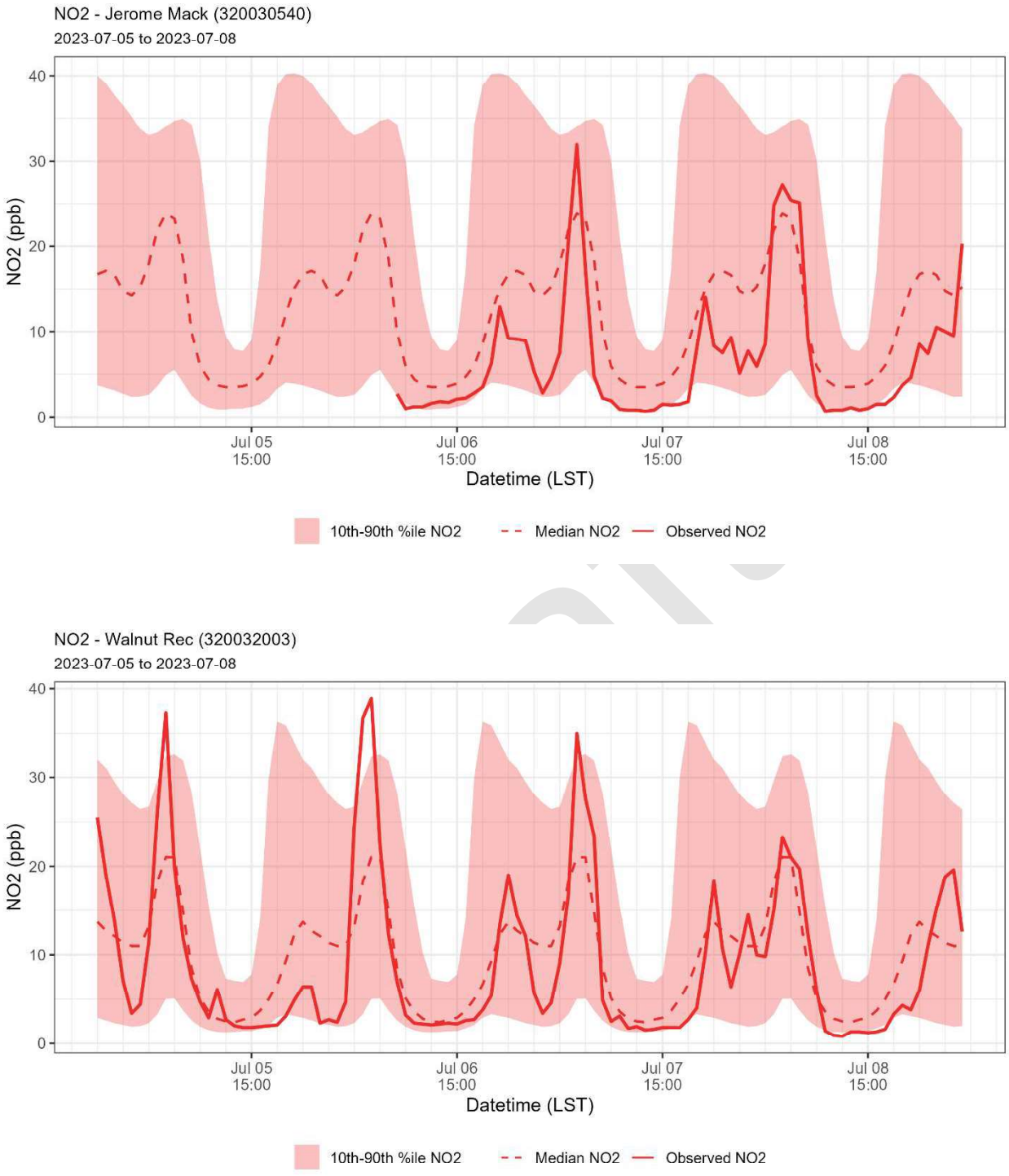
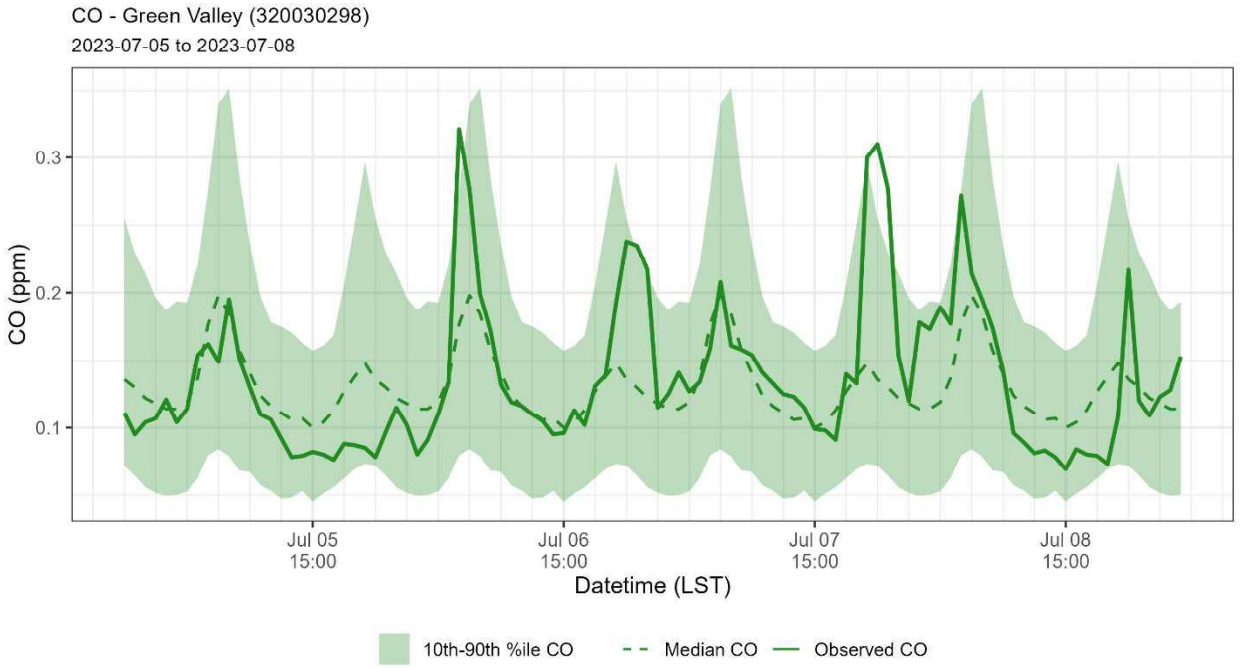


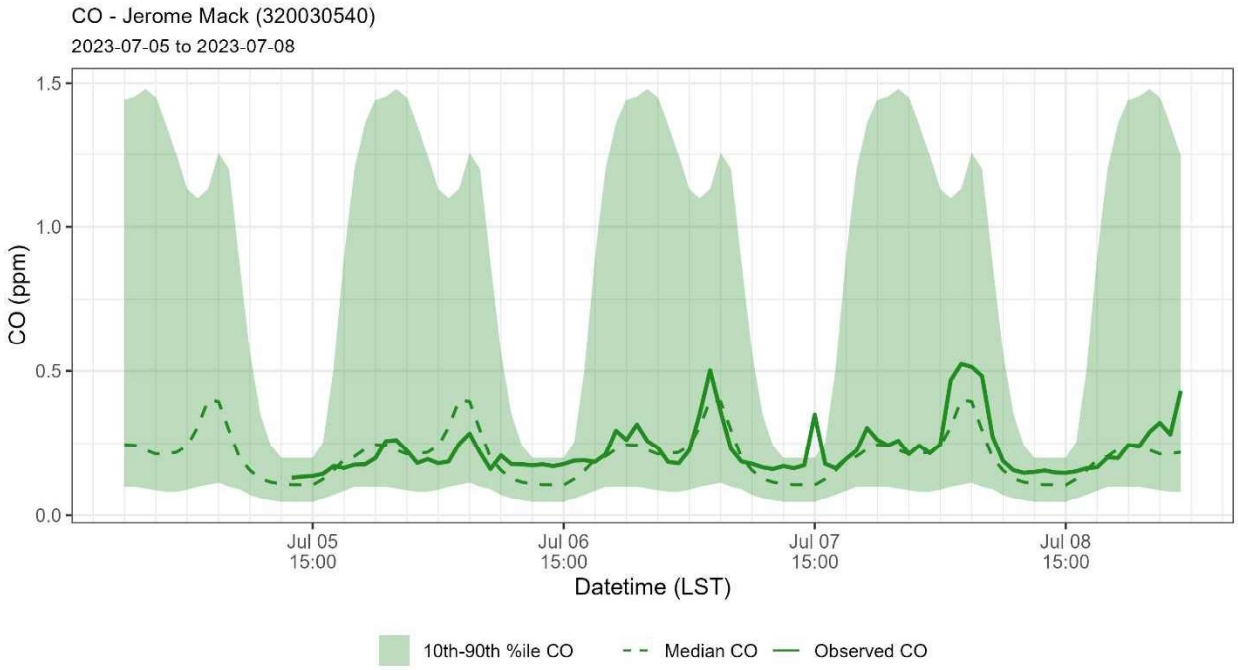
Figure 240. Hourly NO_2 measurements overlaid on the 10th to 90th percentile diurnal concentration at Joe Neal (AQS site code 320030075), Jerome Mack (AQS site code 320030540), and Walnut Recreation (AQS side code 320032003). The 10th to 90th percentile concentration is calculated across the ozone production season (April-September) for 2018-2023. Note: Walnut Recreation only includes data from June 1,2021 and onwards.

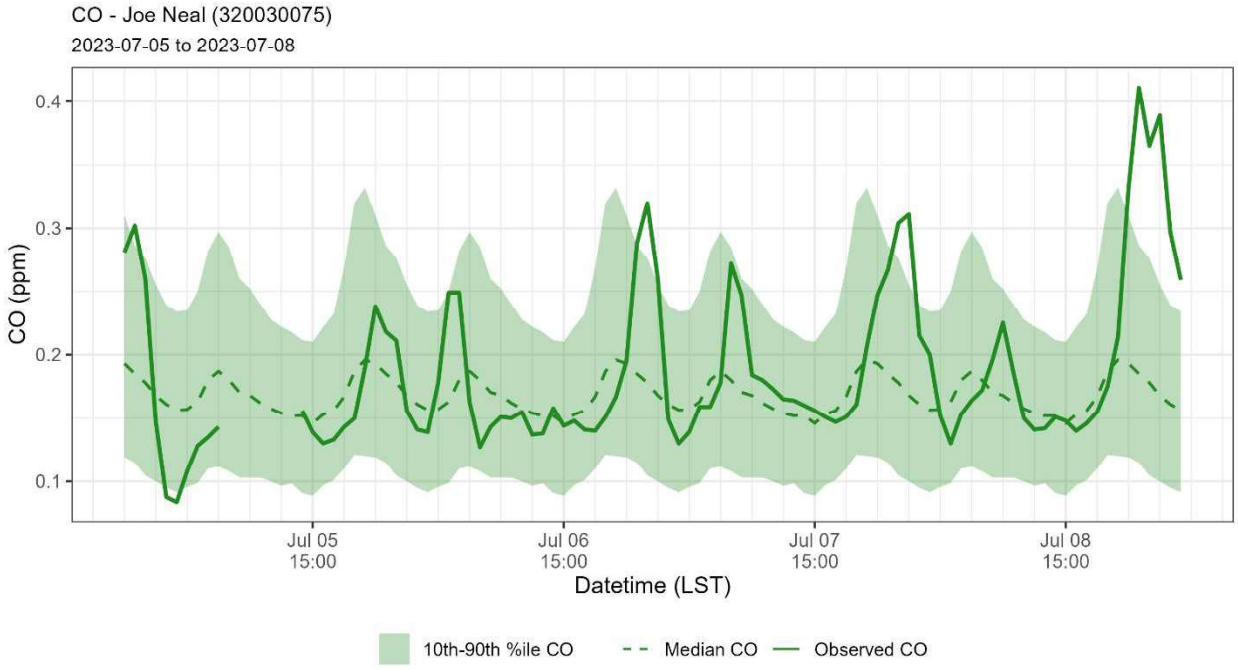
Figure 241 shows hourly CO concentrations at Paul Meyer, Joe Neal, Green Valley, Jerome Mack, and Walnut Recreation for July 5-8 plotted with the seasonal 10th to 90th percentile range of diurnal concentration. Paul Meyer's data collection was from May 2022 through September 2023, Joe Neal's was from June 2019 through September 2023, Green Valley's was from June 2020 through September 2023, and Walnut Rec's data collection started June 2021. CO concentrations followed a typical diurnal pattern, with peak concentrations during the late night and early morning (00:00 to 06:00 PST) that were elevated above the median and at or slightly below the 90th percentile at Paul Meyer, Joe Neal, and Green Valley. Enhanced CO concentrations are indicative of the presence of smoke.

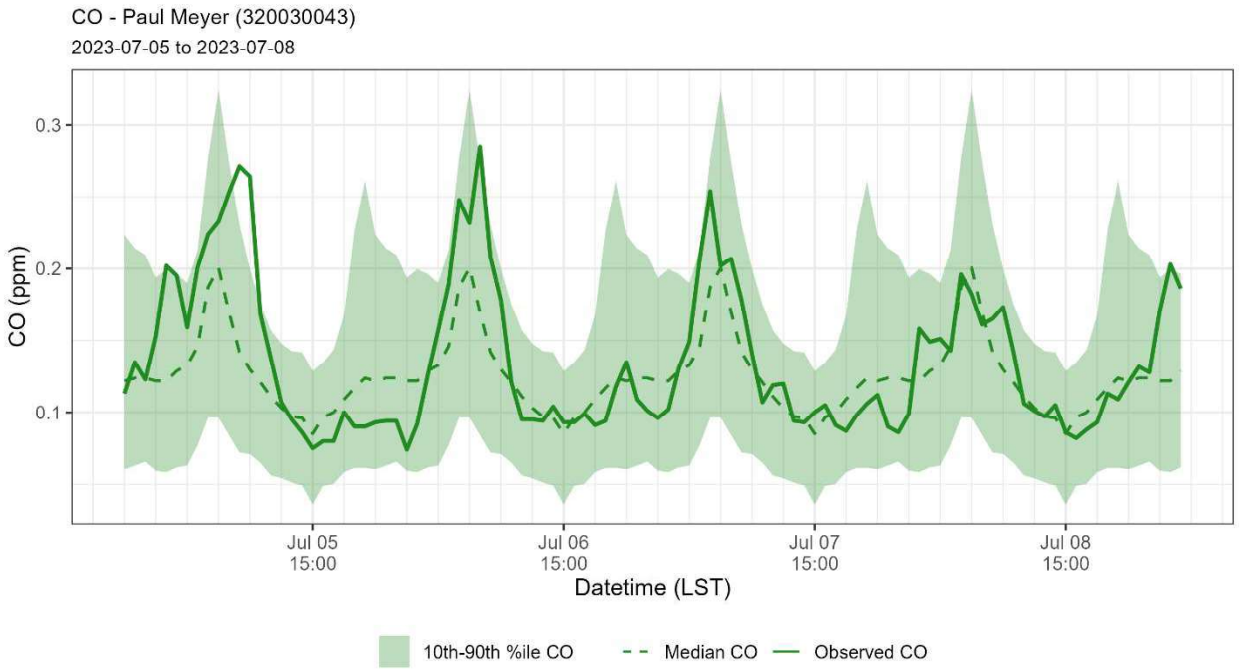
At Jerome Mack, CO concentrations showed the highest concentrations, with notable peaks on July 7 and July 8 at approximately 05:00 PST reaching 0.5 ppm. Joe Neal saw elevated CO concentrations during late night and early mornings where CO peaked during early morning hours on July 8, with concentrations reaching approximately 0.4 ppb and substantially exceeding the 90th percentile. At Walnut Rec, CO concentrations remained near or below the median through July 6, but showed an increase on July 7-8, with maximum concentrations reaching approximately 0.4 ppb on July 8 at 21:00 PST.

Paul Meyer and Green Valley sites exhibited more moderate CO levels, with Paul Meyer showing regular diurnal cycling and peak concentrations of approximately 0.25-0.28 ppm on July 5, July 6, and July 7, which are above the median and close to the 90th percentile. Green Valley displayed several distinct concentration peaks reaching 0.3 ppb on July 6 and July 8, with observed values frequently exceeding the median. Enhanced CO concentrations are indicative of the presence of smoke.




CO - Jerome Mack (320030540)
2023-07-05 to 2023-07-08
CO (ppm)
1.5
1.0
0.5
0.0
Jul 05
15:00
Jul 06
15:00
Jul 07
15:00
Jul 08
15:00
Datetime (LST)
10th-90th %ile CO
Median CO
Observed CO


CO - Joe Neal (320030075)
2023-07-05 to 2023-07-08
CO (ppm)
0.4
0.3
0.2
0.1
Jul 05
15:00
Jul 06
15:00
Jul 07
15:00
Jul 08
15:00
Datetime (LST)
10th-90th %ile CO
Median CO
Observed CO


CO - Paul Meyer (320030043)
2023-07-05 to 2023-07-08
CO (ppm)
0.3
0.2
0.1
Jul 05
15:00
Jul 06
15:00
Jul 07
15:00
Jul 08
15:00
Datetime (LST)
10th-90th %ile CO
Median CO
Observed CO

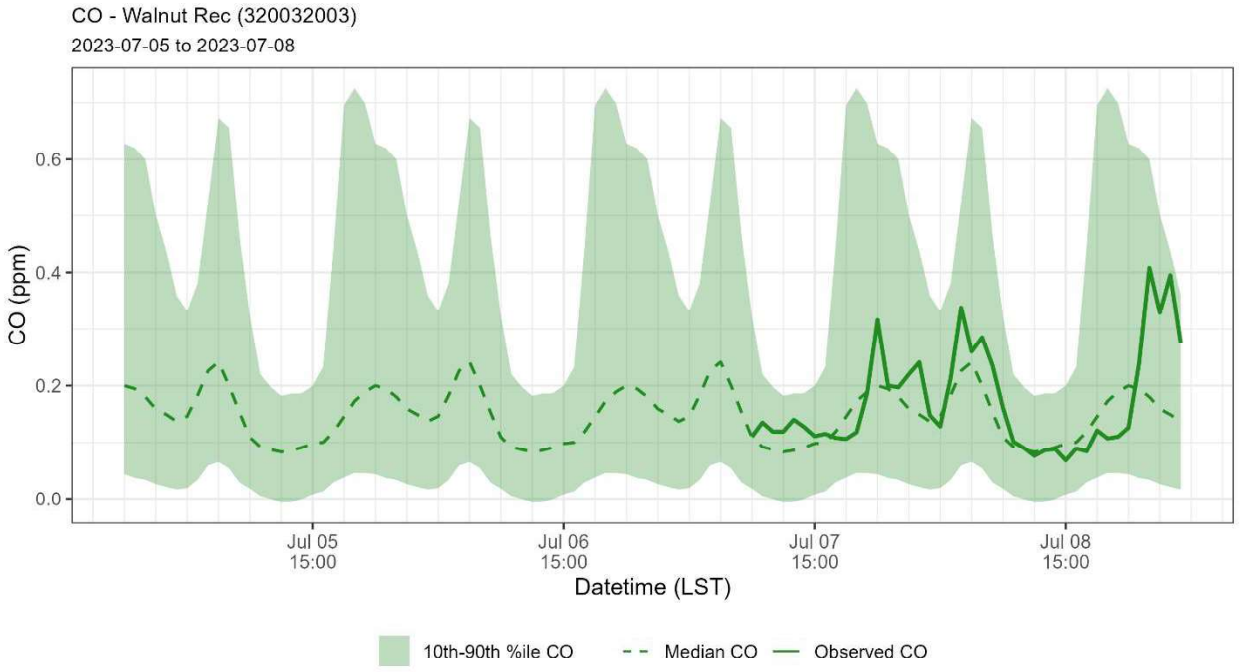
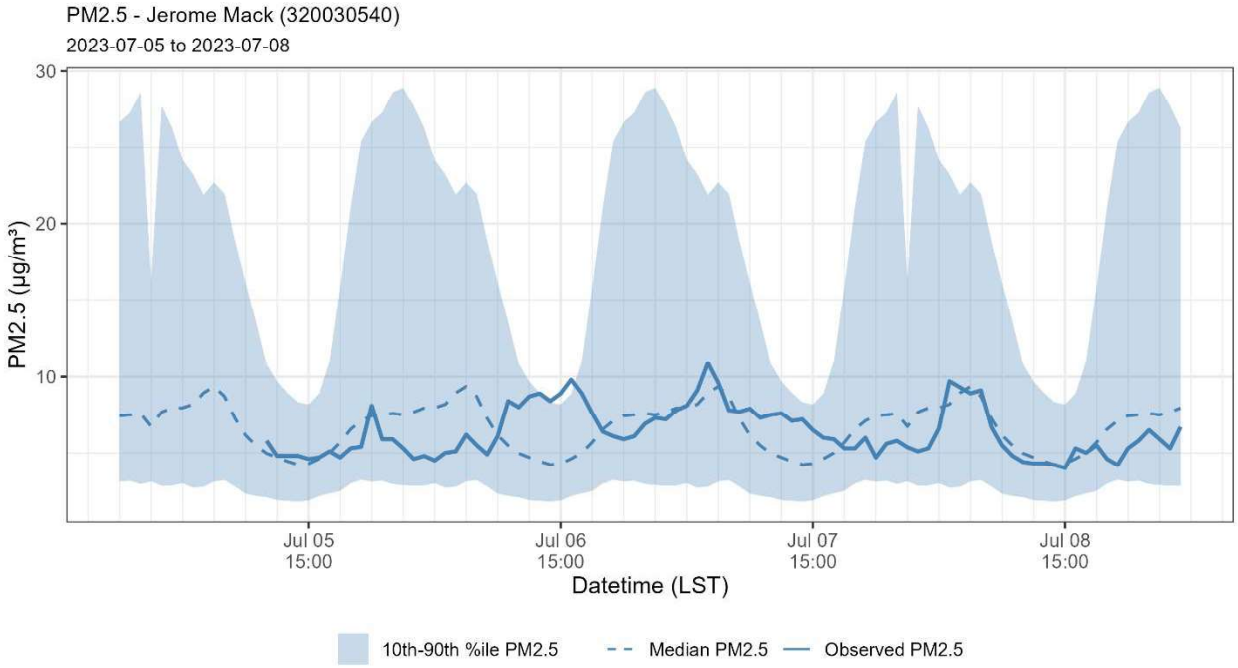
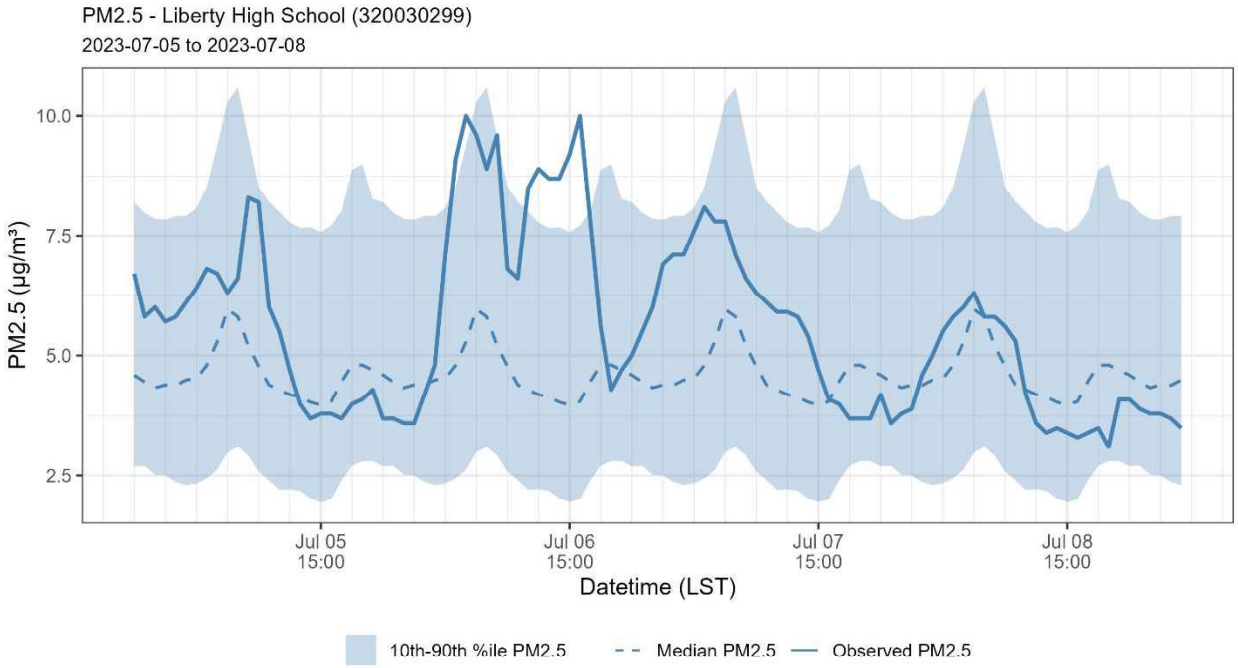

CO - Walnut Rec (320032003)
2023-07-05 to 2023-07-08
CO (ppm)
0.6
0.4
0.2
0.0
Jul 05
15:00
Jul 06
15:00
Jul 07
15:00
Jul 08
15:00
Datetime (LST)
10th-90th %ile CO
Median CO
Observed CO

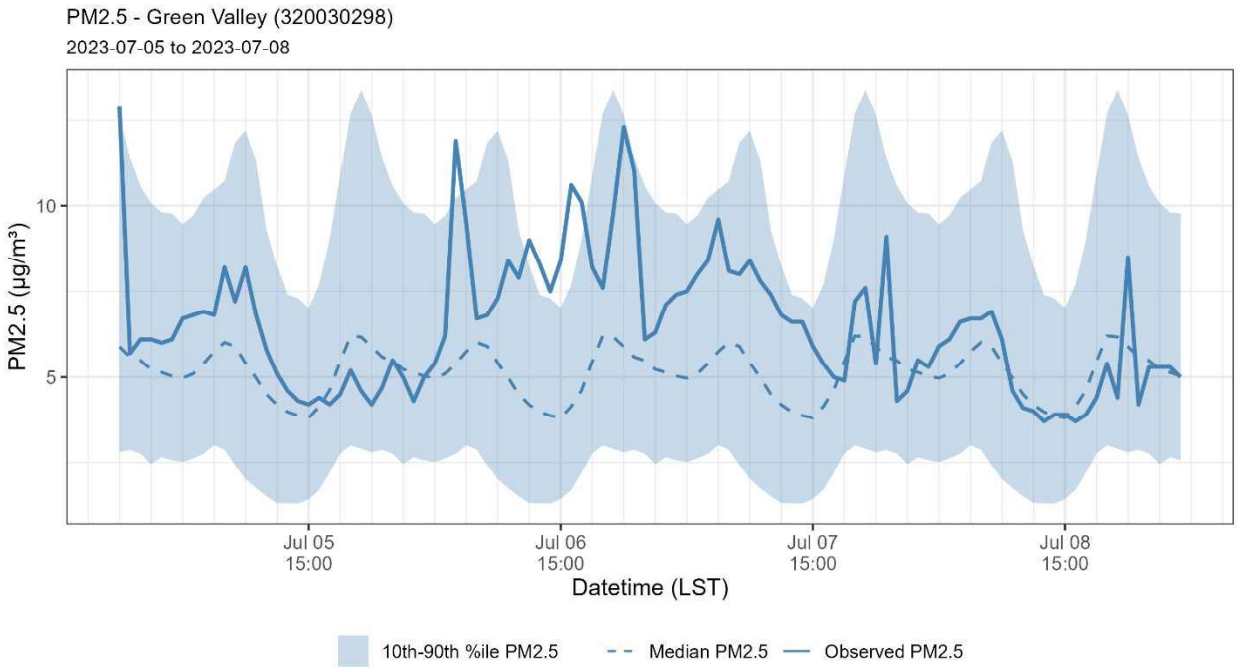
Figure 241. Hourly CO measurements overlaid on the 10th to 90th percentile diurnal concentration at Paul Meyer (AQS site code 320030043), Joe Neal (AQS site code 320030075), Green Valley (AQS site code 320030298), Jerome Mack (AQS site code 320030540), and Walnut Recreation (AQS side code 320032003). The 10th to 90th percentile concentration is calculated across the ozone production season (April-September) for 2018-2023. Note: Walnut Recreation only includes data from June 1, 2021, and onwards. Paul Meyer only includes data from May 2022 through September 2023, Joe Neal only includes data from June 2019 through September 2023, Green Valley only includes data from June 2020 through September 2023.

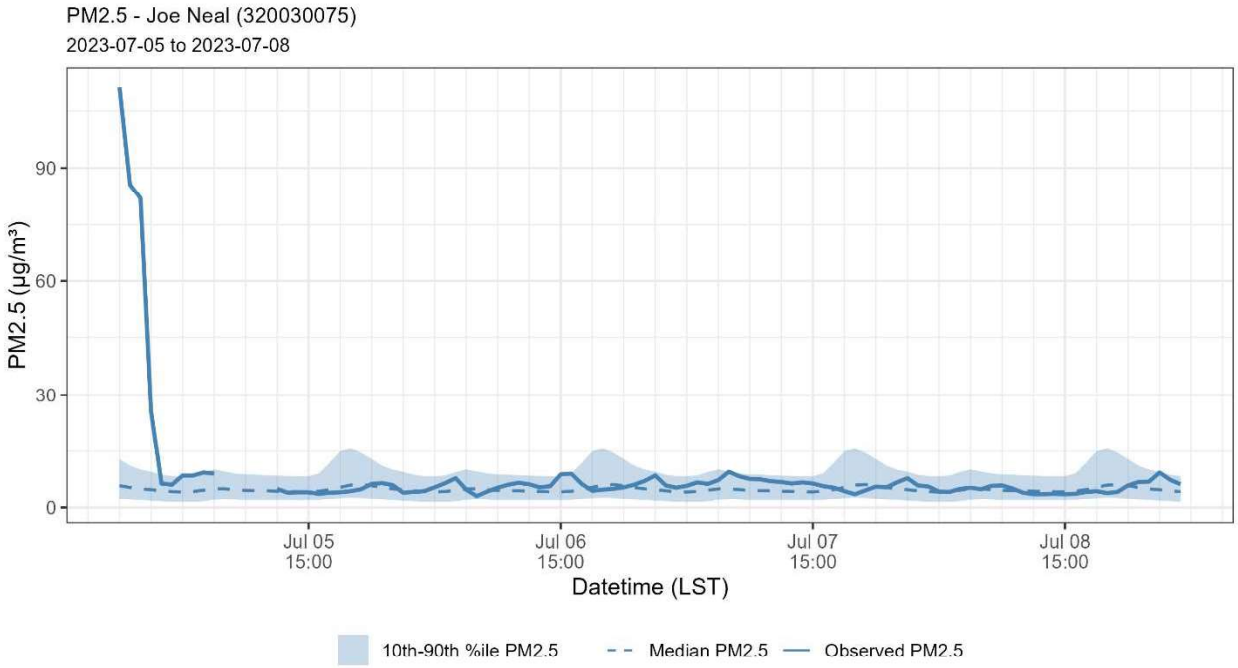
Figure 242 shows hourly $PM_{2.5}$ concentrations at the affected sites (Walter Johnson, Green Valley, Jean, Jerome Mack, Joe Neal, Liberty, Mountain's Edge, Palo Verde, Paul Meyer, Walnut Rec) overlaid on the 10th to 90th percentile hourly concentrations during ozone season (April to September), calculated using data from 2018-2023 (Walnut Rec's data collection began June 2021, and Mountain's Edge began October 2020). Several sites (Paul Meyer, Mountain's Edge, Walter Johnson, Palo Verde, Joe Neal, and Walnut Rec) had large $PM_{2.5}$ spikes above the 90th percentile in the early hours of July 5. Fireworks during the evening hours of July 4th contributed to $PM_{2.5}$ spikes that are shown at midnight on July 5th. $PM_{2.5}$ filter data for Jerome Mack and Sunrise Acres on July 4 and 5 were sent to the Desert Research Institute (DRI) for $PM_{2.5}$ speciation analysis. Additionally, Chemical Speciation Network (CSN) data was analyzed on July 5 and 8 at Jerome Mack. Firework tracers (potassium, strontium, magnesium, copper, barium, and aluminum) were examined. Figure 243 shows elevated firework tracers on July 4 with a significant decrease on July 5 and 8. There was no $PM_{2.5}$ speciation data for July 6 and 7. $PM_{2.5}$ concentrations above the 90th percentile were recorded at all sites on July 6 at approximately 15:00 PST, with sites recording sustained high concentrations during this event starting as early as 02:00 PST on July 6. High $PM_{2.5}$ concentrations were also observed on July 7, with peak values occurring at approximately 05:00 PST during this period, which neared or exceeded the 90th percentile concentration at nine sites.

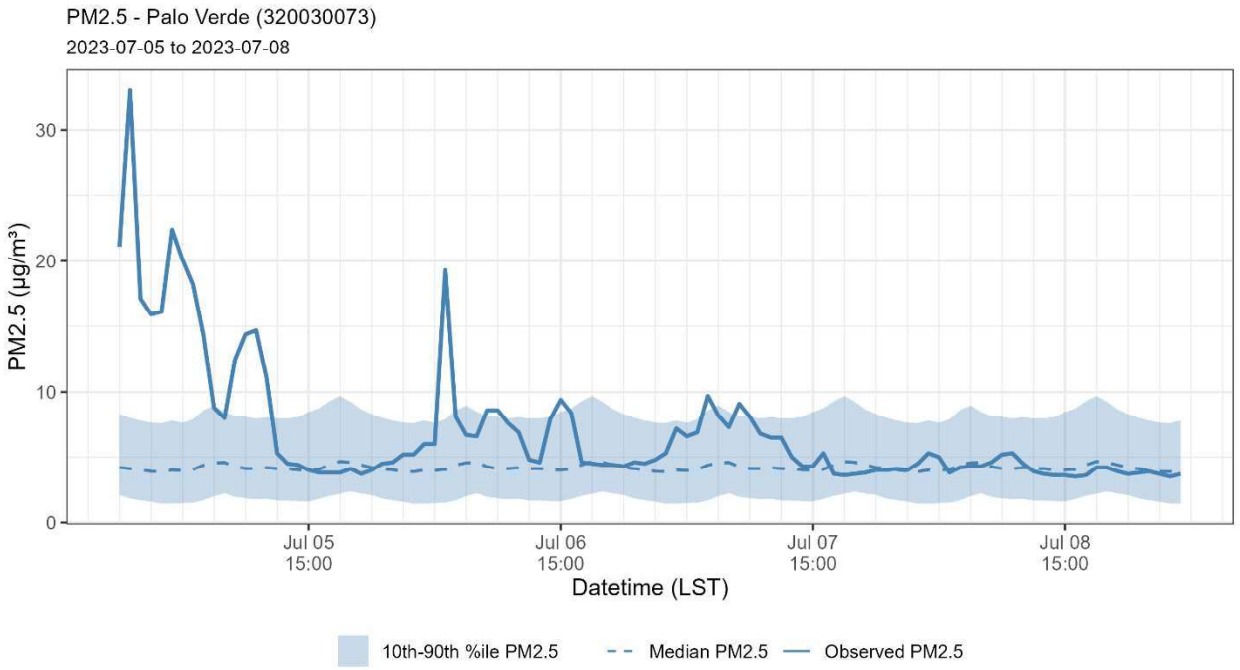
Draft

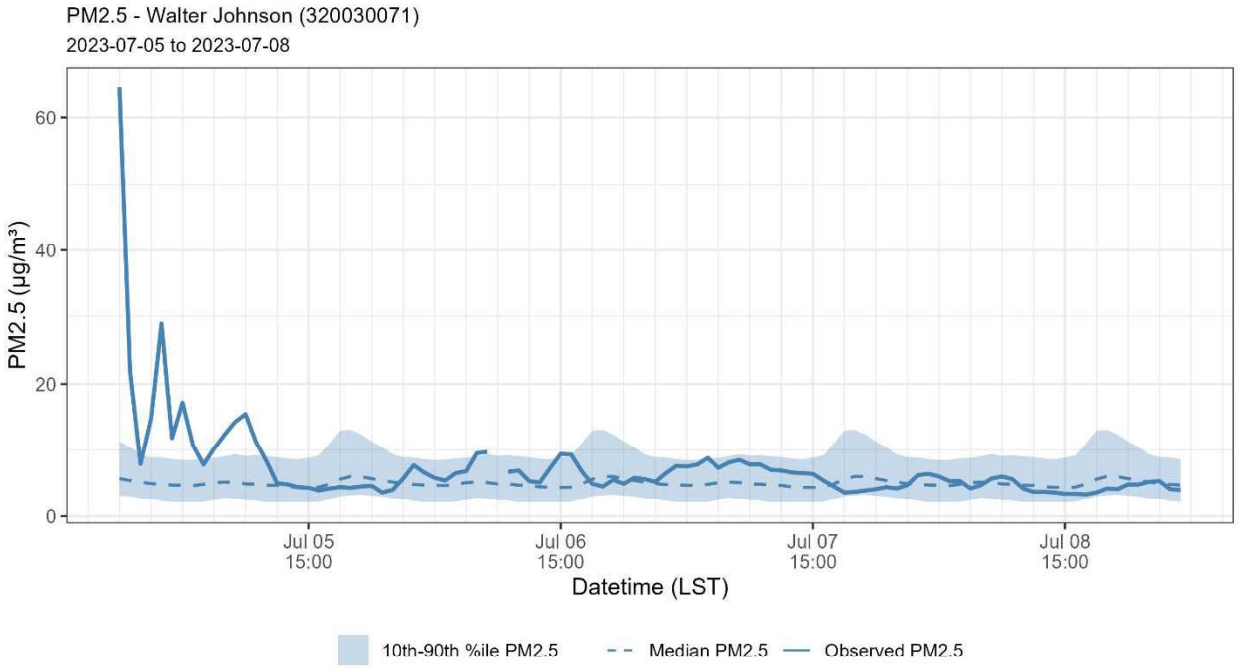

PM2.5 - Jerome Mack (320030540)
2023-07-05 to 2023-07-08
30
20
10
PM2.5 (µg/m³)
Jul 05
15:00
Jul 06
15:00
Jul 07
15:00
Jul 08
15:00
Datetime (LST)
10th-90th %ile PM2.5
Median PM2.5
Observed PM2.5

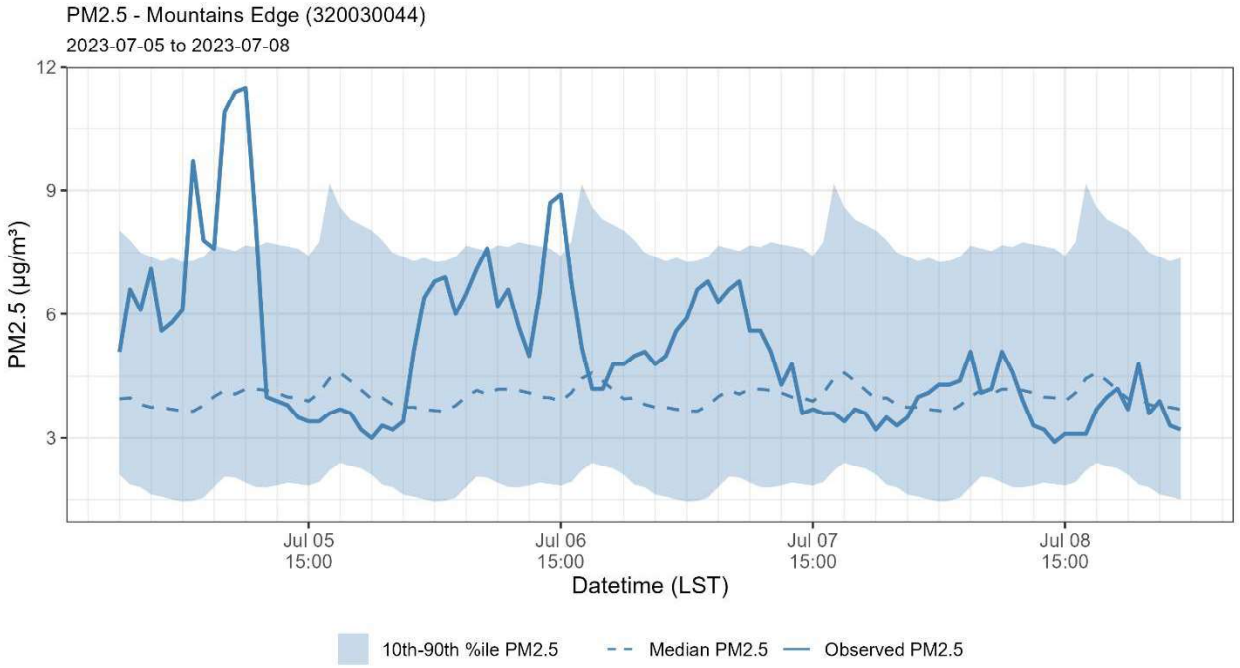

PM2.5 - Liberty High School (320030299)
2023-07-05 to 2023-07-08
10.0
7.5
5.0
2.5
PM2.5 (µg/m³)
Jul 05
15:00
Jul 06
15:00
Jul 07
15:00
Jul 08
15:00
Datetime (LST)
10th-90th %ile PM2.5
Median PM2.5
Observed PM2.5

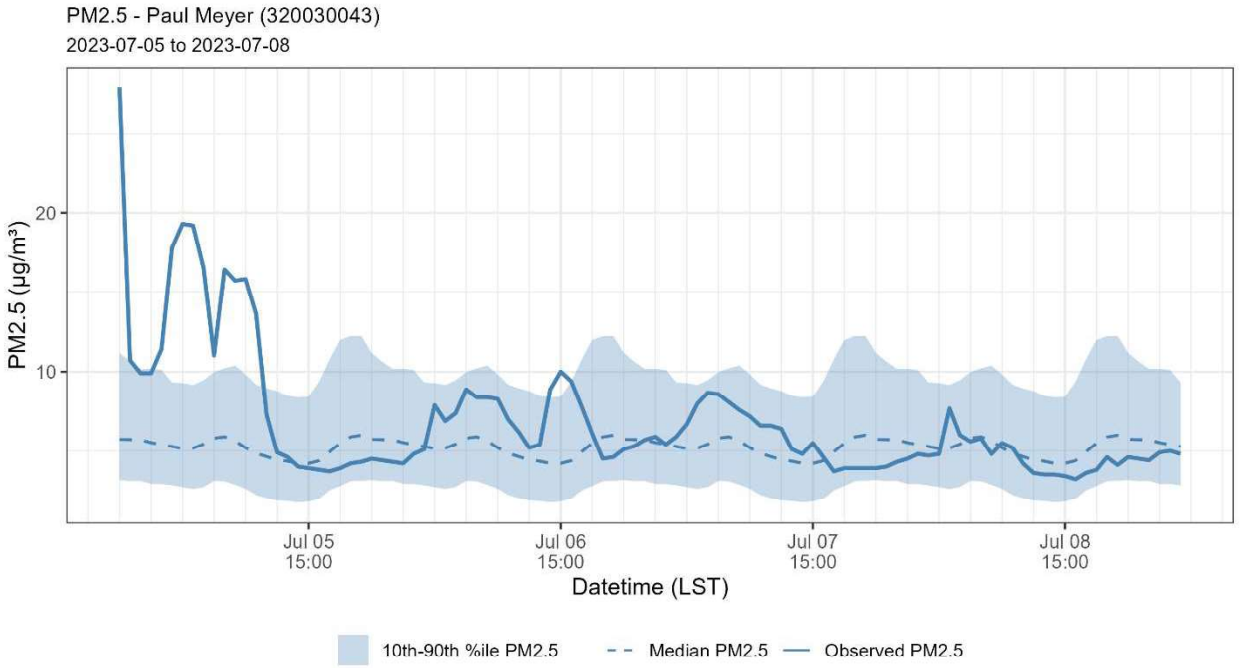

PM2.5 - Green Valley (320030298)
2023-07-05 to 2023-07-08
PM2.5 (µg/m³)
10
5
Jul 05
15:00
Jul 06
15:00
Jul 07
15:00
Jul 08
15:00
Datetime (LST)
10th-90th %ile PM2.5
Median PM2.5
Observed PM2.5


PM2.5 - Joe Neal (320030075)
2023-07-05 to 2023-07-08
PM2.5 (µg/m³)
90
60
30
0
Jul 05
15:00
Jul 06
15:00
Jul 07
15:00
Jul 08
15:00
Datetime (LST)
10th-90th %ile PM2.5
Median PM2.5
Observed PM2.5


PM2.5 - Palo Verde (320030073)
2023-07-05 to 2023-07-08
PM2.5 (µg/m³)
30
20
10
0
Jul 05
15:00
Jul 06
15:00
Jul 07
15:00
Jul 08
15:00
Datetime (LST)
10th-90th %ile PM2.5
Median PM2.5
Observed PM2.5


PM2.5 - Walter Johnson (320030071)
2023-07-05 to 2023-07-08
PM2.5 (µg/m³)
60
40
20
0
Jul 05
15:00
Jul 06
15:00
Jul 07
15:00
Jul 08
15:00
Datetime (LST)
10th-90th %ile PM2.5
Median PM2.5
Observed PM2.5


PM2.5 - Mountains Edge (320030044)
2023-07-05 to 2023-07-08
12
9
6
3
PM2.5 (µg/m³)
Jul 05
15:00
Jul 06
15:00
Jul 07
15:00
Jul 08
15:00
Datetime (LST)
10th-90th %ile PM2.5
Median PM2.5
Observed PM2.5


PM2.5 - Paul Meyer (320030043)
2023-07-05 to 2023-07-08
20
10
PM2.5 (µg/m³)
Jul 05
15:00
Jul 06
15:00
Jul 07
15:00
Jul 08
15:00
Datetime (LST)
10th-90th %ile PM2.5
Median PM2.5
Observed PM2.5

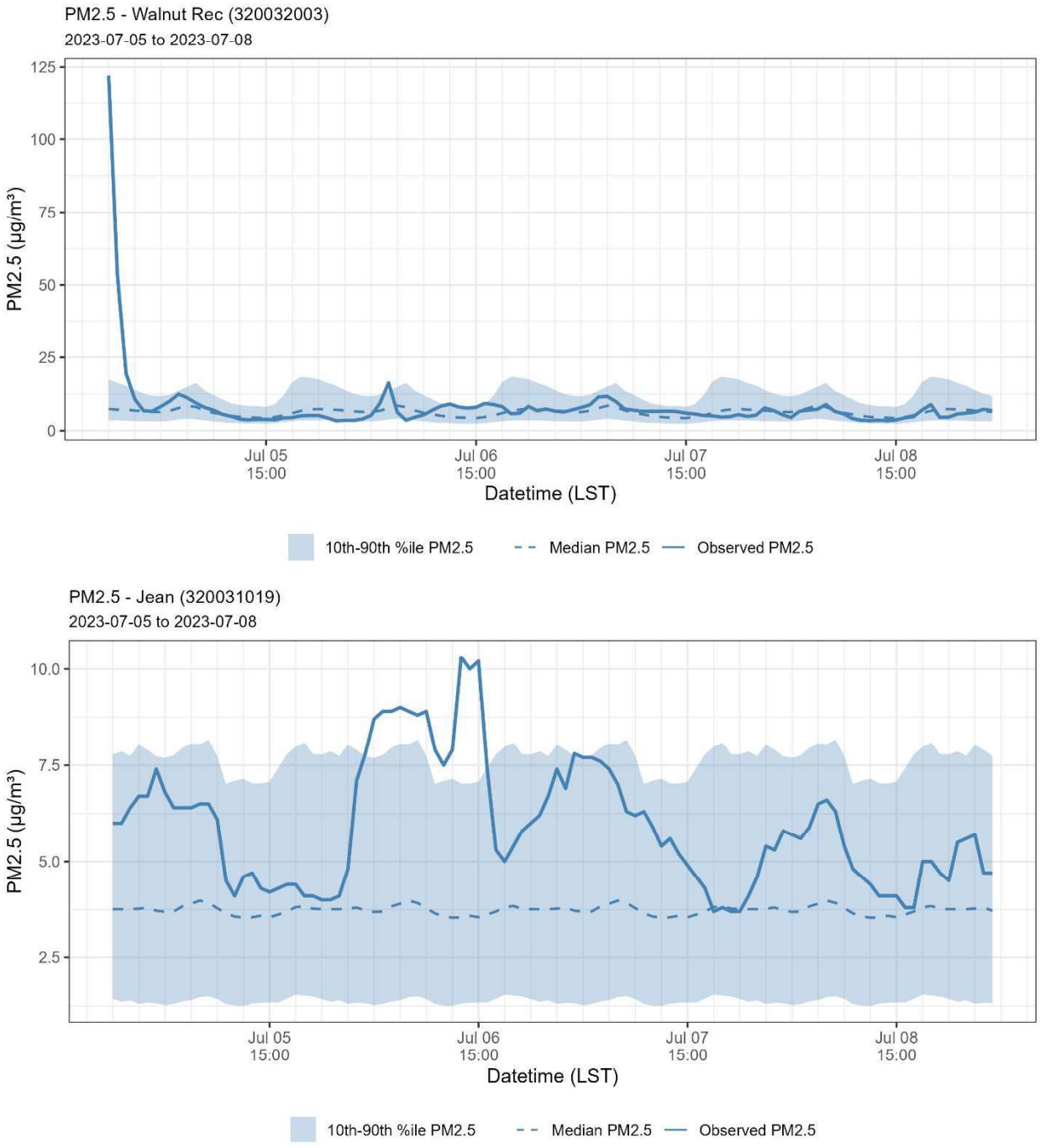


Figure 242. Hourly $PM_{2.5}$ measurements overlaid on the 10th to 90th percentile diurnal concentration at Jerome Mack (AQS site code 320030540), Liberty (AQS site code 320030299), Green Valley (AQS site code 320030298), Joe Neal (AQS site code 320030075), Palo Verde (AQS site code 320030073), Walter Johnson (AQS site code 320030071), Mountain's Edge (AQS site code 320030044), Paul Meyer (AQS site code 320030043), Walnut Recreation (AQS site code 320032003), and Jean (AQS site code 320031019). The 10th to 90th percentile concentration is calculated across the ozone production season April-September for 2018-2023. Note: Walnut Recreation includes data from June 1, 2021, and onwards; Mountain's Edge includes data from October 1, 2020, and onwards; Liberty includes data from May 1, 2021, and onwards.

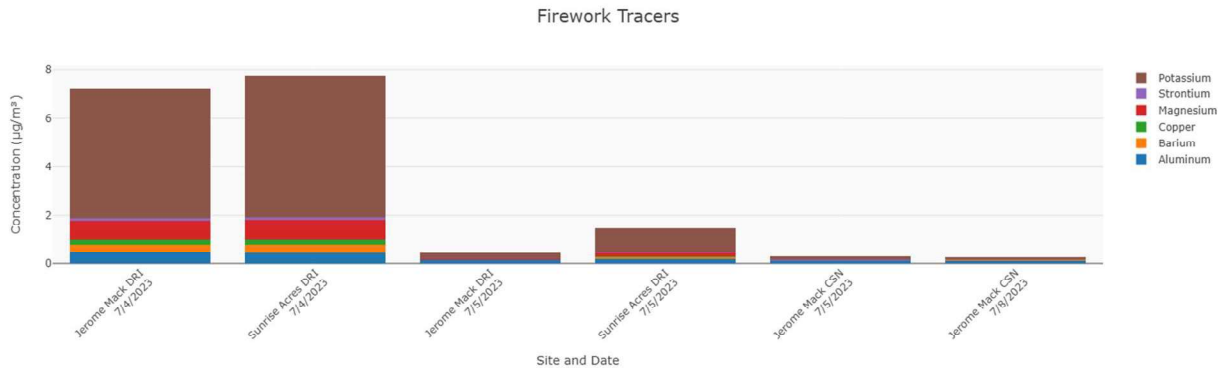


Figure 243. $PM_{2.5}$ firework tracer filter data for Jerome Mack and Sunrise Acres on July 4 and 5, 2023 from DRI. $PM_{2.5}$ firework tracer filter data for Jerome Mack on July 5 and 8, 2023 from CSN.

Figure 244 shows elevated concentrations of key wildfire smoke-related $PM_{2.5}$ components, organic carbon (OC), elemental carbon (EC), and potassium ion (K^+), only July 5 and 8. These peaks align with the wildfire smoke influence that contributed to elevated ozone levels from July 5-8. In contrast, July 11 shows lower levels of these wildfire tracers, consistent with its classification as a non-exceedance day, indicating reduced smoke impact on local air quality.

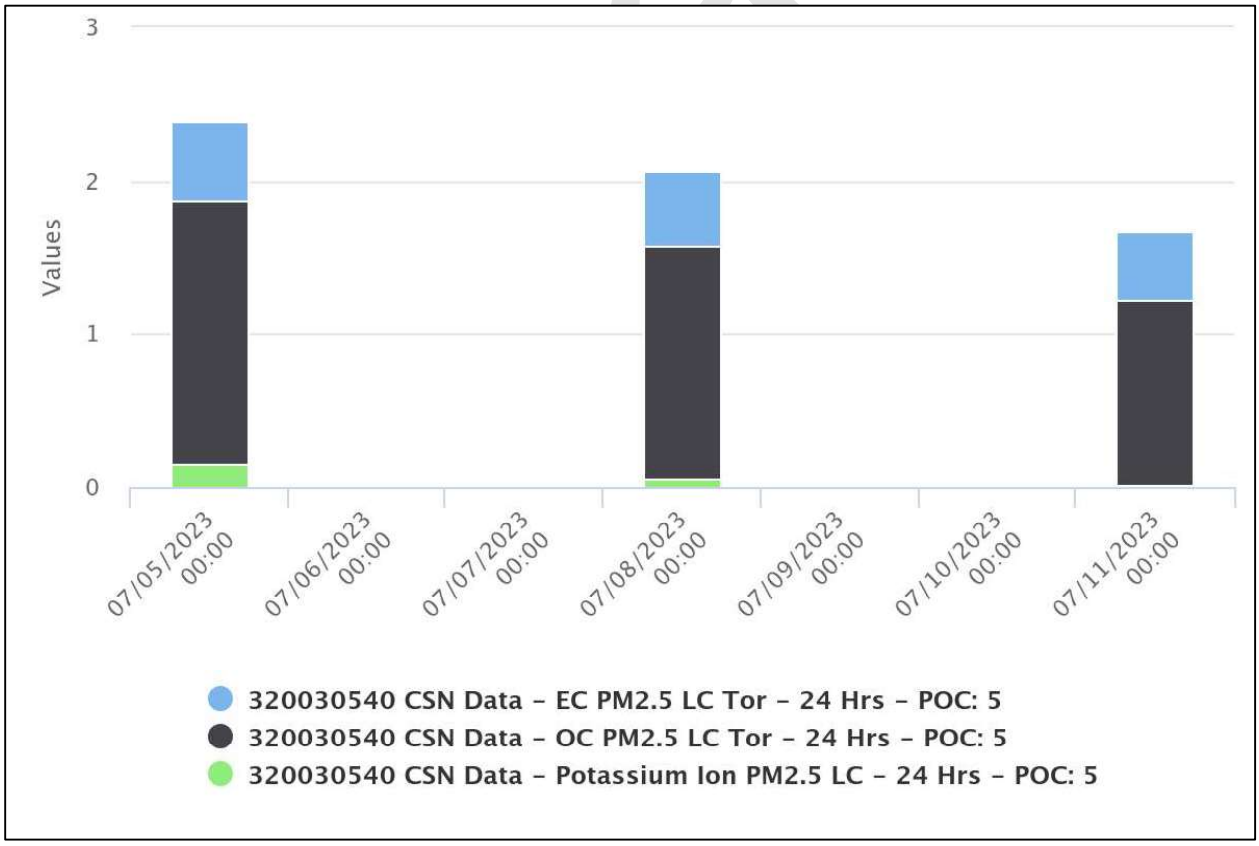
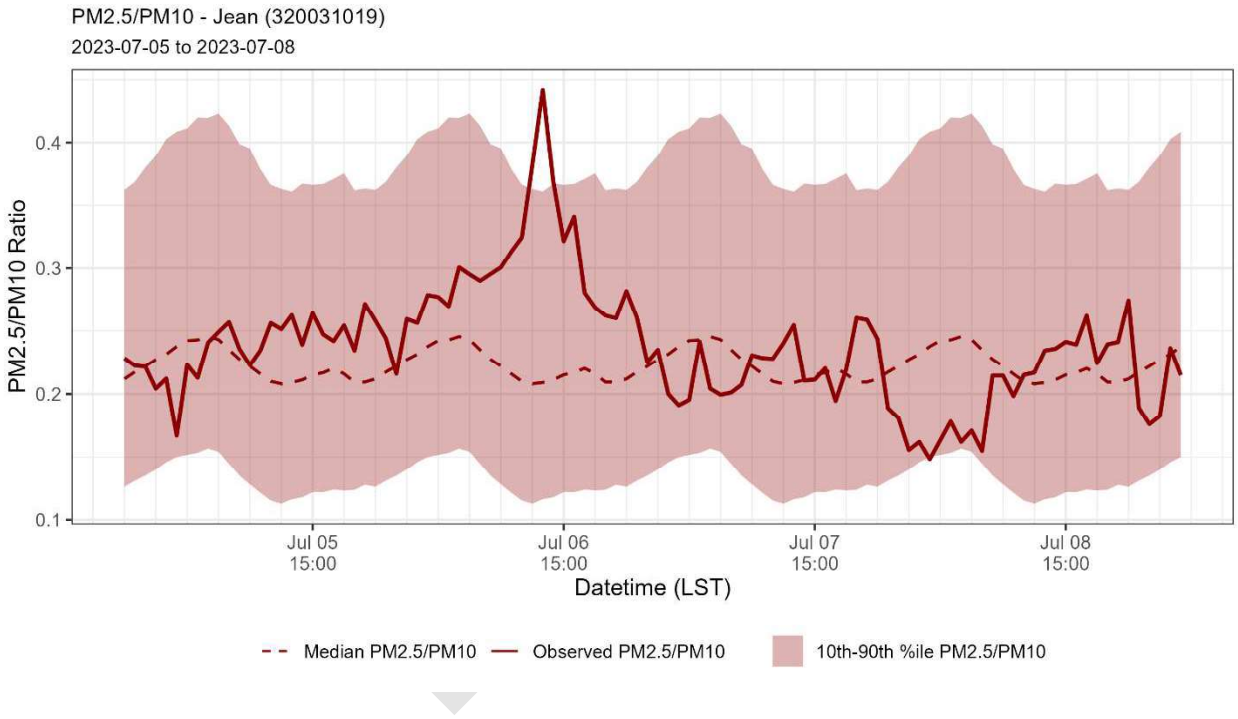
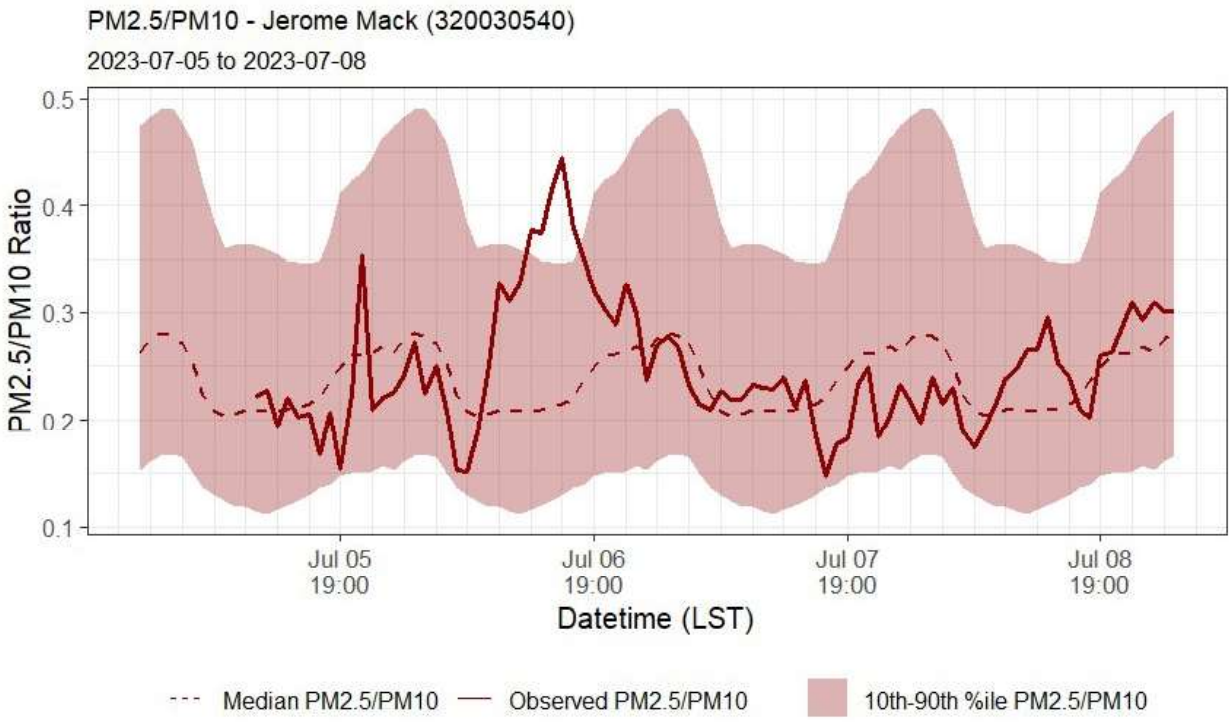
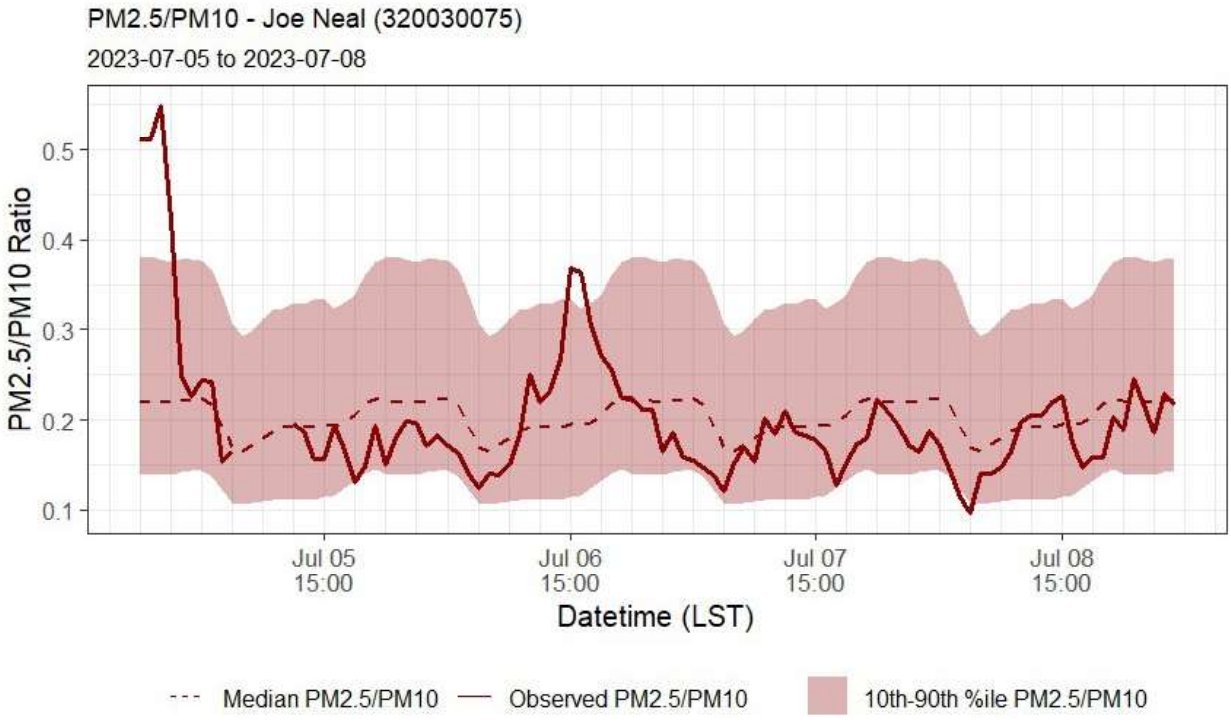


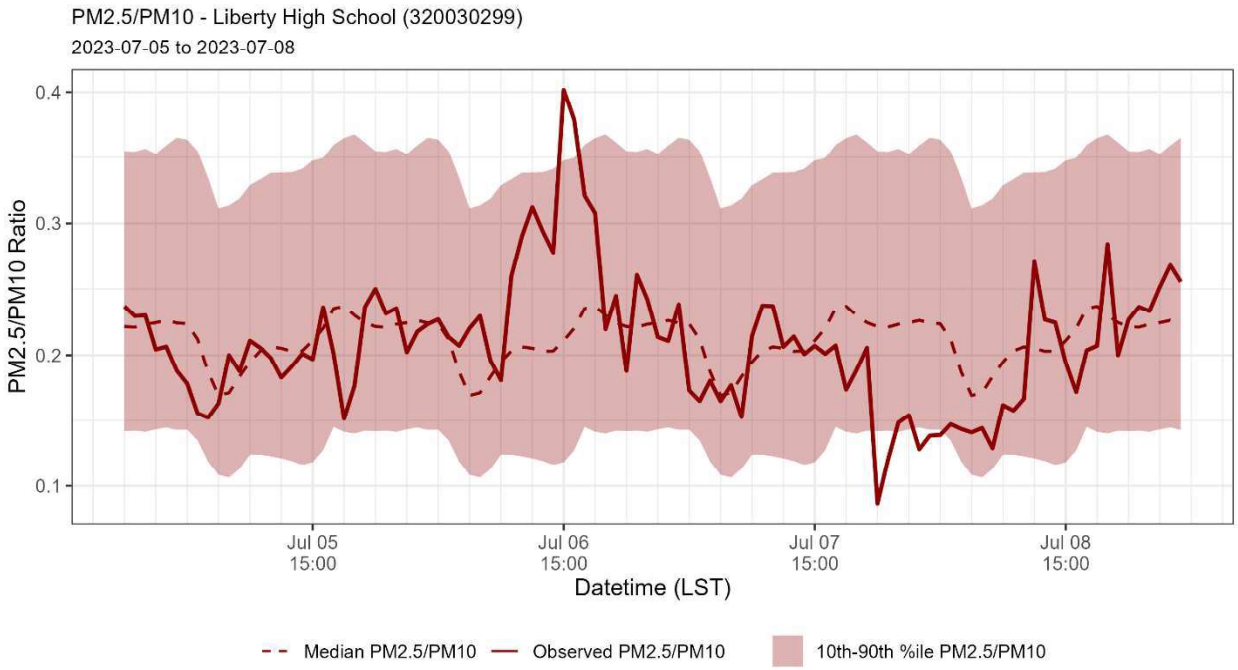
Figure 244. $PM_{2.5}$ speciation filter data from Jerome Mack CSN on July 5, 8, and 11 2023 for wildfire smoke tracers, elemental carbon (EC), organic carbon (OC), and potassium (K^+).

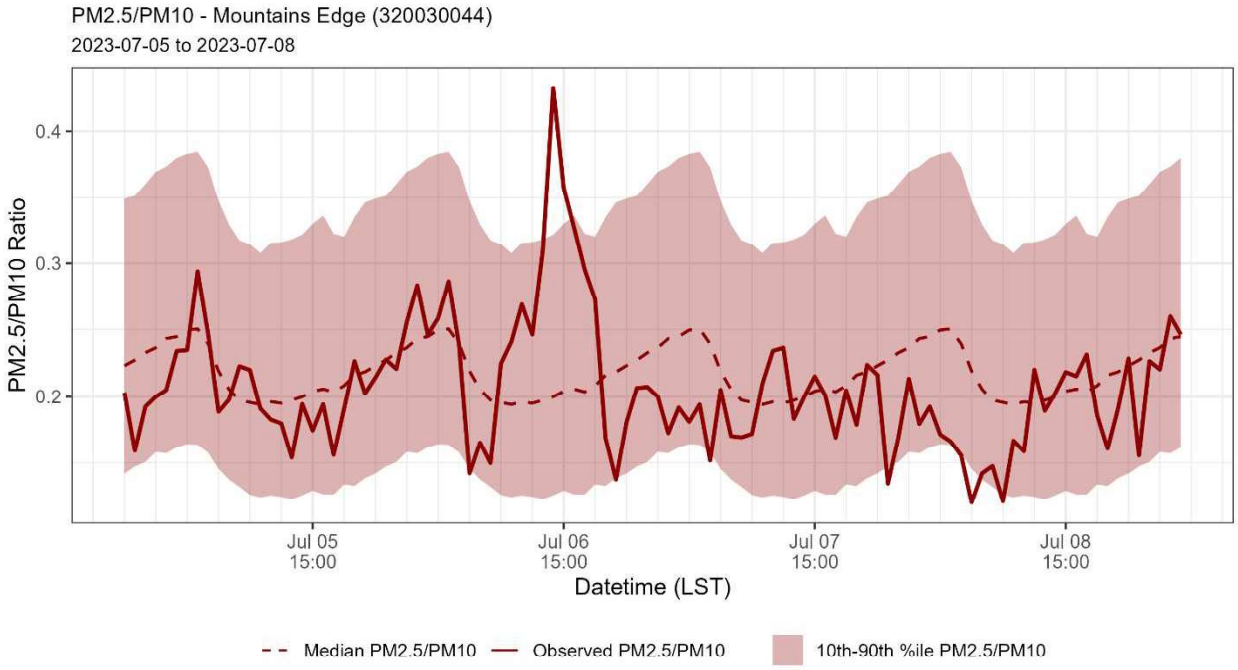
During wildfire events, the ratio of $PM_{2.5}$-to-PM_{10} concentrations increase. This ratio was therefore also examined to determine whether wildfire smoke entered Clark County on or before the exclusion dates. Figure 245 shows a time series of the ratio of $PM_{2.5}$-to-PM_{10} concentrations from July 5-8, with the multiyear average ratio and the 10th to 90th percentile shown for the following sites: Walter Johnson, Green Valley, Jean, Jerome Mack, Joe Neal, Liberty, Mountain's Edge, Palo Verde, Paul Meyer, Walnut Rec. At all nine sites, this ratio fluctuated significantly and regularly exceeded the multiyear median. At all sites, the 90th percentile concentration was exceeded on July 6 at 15:00. During that period, the sites measured values between 0.35 and 0.45, which are indicative of wildfire smoke in the area. These observations of enhanced $PM_{2.5}$ that increased the $PM_{2.5}$-to-PM_{10} ratio provide evidence that wildfire smoke was present in Clark County from July 5-8.

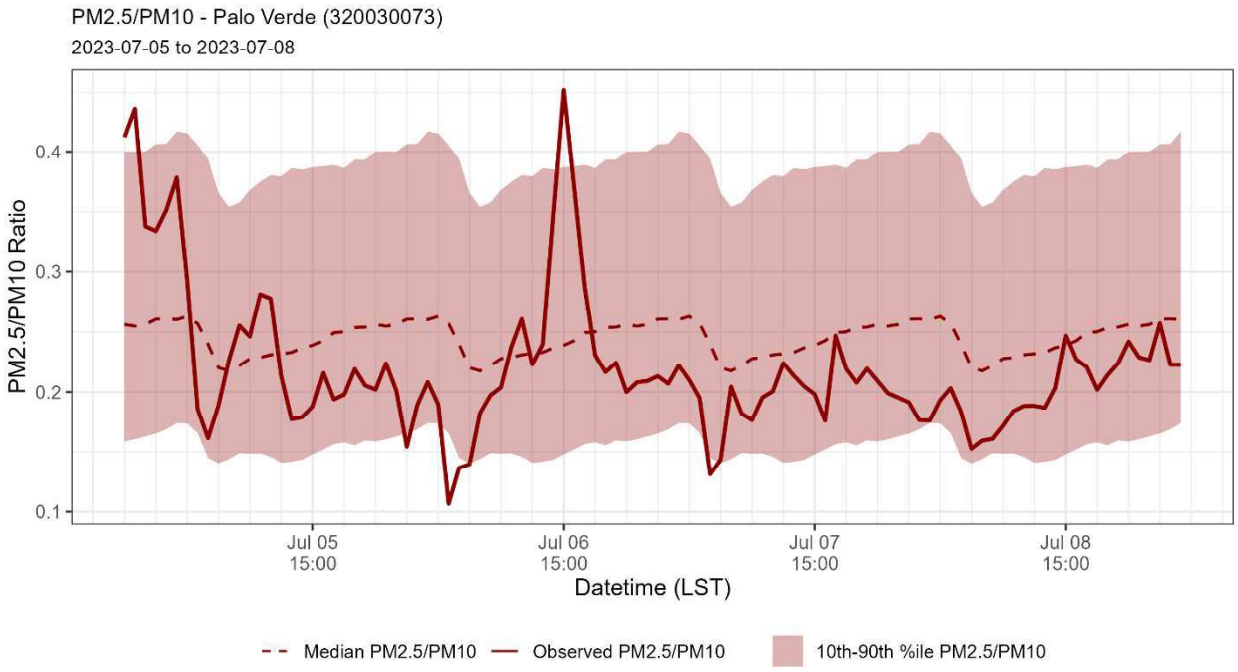


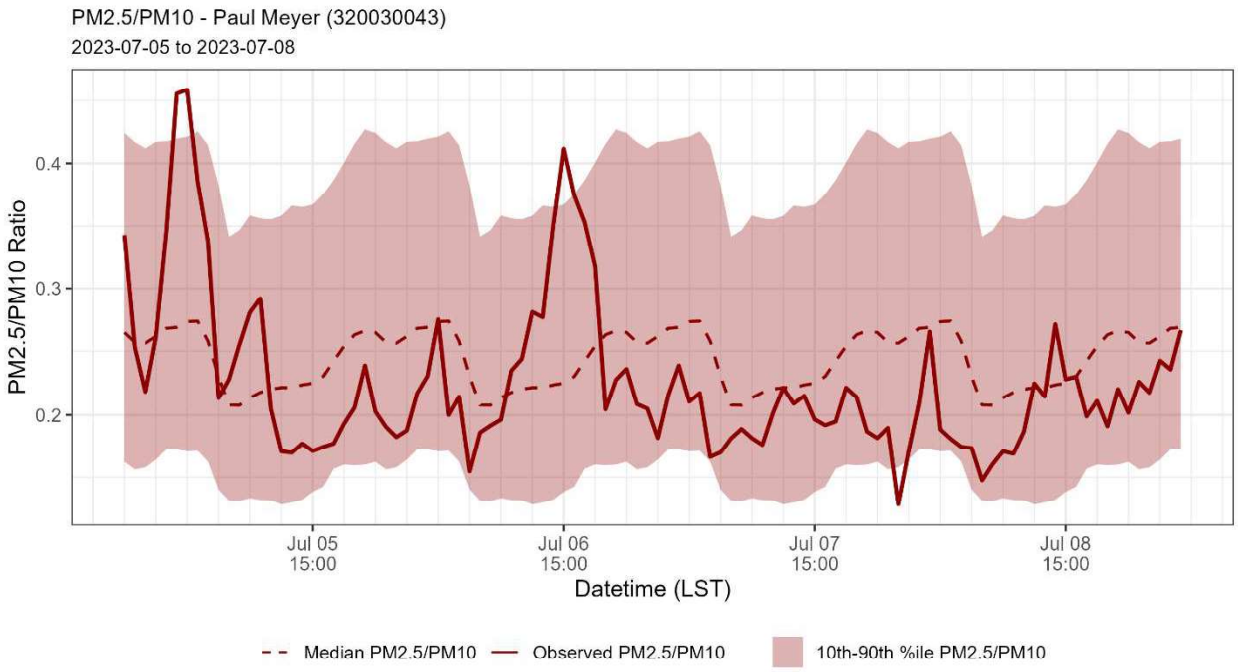

PM2.5/PM10 - Jerome Mack (320030540)
2023-07-05 to 2023-07-08
PM2.5/PM10 Ratio
0.5
0.4
0.3
0.2
0.1
Jul 05
19:00
Jul 06
19:00
Jul 07
19:00
Jul 08
19:00
Datetime (LST)
Median PM2.5/PM10
Observed PM2.5/PM10
10th-90th %ile PM2.5/PM10


PM2.5/PM10 - Joe Neal (320030075)
2023-07-05 to 2023-07-08
PM2.5/PM10 Ratio
0.5
0.4
0.3
0.2
0.1
Jul 05
15:00
Jul 06
15:00
Jul 07
15:00
Jul 08
15:00
Datetime (LST)
Median PM2.5/PM10
Observed PM2.5/PM10
10th-90th %ile PM2.5/PM10


PM2.5/PM10 - Liberty High School (320030299)
2023-07-05 to 2023-07-08
PM2.5/PM10 Ratio
0.4
0.3
0.2
0.1
Jul 05
15:00
Jul 06
15:00
Jul 07
15:00
Jul 08
15:00
Datetime (LST)
Median PM2.5/PM10
Observed PM2.5/PM10
10th-90th %ile PM2.5/PM10


PM2.5/PM10 - Mountains Edge (320030044)
2023-07-05 to 2023-07-08
PM2.5/PM10 Ratio
0.4
0.3
0.2
Jul 05
15:00
Jul 06
15:00
Jul 07
15:00
Jul 08
15:00
Datetime (LST)
Median PM2.5/PM10
Observed PM2.5/PM10
10th-90th %ile PM2.5/PM10


PM2.5/PM10 - Palo Verde (320030073)
2023-07-05 to 2023-07-08
PM2.5/PM10 Ratio
0.4
0.3
0.2
0.1
Jul 05
15:00
Jul 06
15:00
Jul 07
15:00
Jul 08
15:00
Datetime (LST)
Median PM2.5/PM10
Observed PM2.5/PM10
10th-90th %ile PM2.5/PM10


PM2.5/PM10 - Paul Meyer (320030043)
2023-07-05 to 2023-07-08
PM2.5/PM10 Ratio
0.4
0.3
0.2
Jul 05
15:00
Jul 06
15:00
Jul 07
15:00
Jul 08
15:00
Datetime (LST)
Median PM2.5/PM10
Observed PM2.5/PM10
10th-90th %ile PM2.5/PM10

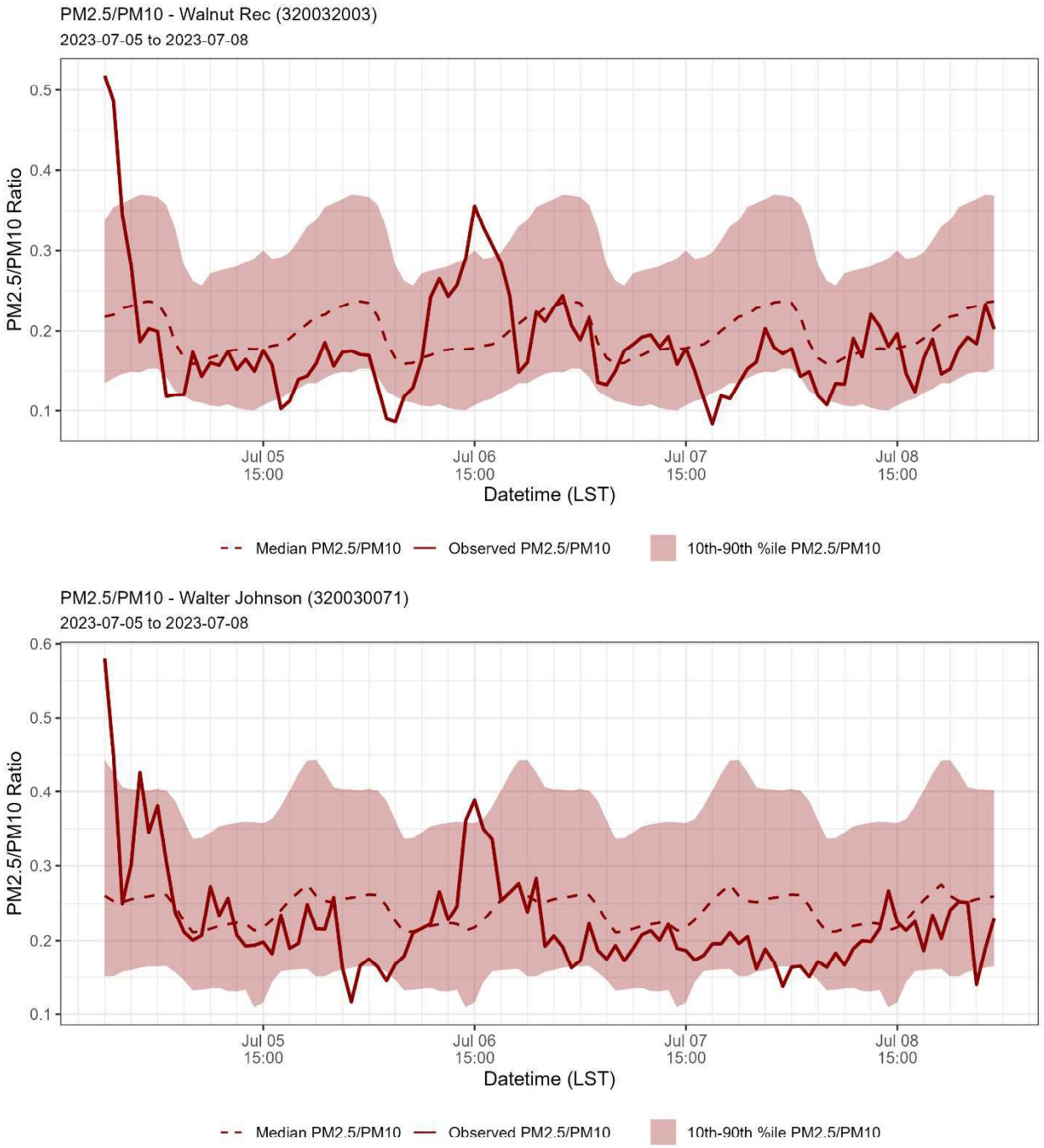
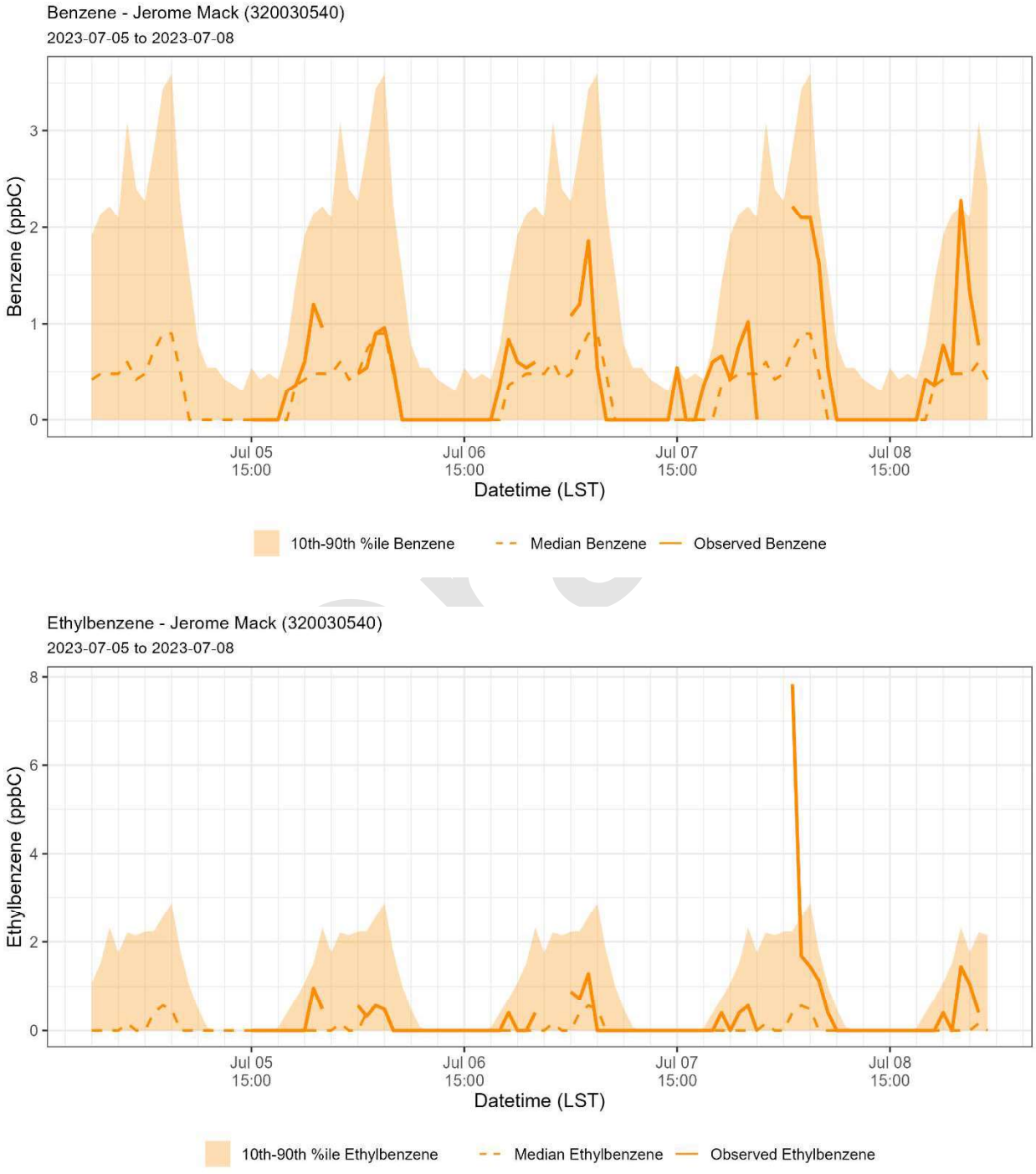
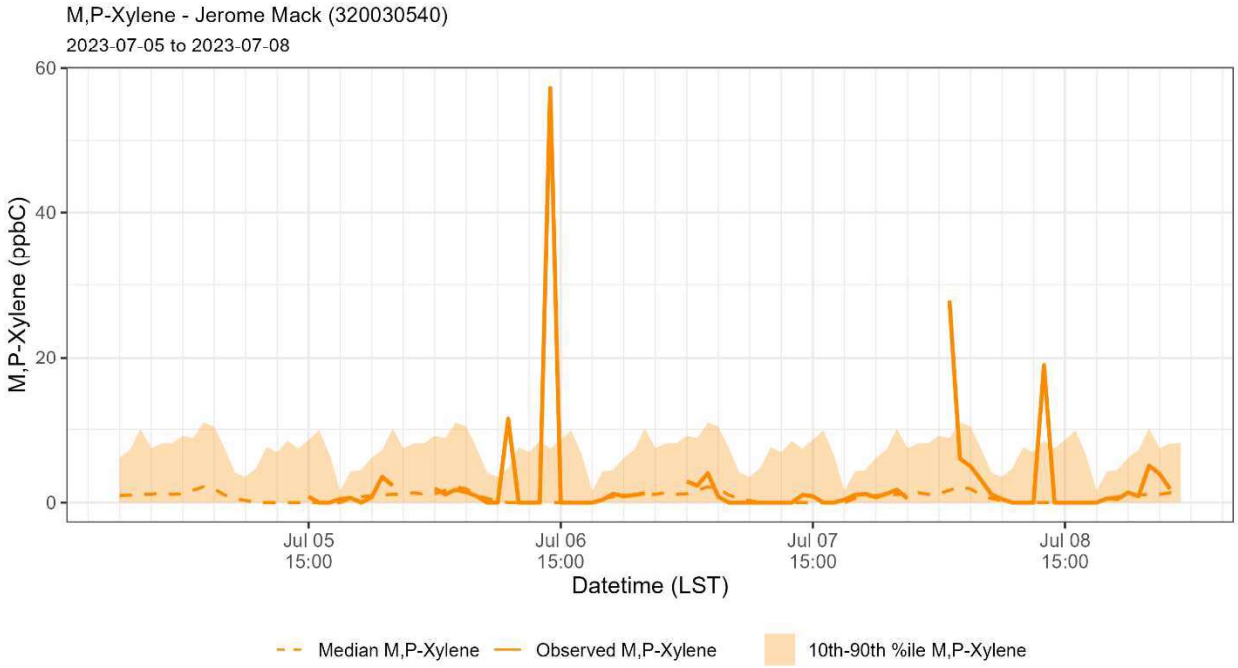
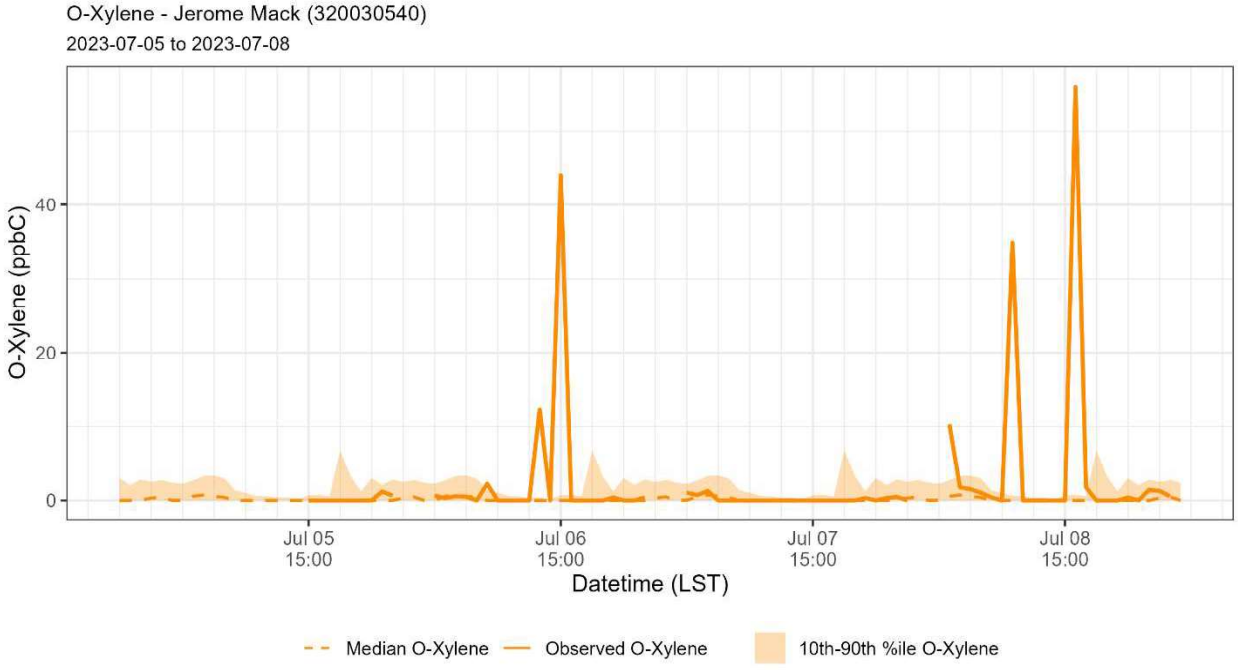


Figure 245. Ratio of $PM_{2.5}$-to-PM_{10} concentrations during the event period overlaid on the 10th to 90th percentile diurnal concentrations at Jean (AQS site code 320031019), Jerome Mack (AQS site code 320030540), Liberty (AQS site code 320030299), Green Valley (AQS site code 320030298), Joe Neal (AQS site code 320030075), Palo Verde (AQS site code 320030073), Walter Johnson (AQS site code 320030071), Mountain's Edge (AQS site code 320030044), Paul Meyer (AQS site code 320030043), and Walnut Recreation (AQS site code 320032003). The 10th to 90th percentile concentration is calculated across the ozone production season (April-September) for 2018-2023. Note: Walnut Recreation includes data from June 1, 2021, and onwards; Mountain's Edge includes data from October 1, 2020, and onwards; Liberty includes data from May 1, 2021, and onwards.

Figure 246 shows hourly measurements of select PAMS parameters alongside the median and 10th-90th percentile diurnal concentrations, calculated from June-August 2022-2024, recorded at the Jerome Mack-NCore site. Benzene, ethylbenzene, m,p-xylene, o-xylene, and toluene exhibited distinct increases that met or exceeded the 90th percentile at various times during July 5-8, 2023.




M,P-Xylene - Jerome Mack (320030540)
2023-07-05 to 2023-07-08
M,P-Xylene (ppbC)
60
40
20
0
Jul 05
15:00
Jul 06
15:00
Jul 07
15:00
Jul 08
15:00
Datetime (LST)
Median M,P-Xylene
Observed M,P-Xylene
10th-90th %ile M,P-Xylene


O-Xylene - Jerome Mack (320030540)
2023-07-05 to 2023-07-08
O-Xylene (ppbC)
40
20
0
Jul 05
15:00
Jul 06
15:00
Jul 07
15:00
Jul 08
15:00
Datetime (LST)
Median O-Xylene
Observed O-Xylene
10th-90th %ile O-Xylene

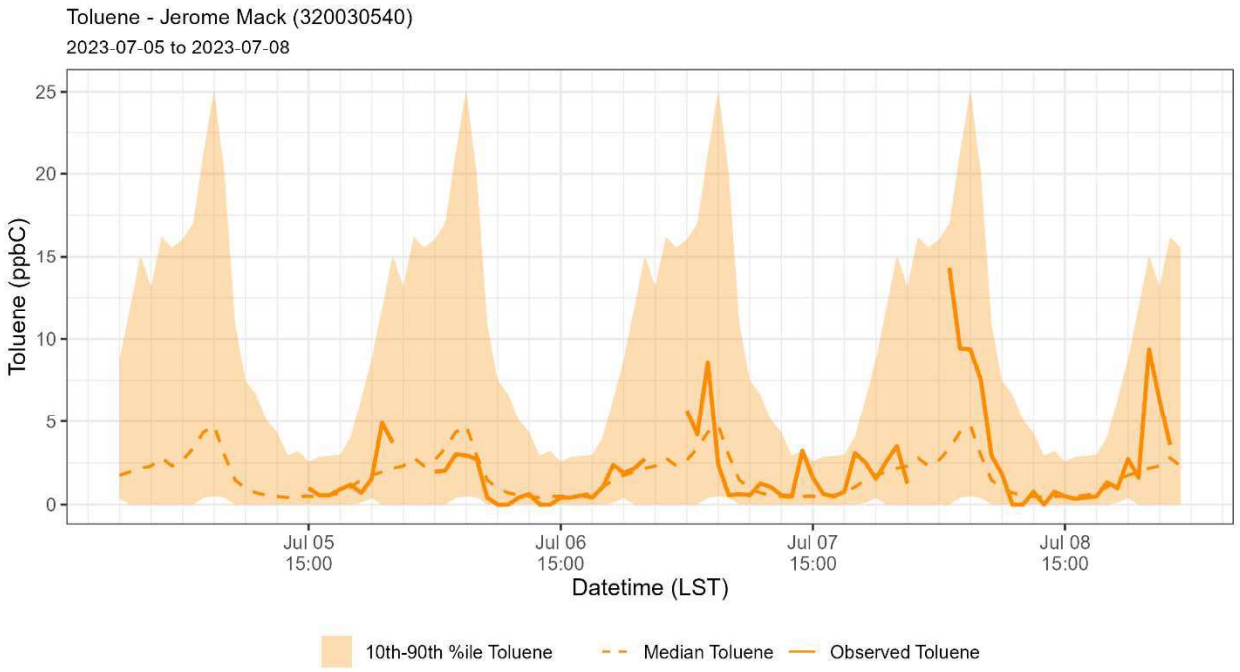


Figure 246. Hourly measurements from select PAMS parameters overlaid on the 10th-90th percentile diurnal concentration at the Jerome Mack-NCore site. The 10th-90th percentile concentration is calculated across the PAMS season (June-August) of 2022-2024.

6.5 Event Statistics

Table 56 summarizes the concentrations of ozone, $PM_{2.5}$, CO, and NO_2 on the exclusion days, as well as the percentile rank of the observation compared to the previous six-years of data (i.e., from 2018-2023 or years available if site sampling started after 2018). Ozone MDA8 concentrations ranged from the 95th to 99th percentile on July 5-8.

24-hour $PM_{2.5}$ concentrations ranged from the 51st and 92nd percentile. CO and NO_2 concentrations were not well represented at the affected sites and in most cases have less than six years of data for comparison. CO concentrations were available from Paul Meyer, Joe Neal, Green Valley, Jerome Mack, and Walnut Recreation; however Walnut Recreation only includes data from June 1, 2021, and onwards, Paul Meyer only includes data from May 2022 through September 2023, Joe Neal only includes data from June 2019 through September 2023, and Green Valley only includes data from June 2020 through September 2023. CO concentrations ranged from the 26th-89th percentiles, with Jerome Mack being the 26th percentile but not the lowest CO 1-hr daily max with a concentration of 0.316 ppm and Joe Neal being the 89th percentile with a concentration of 0.411 ppm. NO_2 concentrations were only available for Joe Neal, Jerome Mack, and Walnut Recreation and ranged from 12.9-38.9 ppb or the 19th-93rd percentile.

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Table 56. Percentile of pollution concentration on exclusion days compared with most recent six years (2018-2023). The percentile rank is calculated across the ozone production season (April – September 30) of 2018-2023. Sites that have less than six years of data available for a given parameter are indicated with asterisk.

Date	Site Name	Site Code	Ozone MDA8 (ppb)	Percent rank	$PM_{2.5}$ 24-hr average ($\mu g/m^3$)	Percent Rank	CO 1-hr daily max (ppm)	Percent Rank	NO_2 1-hr daily max (ppb)	Percent Rank
7/5/2023	Indian Springs	320037772	72	99.1%						
	Walter Johnson	320030071	71	95.9%	8.9	92.90%				
7/6/2023	Green Valley	320030298	72	98.4%	8.0	92.10%	0.321	73.70%		
	Indian Springs	320037772	71	98.6%						
	Jean	3200321019	72	99.3%	6.6	92.10%				
	Jerome Mack	320030540	71	98.6%	6.7	51.60%	0.316	26.60%	12.9	19.70%
	Joe Neal	320030075	74	98.60%	5.8	75.30%	0.32	72.40%	20.6	87.60%
	Liberty High School	320030299	72	99.0%*	7.2	90.1%*				

Date	Site Name	Site Code	Ozone MDA8 (ppb)	Percent rank	$PM_{2.5}$ 24-hr average ($\mu g/m^3$)	Percent Rank	CO 1-hr daily max (ppm)	Percent Rank	NO_2 1-hr daily max (ppb)	Percent Rank
	Mountain's Edge	320030044	76	99.3%*	5.9	87.1%*				
	Palo Verde	320030073	73	98.90%	6.7	91.20%				
	Paul Meyer	320030043	71	96.30%	6.7	82.80%	0.285	68.50%		
	Walnut Recreation	320032003	71	97.1%*	7.1	67.9%*	0.3	40.90%	38.9	93.00%
	Walter Johnson	320030071	71	95.90%	6.5	83.00%				
7/7/2023	Indian Springs	320037772	76	99.7%						
	Joe Neal	320030075	77	99.3%	6.4	81.30%	0.304	68.20%	17.4	77.70%
	Mountain's Edge	320030044	72	96.9%*	4.7	76.8%*				
	Palo Verde	320030073	71	98.2%	5.7	86.10%				
	Paul Meyer	320030043	71	96.3%	5.8	75.50%	0.254	55.50%		

Date	Site Name	Site Code	Ozone MDA8 (ppb)	Percent rank	$PM_{2.5}$ 24-hr average ($\mu g/m^3$)	Percent Rank	CO 1-hr daily max (ppm)	Percent Rank	NO_2 1-hr daily max (ppb)	Percent Rank
	Walter Johnson	320030071	75	98.70%	6.2	80.90%				
7/8/2023	Green Valley	320030298	71	97.3%	5.1	66.20%	0.272	58.50%		
	Indian Springs	320037772	72	99.1%						
	Jean	320031019	71	99.0%	4.1	71.70%				
	Joe Neal	320030075	72	97.7%	5.0	63.80%	0.411	89.60%	15.2	65.70%
	Mountain's Edge	320030044	72	98.0%*	3.9	61.7%*				
	Palo Verde	320030073	71	98.20%	4.1	64.60%				
	Paul Meyer	320030043	71	96.30%	4.6	54.70%	0.196	32.20%		
	Walter Johnson	320030071	72	97.00%	4.6	57.70%				

6.6 Request for Exclusion

The wildfire smoke events resulted in ozone measurements that are atypical, extreme, and nonrepresentative of past and future days for Clark County, NV. Appendix W to Part 51 states "control agencies have long expressed a need for consistency in the application of air quality models for regulatory purposes…the expanded requirements for models to cover even more complex problems have emphasized the need for period review and update of guidance on these techniques". Wildfire smoke events are one such complex problem, as wildfire season has extended and encompasses the summer months, also considered to be ozone production season. Wildfire occurrence is wildly considered to be a stochastic natural phenomenon and is therefore inconsistent year-to-year. Downstream smoke impacts, including ozone formation, are not typical nor representative of the ambient conditions of Clark County, Nevada. The wildfire smoke event identified in this report is inconsistent with previous records and determined to be extreme, as indicated by:

- All site exceedances are above the 95th percentile of all ozone measurements.
- Multiple sites were affected during each event, including those that did not exceed regulatory standards.
- Significant smoke was identified from regional wildfire incidents.

Table 57 provides the evidence and exclusion narrative for each date.

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Table 57. Evidence provided for each exclusion date.

Exclusion Date(s)	Event Summary
July 5-8, 2023	Regional smoke transport from wildfires in northwestern Mexico and Arizona contributed to elevated ozone across Clark County on July 5–8, 2023. A persistent ridge and weak pressure gradient produced hot, stagnant conditions that limited dispersion and allowed transported smoke and precursors to accumulate. Statistics indicate ozone and other pollutant concentrations were atypical, webcam imagery confirmed visible smoke, and HYSPLIT trajectories verified transport into the region.

Based on the evidence provided, we formally request exclusion of the following dates in base and projected ozone design values.

7. 2024 Ozone Technical Supporting Documents

7.1 Introduction

The U.S. Environmental Protection Agency (EPA) published the memorandum "Clarification Memo on Additional Methods, Determinations, and Analyses to Modify Air Quality Data Beyond Exceptional Events,"[57] which illustrates cases where air quality data may be modified for certain regulatory determinations, actions, and analysis. The memorandum defines cases where a request to exclude data can be made through the Exceptional Events Rule, such as when a National Ambient Air Quality Standard (NAAQS) design value is recalculated in EPA's Air Quality System (AQS) using modified data to determine attainment. The memorandum also defines additional analyses that are not covered in the Exceptional Events Rule, where submitting modified data may be appropriate. These additional cases that are not covered in the Exceptional Event Rule are defined as conditions where ambient air quality data may have been "influenced by an atypical, extreme or unrepresentative event." The Clark County Department of Environment & Sustainability (DES) is submitting a request to exclude data on this basis for the following five event date cases explicitly defined in the document as "Estimating base and future year design values ozone SIP attainment demonstrations," as a part of their State Implementation Plan (SIP).

The EPA memorandum states that monitoring data could qualify for exclusion if "[A]mbient data are not representative to characterize background or base period concentrations in accordance with the *Guideline,*" in reference to *Guideline on Air Quality Models*, 40 CFR Part 51, Appendix W.[58] Extreme wildfire events are increasingly prevalent in the western U.S., resulting in increased smoke impacts. Clark County, NV, was impacted by wildfire smoke from local and regional sources from wildfires in the summer of 2024, and Table 58 provides a list of five event dates where atypical smoke intrusion caused high ozone concentrations to be measured as a direct result of direct transport and secondary photochemical processes.

As stated in the memorandum, the EPA or the appropriate reviewing authority will determine whether the air agency, in this case Clark County DES, has appropriately documented and justified the data exclusion and/or adjustment when it acts on a SIP submission. The following documentation is provided to demonstrate that five local and regional wildfire smoke events in the period of June-September 2024 meet the criteria as defined in the document and guidance. This evidence is

[57] https://www.epa.gov/air-quality-analysis/clarification-memo-additional-methods-determinations-and-analyses-modify-air
[58] https://www.epa.gov/scram/2024-appendix-w-final-rule

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included as part of Clark County's request to exclude these data from base and future year design values for ozone SIP attainment demonstrations as a part of their SIP.

Table 58. Summary of events requested for exclusion from ozone SIP base and future year design values.

Event Date	Event Percentile	Sites Exceeded During Event	Type of Event
June 16, 2024	95th – 100th	*(5)* Apex, Garrett Jr. High, Joe Neal, Virgin Valley High School, and Walnut Community Center	Regional Smoke
July 9-12, 2024	94th – 99th	*(7)* Green Valley, Joe Neal, Palo Verde, Paul Meyer, SM Youth Camp, Walnut Community Center, and Walter Johnson	Regional Smoke
July 15-17, 2024	95th – 99.7th	*(7)* Green Valley, Joe Neal, Mountain's Edge, Palo Verde, Paul Meyer, Walnut Community Center, and Walter Johnson	Regional Smoke
July 24-25, 2024	95.5th – 99.7th	*(9)* Apex, Garrett Jr. High School, Green Valley, Joe Neal, Mountain's Edge Park, Palo Verde, Paul Meyer, SM Youth Camp, and Walnut Community Center	Regional Smoke
September 6, 2024	97th	*(1)* Palo Verde	Regional Smoke

7.1.1 Meteorological Analyses

Several analyses were conducted to describe the meteorological conditions that influenced each ozone exceedance date. Understanding the atmospheric dynamics from the surface to the upper levels of the atmosphere can help determine the potential for ozone formation, smoke transport, subsidence of aloft smoke, and the potential for smoke accumulation over the Clark County region. Mixing heights and back trajectories provide further detail as to the origin of air masses affecting a region and whether those air masses contained smoke.

HRRR Smoke Model Output

The National Oceanic and Atmospheric Administration's (NOAA) High-Resolution Rapid Refresh Smoke (HRRR-Smoke) model is a three-dimensional coupled weather-smoke model developed for real-time smoke prediction over flat and complex terrain. The model is run on a 3-km horizontal grid

with 50 vertical levels. It assimilates surface and upper-air meteorological data, as well as fire radiative power data from Visible Infrared Imaging Radiometer Suite (VIIRS) and Moderate Resolution Imaging Spectroradiometer (MODIS) satellites. Taking all these parameters into consideration, it produces hourly operational surface and aloft smoke forecasts that are widely used by air quality forecasters in the United States. Its operational products include predictions of hourly near-surface fine particulate matter with diameters of 2.5 micrometers or less ($PM_{2.5}$) attributed to wildfire smoke.

Upper-Level Analysis

The height of the 500 millibar (mb) pressure level AGL, as well as the curvature of the 500 mb height field, are useful in discerning the potential for ozone production on the synoptic (large) scale. First, higher heights indicate the potential for warm air aloft. Warm air aloft can result in increased atmospheric stability, which results in a decrease in atmospheric mixing. A decrease in vertical mixing can allow pollutants to accumulate near the surface and increase ozone production. Second, higher heights can also indicate warmer surface temperatures. Ozone production increases as temperature increases; thus, increased heights can also provide evidence for enhanced ozone production at the surface. Additionally, an amplified ridge in the height fields and the associated anticyclonic curvature increases the potential for sinking air and sunny skies – conditions that are also conducive to ozone formation. Sinking air can gradually transport aloft layers of smoke down to the surface, or confine near-surface smoke to the lower levels of the atmosphere, both of which can enhance ozone development.

Surface Analysis

Surface pressure patterns can determine whether conditions at ground level support ozone formation. Surface high pressure generally indicates sinking air and increased stability, which can limit atmospheric mixing and increase ozone production. Conversely, surface low pressure typically yields rising air and increased atmospheric mixing, which can reduce ozone formation. However, in the desert during the summer, surface low pressure can also be indicative of rising air due to very warm surface temperatures. The increase in ozone production from warm surface temperatures can sometimes balance out, or even outweigh, the potential improvement in air quality due to enhanced atmospheric mixing in the vicinity of a weak surface low. Furthermore, surface pressure patterns can indicate the strength of surface winds. When lines of constant pressure (isobars) are packed closely together (a strong pressure gradient) on a map of surface weather conditions, there is increased potential for wind and dispersion. Alternatively, when isobars are farther apart (weak pressure gradient), periods of light winds and reduced dispersion are more likely, thus increasing ozone and ozone precursor concentrations.

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Satellite Smoke and Fire Detections

Satellite imagery generated and analyzed by NOAA provides evidence that wildfire emissions are occurring through detections of fires and smoke plumes. If smoke is present in or near the nonattainment area, there is a significant likelihood that ozone precursor emissions or ozone generated by the smoke can impact air quality monitors within the nonattainment area. Satellite observations of smoke can be helpful in determining the potential for smoke-enhanced ozone formation over a region. However, satellite detections of smoke can be hindered by clouds and can be visually difficult to discern because ground colors in desert areas can be similar to smoke. Furthermore, satellite-based detections of smoke plumes do not directly indicate whether the layer of smoke is at ground level or aloft.

NOAA Smoke Discussions and Surface Observations

When available, NOAA smoke discussions are provided for the wildfire event days as additional evidence of smoke presence from known wildfires impacting the region. Additionally, Meteorological Aerodrome Reports (METAR) are also provided when available; METAR are coded hourly weather observations typically collected at airports and used by pilots and meteorologists. METAR reports contain useful information in describing atmospheric conditions, including visibility observations, meteorological variables, weather phenomena, and presence of smoke.

Soundings

Meteorologists use upper-air sounding data to analyze vertical profiles of temperature, dewpoint, and wind speed above the surface. The main factors of interest when analyzing soundings for an event are stability and mixing heights from the air temperature profiles. On a Skew-T Log-P diagram, when the air temperature profile extends sharply to the right with height, that indicates an increase of temperature with height; a stable configuration known as a temperature inversion. Near-surface temperature inversions are common in the overnight and morning hours and can allow pollutants to accumulate near the surface due to inhibited vertical mixing with the upper troposphere. When the temperature profile is parallel to the lines called dry adiabats (which extend upward and to the left), that can indicate a conditionally unstable configuration, which allows pollutants to mix upward into the atmosphere. Unstable configurations are common during the daytime hours as the ground and lower atmosphere heat up. While deep mixing generally hinders ozone development, this mixing can also transport aloft smoke to the surface, which can enhance ozone formation.

The units of the x-axis on sounding plots are temperature in degrees Celsius, and the units of the primary y-axis are pressure in mb, with height in meters or feet also annotated along that axis. The left vertical profile on each graph represents dewpoint temperature, and the right vertical profile represents air temperature. In addition, wind barbs along the secondary y-axis right of the images represent wind speed and direction at each vertical level. These wind barbs can assist in determining

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transport directions at different heights in the atmosphere. Each short feather indicates wind speeds of 5 knots; each longer feather indicates wind speeds of 10 knots; and flags represent wind speeds of 50 knots. By adding the value of the feathers and flags at a given height, the observed wind speed in knots is determined for each level. In addition, the orientation of the barb indicates the direction that the wind is blowing from at each level.

Smoke Transport

NOAA HYSPLIT back trajectories were used to evaluate whether an air mass arriving in the Clark County region originated from, or passed through, areas with active fires or satellite-observed smoke. While there is some uncertainty regarding the height of observed smoke, it has been widely observed that near-surface trajectories that pass through upwind regions with fire and smoke are associated with an increased potential for local and long-range transport of wildfire-generated smoke and its associated ozone precursors.

In analyses performed on the 2024 ozone exceedance days in Clark County, back trajectory heights were chosen based on the specific PBL heights for each exceedance day. Meteorologists at Sonoma Technology used upper-air temperature sounding data to determine daily observed PBL heights during the proposed event days, then selected back trajectory altitudes with heights near the surface, at the middle of the PBL, and at the top of the PBL evaluated for each day. These back trajectories were typically initialized during times of peak heating and ozone formation each afternoon to correlate with observed maximum mixing heights and to best represent the transported air mass impacting peak ozone production.

7.1.2 Volatile Organic Compound (VOC) Analysis

Wildfires emit primary pollutants such as $PM_{2.5}$ and VOCs, which contribute to the formation of secondary pollutants such as ozone. Surface measurements of wildfire primary and secondary pollutants such as $PM_{2.5}$, ozone, carbon monoxide, and nitrogen oxides are used to confirm the presence of wildfire impacts, but each wildfire has a unique emissions profile based on the type of vegetation burning and the plume distance traveled. Therefore, interpreting the typical ground-based pollutant measurements to determine wildfire impacts can be complicated (e.g., rapid production of ozone, variable production of ozone, and depletion of ozone downwind of a wildfire). For this reason, wildfire tracers (i.e., compounds that have a medium-to-long atmospheric lifetime that are almost solely emitted from wildfires) are key in identifying the direct contribution of wildfire emissions, especially in urban areas where pollutant concentrations are typically enhanced.

Acetonitrile is often used as a wildfire tracer due to its long atmospheric lifetime (5-6 months), emission sources that are predominantly from wildfires (~90-95% from wildfires and <6% from automobile emissions), and low background mixing ratios (0.1-0.3 ppb). However, acetonitrile has been observed from some urban sources such as universities and labs where it is used as a solvent in

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liquid chromatography. Ultimately, due to its low emissions from sources other than wildfires and long atmospheric lifetime, acetonitrile is an excellent wildfire tracer. Due to the occurrence of some other local sources of acetonitrile, typically this wildfire tracer is measured concurrently with other reactive oxygenated VOCs, which are typically emitted from wildfires (e.g., acetone, furan, acrolein, methacrolein, methyl ethyl ketone [MEK], 2,3-butanedione, 2,5-dimethylfuran, and furfural). To fully characterize the sample taken, it is best practice to also sample anthropogenic tracers such as pentane, benzene, and toluene. Overall, these tracers can help identify when, and how intensely, wildfire smoke is in a given area.

Since 2023, Clark County has been measuring acetonitrile as well as other wildfire- and anthropogenic-specific VOCs via the EPA TO-15 method at the Jerome Mack, Sunrise Acres, and Jean sites. The Jerome Mack and Sunrise Acres sites are urban sites, while the Jean site is typically upwind of the Las Vegas Valley and considered to be a background site. Information on TO-15 data completeness for all sites is included in Table 59. Additionally, data verified to be wildfire-impacted for all sites is included in Table 60.

Table 59. 2023-2024 TO-15 sample validity summary.

Data Quality	2023	2024
Valid	89%	85%
Invalid	11%	15%

Table 60. Number and percent of valid observations of unique chemical species by sample type and year.

Sample type	2023	2024
Fire	85 (7%)	456 (46%)
No fire	1205 (93%)	540 (54%)

Ratio analyses can identify differences between wildfire and background conditions. Ranges of these ratios can be used to help identify air parcels potentially impacted by wildfires. In this case, we use the 2023-2024 Clark County TO-15 VOC data, including the tracer acetonitrile, to determine fire and no-fire conditions. This analysis showed significant differences between wildfire and background days. To quantify these differences, the Wilcoxon signed rank test was used on each set of VOC ratios to confirm statistical significance. Table 61 shows the statistical results for each of the ratios.

Table 61. VOC ratios with a significant difference in background versus wildfire concentrations for the 2023 and 2024 sampling periods.

Ratio	Type	Mean	Standard Deviation	Median	Interquartile Range	N	Min	Max
Acetone:Acrolein (ACE_ACR)	Background	15.73	10.40	13.75	6.82	163	3.07	92
	Wildfire	19.17	8.36	16.76	8.72	48	4.64	40
Acetonitrile:Acetone (ACN_ACE)	Background	0.04	0.02	0.03	0.03	163	0.01	0.16
	Wildfire	0.07	0.03	0.07	0.04	48	0.02	0.14
Acetonitrile:Acrolein (ACN_ACR)	Background	0.47	0.49	0.33	0.29	163	0.07	3.65
	Wildfire	1.13	0.59	1.04	0.74	48	0.33	2.32
Acetonitrile:Benzene (ACN_BZN)	Background	0.43	0.24	0.42	0.20	163	0.14	1.04
	Wildfire	1.15	0.94	0.65	0.84	48	0.57	2.24
Acetonitrile:Pentane (ACN_PEN)	Background	0.42	0.30	0.35	0.31	163	0.02	1.45
	Wildfire	0.79	0.57	0.86	0.75	48	0.02	2
Acetonitrile:Toluene (ACN_TOL)	Background	0.38	0.37	0.29	0.28	163	0.03	1.97
	Wildfire	0.71	0.59	0.55	1.00	48	0.04	2

Mean ratio values for Acetone: Acrolein (ACE_ACR) were much higher than the other five VOC ratios, with the mean wildfire regime ratio nearing 20. By comparison, the mean ratio for the background regime was just under 16. Wildfire VOC ratios for the median, interquartile range, and minimum values were all larger than the background regime. Figure 247 displays box and whisker plots for the six ratios that exhibited a significant difference between wildfire and background conditions as determined by the Wilcoxon signed rank test.

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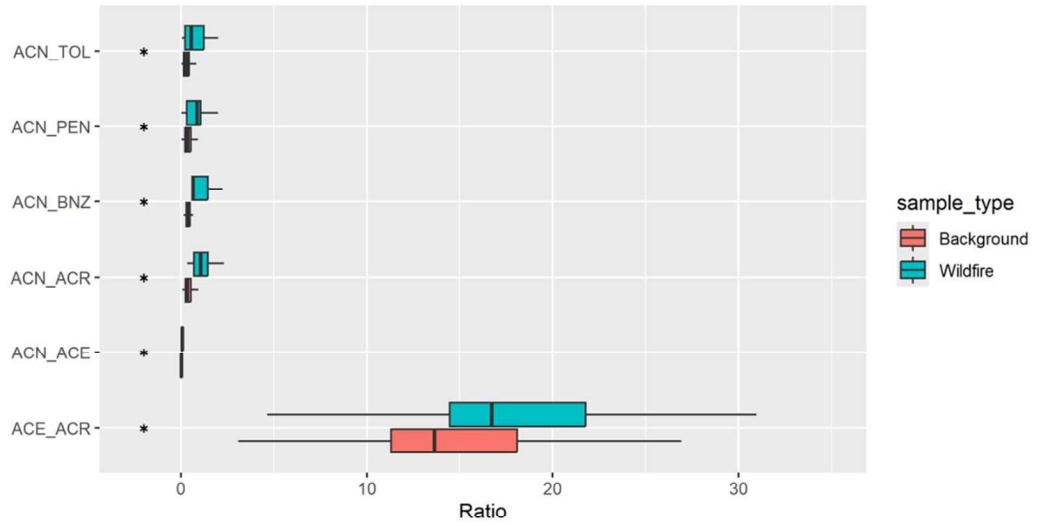

Figure 247. Box and whisker display for the six VOC ratios with significant differences between background and wildfire conditions.

For the remaining five ratios with significant differences in wildfire versus background conditions, mean ratio and median ratio values were generally between 0 and 1. Figure 248 shows a zoomed-in version of the box and whisker plot from Figure 247 to better decipher each regime at this smaller range. Of the five ratios shown, the key species contributing to higher wildfire versus background ratios is Acetonitrile (ACN). This underscores the importance of Acetonitrile as a key wildfire tracer.

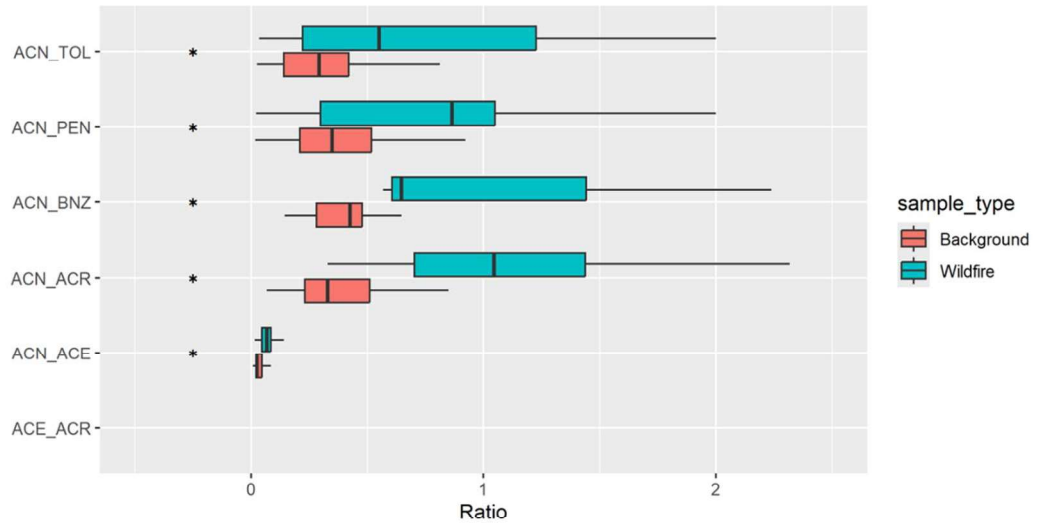

Figure 248. Box and whisker display for the six VOC ratios with significant differences between background and wildfire conditions. ACE_ACN are not shown due to the ratios being larger than 2.

For the following events, if TO-15 VOC data was available for the date, information on the VOC ratios will be provided for all six ratios.

7.1.3 Event Statistics

Statistics are used to provide analysis of data, identify patterns, and make predictions, as well as understand trends, evaluate outcomes, and make informed decisions based on evidence. Percentile rankings were used to quantify and interpret data to provide evidence that observed data (ozone exceedances) and the impacts of smoke were outside the normal distribution and thus an atypical exceedance event. Event statistics summarize the percentile of ozone measurements on the atypical dates compared with six years of ozone data (2019 – 2024), where available. The percentile rank is calculated across the ozone production season in the nonattainment area (April 1 – September 31).

Most observation sites that were exceeded during the exclusion events have ozone measurement data available for 2019 – 2024. However, data collection began after 2019 at several sites in the non-attainment area. Table 62 provides a list of the data record length for the sites used to calculate event statistics. Sites that have less than six years of data available for a given parameter discussed in text will be indicated with an asterisk.

Table 62. Summary of data record length at sites exceeded during event and used for calculating event statistics.

Length of Data Record	Starting Month and Year	Site Names
2019 – 2024	*N/A*	Green Valley Joe Neal Palo Verde Paul Meyer SM Youth Camp Walter Johnson
2021 – 2024	October 2020 April 2021 January 2021 June 2021	Mountain's Edge Garrett Jr. High School Virgin Valley High School Walnut Community Center
2023 – 2024	June 2023	Apex

7.2 June 16, 2024

7.2.1 Event Summary

The unrepresentative ozone event took place on June 16, 2024, and affected the following five sites in Clark County, NV: Apex, Garrett Jr. High, Joe Neal, Virgin Valley High School, and Walnut Community Center. Figure 249 shows the time series of hourly ozone and statistical median overlaid onto the 10th to 90th percentile concentrations at the exceeding sites on the day before, the day of, and day after the atypical ozone event.

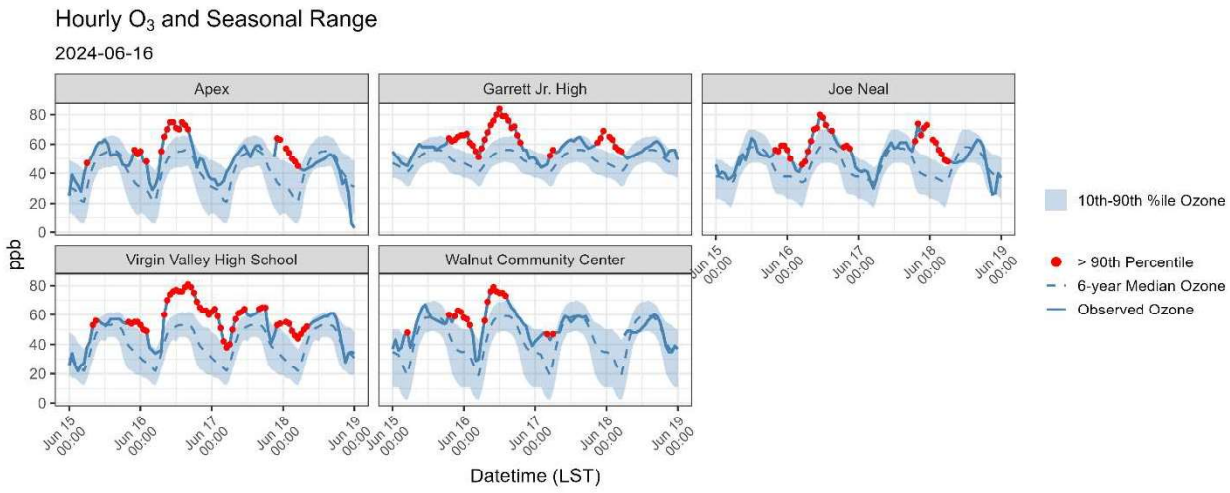

Figure 249. Hourly ozone concentrations (ppb) compared to 6-year ozone season (April 1 – September 30) hourly medians and 10th-to-90th percentiles. Red points indicate hourly ozone concentrations that exceeded the 90th percentile. Note: the Apex site only includes data from June 1, 2023, and onwards; the Garrett Jr. High site only includes data from April 1, 2021, and onwards; the Virgin Valley High School only includes data from 2021, and onwards; and the Walnut Community Center site only includes data from June 1, 2021, and onwards.

Beginning at approximately 18:00 PST on June 15, all five affected sites began to measure ozone above the 6-year ozone season median and 90th percentile. Peak ozone measurements at each site were recorded at midday on June 16, all of which exceeded the 6-year ozone season median values and 90th percentile concentrations. Ozone concentrations at the affected sites returned to typical seasonal values by the afternoon and evening of June 18. The MDA8 ozone concentrations at affected sites ranged from 71-77 ppb: 72 ppb at Apex, 77 ppb at Garrett Jr. High, 71 ppb at Joe Neal, 77 ppb at Virgin Valley High School, and 74 ppb at Walnut Community Center on June 16.

Wildfires west of Clark County in southern California were identified as a major contributor to this event. Evidence includes (1) HMS smoke perimeters over the county; (2) HYSPLIT trajectories and

meteorological analysis showing accumulation of smoke in Clark County; (3) visible smoke in camera images and news coverage; and (4) synchronous enhancement of $PM_{2.5}$ and carbon monoxide (CO) concentrations as well as enhanced ratios of $PM_{2.5}$ to particulate matter with a diameter of 10 micrometers or less (PM_{10}) that aligned with ozone enhancement. This combination of evidence indicates that this is an unrepresentative event for base and future design value ozone assessments.

7.2.2 Identification of Wildfire(s)

The Post Fire in southern California broke out on June 15, 2024 (Figure 251), and was active during June 16, 2024, the exclusion day. The Post Fire began near Gorman, CA, northwest of Santa Clarita, CA, and was contained by June 24, 2024. By June 16, 2024, at 02:00 PST, the Post Fire had reached 12,265 acres (Figure 252).[59] The Little Twist Fire 15.4 miles southeast of Beaver, UT, and northeast of Clark County was also active on the days leading up to and during the exclusion day, and may have contributed to the smoke plume covering the southwestern United States (Figure 250). The Little Twist Fire was reported to have grown to 2,402 acres by June 15.[60]

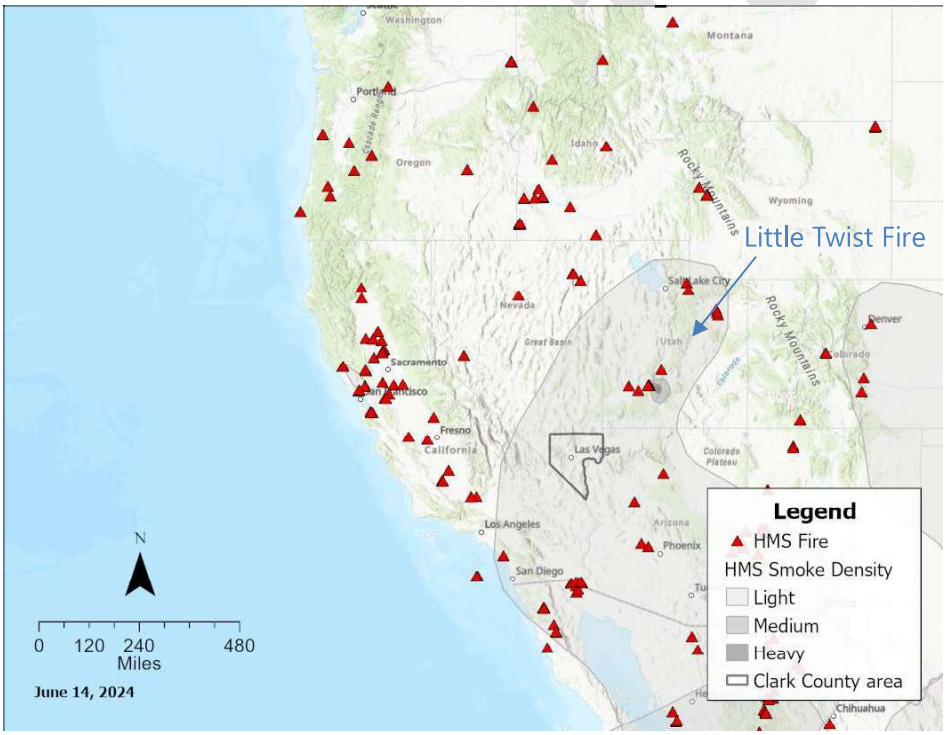

Figure 250. Western U.S. view of HMS fire detections (red triangles) and smoke density (grey contours) from June 14, 2024.

[59] https://www.fire.ca.gov/incidents/2024/6/15/post-fire/updates/6ab5c683-df51-4b72-9ace-84f894f44507
[60] https://kutv.com/news/local/little-twist-fire-est-at-25k-acres-expected-to-ramp-up-as-humidity-drops-winds-pick-up-beaver

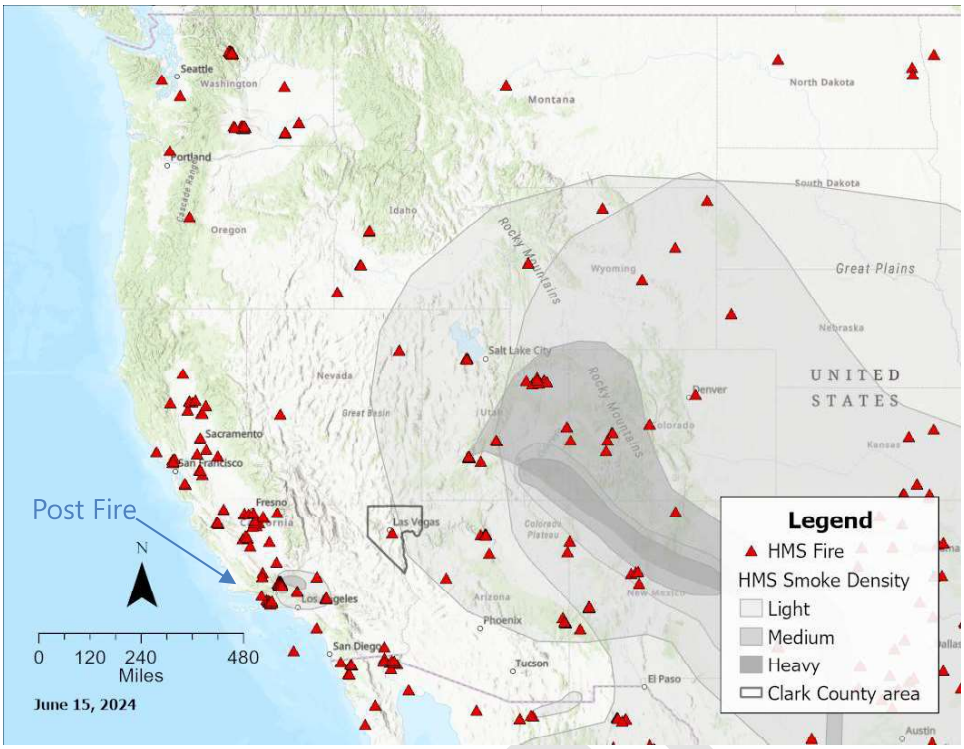

Figure 251. Western U.S. view of HMS fire detections and smoke density from June 15, 2024.

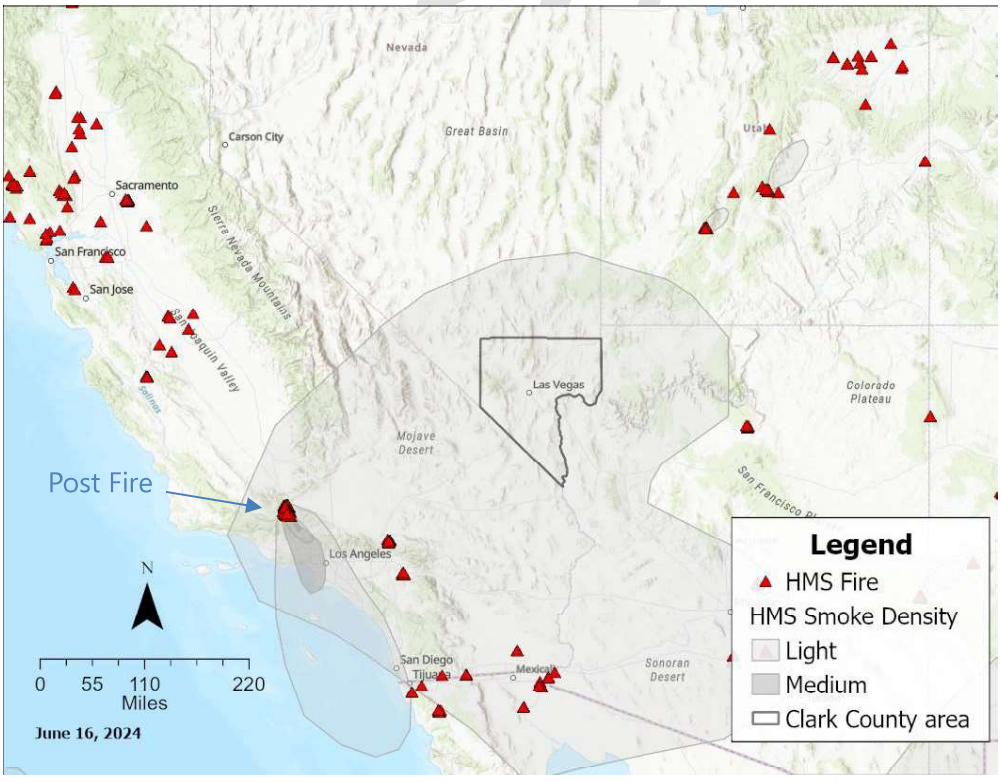

Figure 252. Regional view of HMS fire detections and smoke density from June 16, 2024.

7.2.3 Meteorological Analysis

HRRR-Smoke Model Output

The High-Resolution Rapid Refresh Smoke (HRRR-Smoke) model is a three-dimensional coupled weather-smoke model developed for real-time smoke prediction over flat and complex terrain. The model is run on a 3-km horizontal grid spacing at 50 vertical levels. It assimilates surface and upper-air meteorological and smoke data every hour, including fire radiative power data from VIIRS and MODIS satellites. Taking all these parameters into consideration, it produces hourly operational surface and aloft smoke forecasts that are widely used by air quality forecasters in the United States.

Figure 253 shows the archived HRRR-Smoke forecast product for June 16, 2024, initialized at 22:00 PST on June 15. The model output predicted near-surface smoke in the Las Vegas area that ranged from 20 to 100 µg/m^3 at 02:00 PST on June 16, originating from the Post Fire in southern California.

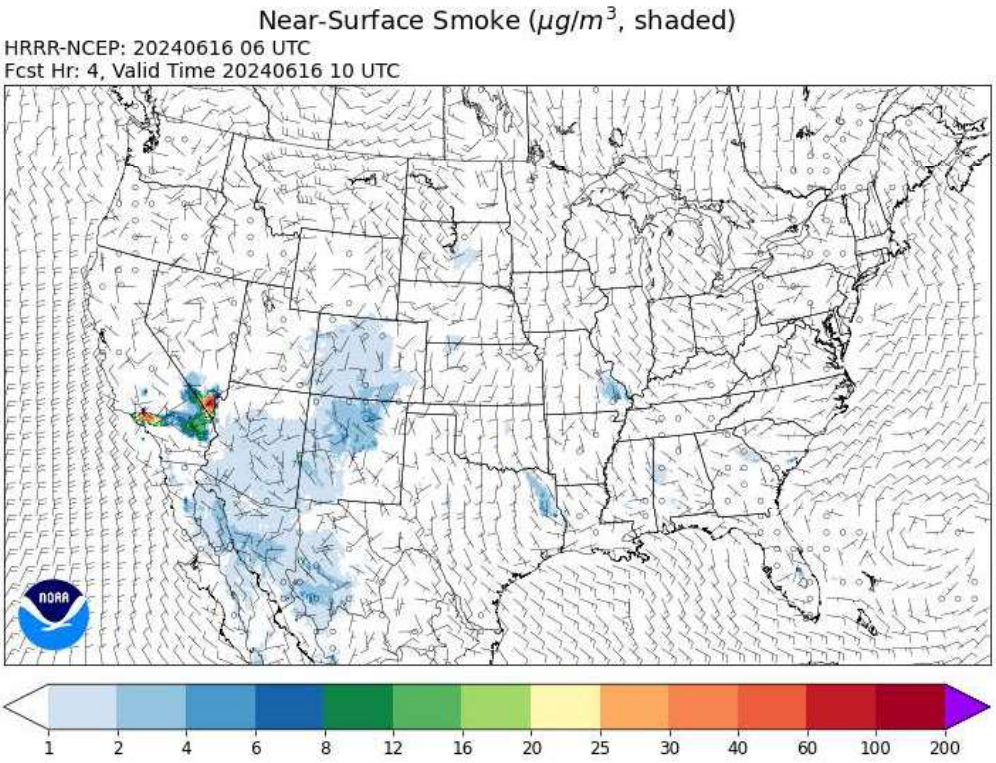

Figure 253. Model prediction (initialized 22:00 PST June 15) of near-surface smoke (µg/m^3) at 02:00 PST on June 16, 2024, shows near-surface smoke over southern Nevada. Image courtesy of NOAA's Global Systems Laboratory.

Upper-Level Weather Patterns

The height of the 500-millibar (mb) pressure level AGL, as well as the curvature of the 500-mb height field, can be useful in discerning the potential for ozone production on the synoptic (large) scale. Low pressure aloft is generally associated with cloud development and precipitation as cool temperatures in the mid-levels promote atmospheric mixing and instability. Areas of aloft low pressure generally coincide with decreased ozone development. Alternatively, high pressure aloft is normally indicative of a warm dry air mass in the mid-levels of the atmosphere. Those warm, dry mid-level conditions often promote sunny skies, increasing the potential for ozone development.

The contour plots of geopotential height at 500 mb (approximately 18,000 feet) from June 16, 2024, pictured in Figure 254 show a broad upper-level trough of low pressure over the western United States.

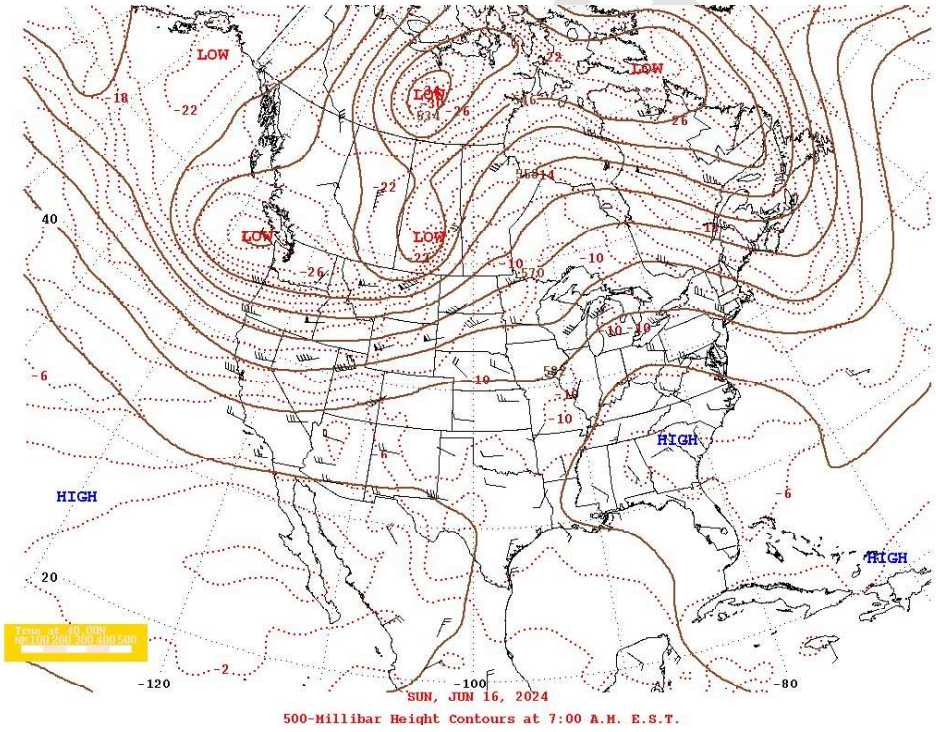

Figure 254. 500-mb heights, winds, and temperatures at 04:00 PST on June 16, 2024. Image courtesy of NOAA's Weather Prediction Center.

Although the upper-level trough of low pressure over the West Coast would normally be associated with decreased ozone formation, in this case it likely enhanced atmospheric mixing and strengthened the low-level westerly winds, which facilitated the transport of smoke from the Post Fire into Clark County.

Surface Weather Patterns

Surface pressure patterns can indicate whether conditions at ground level are conducive to pollutant transport and accumulation, as well as ozone formation. Surface high pressure generally indicates sinking air and increased stability, which can limit atmospheric mixing and increase ozone production. Conversely, surface low pressure can indicate rising air and increased atmospheric mixing, which can help reduce ozone formation. In some cases, however, enhanced mixing associated with low pressure systems and frontal passages can bring aloft smoke to the surface, further supporting ozone development.

Surface pressure patterns also indicate the potential for wind. When lines of constant pressure (isobars) are packed closely together (strong pressure gradient), there is increased potential for stronger wind and increased dispersion. Alternatively, when isobars are spaced farther apart (weak pressure gradient), periods of light winds and reduced dispersion are more likely. The orientation of the pressure gradient influences the direction of surface winds. Stronger surface winds associated with low pressure systems and frontal passages can increase mixing and dispersion in the lower levels of the atmosphere. However, these winds can also facilitate rapid smoke transport.

Figure 255 shows a surface cold front stalled just north of Clark County. South of the front, with high surface pressure over the comparatively cool temperatures of the eastern Pacific, a strengthening west-to-east pressure gradient developed, producing moderate southwesterly winds through the early morning hours of June 16. Similar to the upper-level weather pattern on this day, although this pattern is not normally associated with enhanced ozone formation, the position of the cold front, the configuration of the pressure gradient, and the resulting surface winds contributed to smoke transport into the Clark County area.

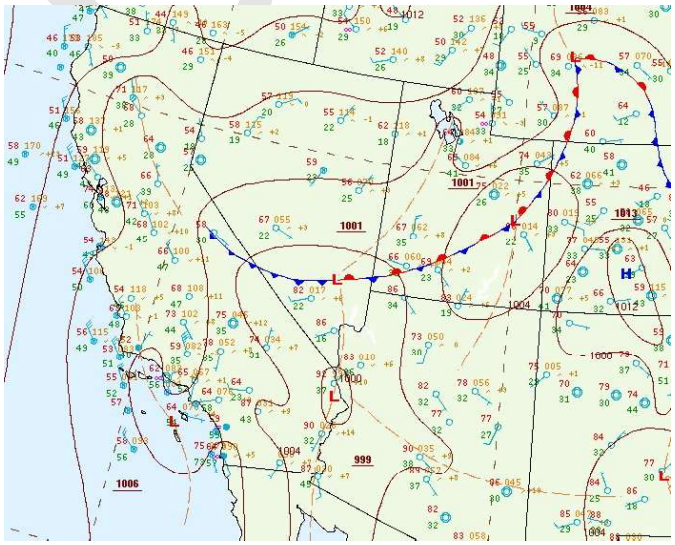

Figure 255. Surface weather conditions at 07:00 PST on June 16, 2024. Image courtesy of NOAA's Weather Prediction Center.

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Observed daily average surface winds at Las Vegas-Harry Reid International Airport (KLAS) on this day were moderate out of the southwest, with an average wind speed of 10 mph and a vector-average wind direction of 210 degrees. Consistent with the upper-level trough of low pressure and moderate onshore winds, the maximum observed temperature was slightly cooler than average for June in Las Vegas at 104°F (Table 63).

Table 63. Maximum surface temperature, average wind speed, and average wind direction at Las Vegas-Harry Reid International Airport (KLAS) on June 16, 2024.

Date	Maximum Temperatures (°F)	Average Wind Speed (mph)	Average Wind Direction (degrees)
June 16, 2024	104	10	210

Vertical Temperature Profiles and Mixing Heights

Soundings are one of the most useful tools to determine how deeply the atmosphere mixes each afternoon, and whether mixing could be deep enough to bring aloft smoke to ground level. When determining the height of mixing from soundings, meteorologists compare the observed change of temperature with height (lapse rates) with the background grid of dry adiabats. Dry adiabats follow the dry adiabatic lapse rate, a decrease of roughly 10°C per kilometer. If the observed temperature lapse rate parallels the dry adiabats from the surface upward, it indicates that vertical mixing occurred from the surface to the height where the observed lapse rate is no longer parallel to the dry adiabats. And while deep mixing normally helps ozone concentrations plateau during the afternoon due to mixing and dispersion, when that mixing transports aloft smoke to the surface, ozone formation can be enhanced.

The units of the x-axes on the soundings in Figure 256 are temperature in degrees Celsius, and the units of the primary y-axes are pressure in millibars, with height in meters also annotated along that axis. The left black vertical trace on each graph represents observed dewpoint temperature, and the right black vertical trace represents observed air temperature. The green, slightly curved diagonal lines that slope downward from left to right are the dry adiabats. As long as the right black line originating from the surface parallels the green lines, vertical mixing is inferred through that layer, called the boundary layer. The boundary layer is the layer of air that can freely mix with air near the surface. The height of the top of the boundary layer is called the mixing height. The plot in Figure 256 shows that the afternoon mixing height was at least 3,000 m AGL in Las Vegas on the afternoon of June 16.

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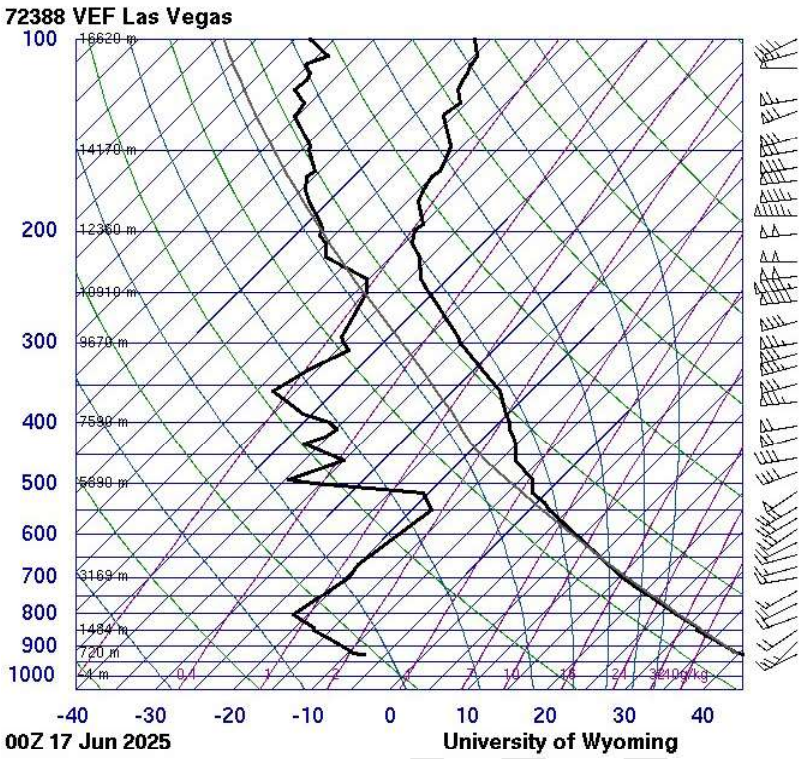

Figure 256. Observed soundings at 16:00 PST on June 16. Images courtesy of the University of Wyoming.

In addition to assessing mixing heights from plots of vertical temperature, meteorologists also used raw vertical temperature data to determine afternoon mixing heights. Using sounding data from the KVEF site in Las Vegas, the mixing height was determined to be the height at which the aloft potential temperature exceeded the surface potential temperature. Using this method, the mixing height at 16:00 PST on June 16 was determined to be 3,500 m AGL.

Smoke Transport

The mixing heights found in the previous section are not only useful for determining the general potential for mixing aloft smoke to the surface. These heights can also be used to compute the origins of air masses that arrive in the boundary layer at a specified time using the HYSPLIT model. Initialized near the time of observed maximum ozone concentrations, back trajectories were computed for the afternoon of June 16. The back trajectories were run for up to 72 hours to determine air mass source regions at three different heights within the boundary layer (i.e. below the mixing height) for each day. These trajectories were overlaid on imagery of satellite smoke and fire detections from previous days to determine the potential for smoke transport.

Figure 257 displays 33-hr back trajectories ending at 50 m, 1,700 m, and 3,500 m AGL in Las Vegas at 13:00 PST on June 16. The HMS fire detections (red triangles) and smoke plumes (gray shading)

correspond to the previous day, June 15. Date and time stamps indicate air parcel positions along those trajectories.

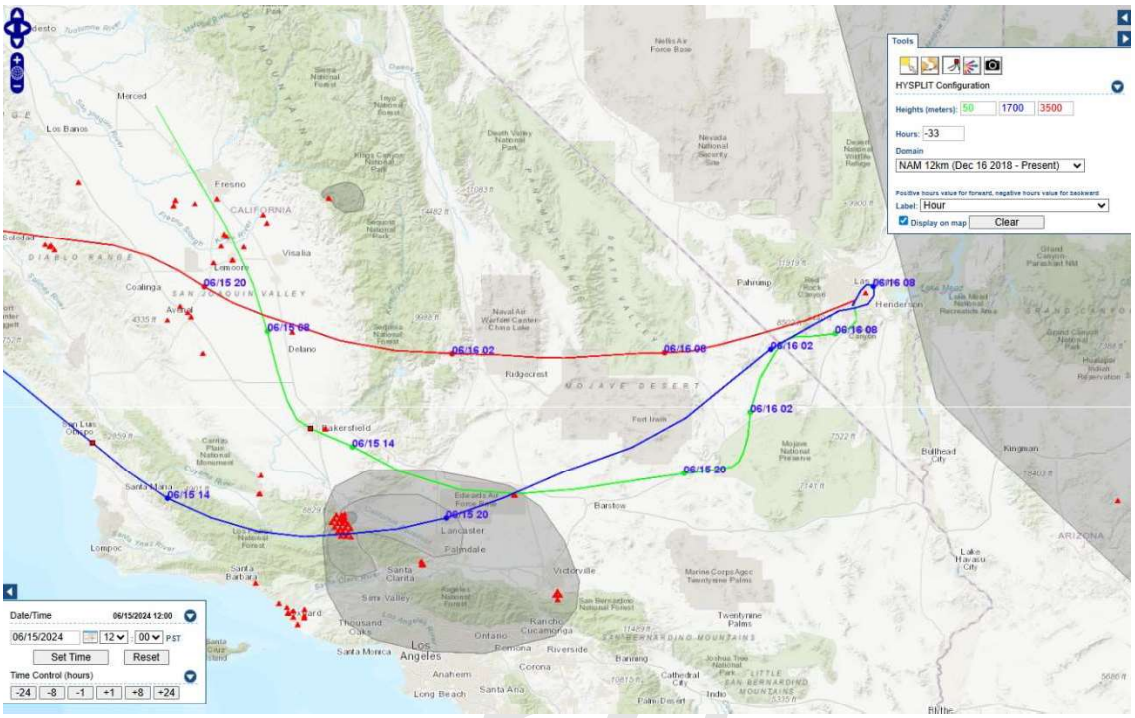

Figure 257. 33-hr boundary-layer back trajectories from the NAM model ending in Las Vegas at 13:00 PST on June 16, 2024, at 50 m (green line), 1,700 m (blue line), and 3,500 m (red line). HMS fires (triangles) and smoke (gray shading) on June 15 are also displayed. Image courtesy of EPA's AirNow-Tech.

As shown in Figure 257, the back trajectory ending in Las Vegas at 13:00 PST on June 16 at the 1,700 m AGL level (blue line) indicates direct transport from a large fire detected northwest of Santa Clarita on the previous day, June 15. Additionally, back trajectories at both 50 m and 1,700 m AGL indicate a transport path through the smoke plume associated with that fire. Furthermore, the back trajectory at 50 m AGL extends to the northwest in the San Joaquin Valley where several additional, small fires were detected on June 15. However, the dominant smoke transport path was from the fire detected to the northwest of Santa Clarita.

The transport paths at lower levels – 50 m and 1,700 m – are consistent with the surface weather patterns and observations at KLAS on June 16, which indicated southwesterly flow associated with pre-frontal conditions at the surface. The upper-level trough of low pressure likely enhanced mixing and strengthened this low-level southwesterly flow, further supporting the smoke transport mechanism from the southern California fire into the Clark County area.

These trajectories provide evidence of direct smoke transport into the Clark County region on June 16 from a large fire and the resulting smoke plume observed in southern California the previous day.

In addition to the trajectories indicating smoke transport into the Clark County area from regional fires, the NOAA HMS smoke discussion text (Figure 258) described smoke transport into southern Nevada on June 16.

Sunday, June 16, 2024

DESCRIPTIVE TEXT NARRATIVE FOR SMOKE/DUST OBSERVED IN SATELLITE IMAGERY THROUGH 1620Z June 16, 2024

SMOKE: Central US/Southern US/ Atlantic Seaboard...
Continued remnant smoke originating from previous and ongoing wildfires in Canada, has mixed with both current smoke from ongoing fires in the Central United States and continuing smoke/aerosols emanating from the Gulf of Mexico. The smoke was mostly moving eastward within the Central and Eastern United States into the Atlantic Ocean.

Southern California...
Lite to Medium density smoke emanating from suspected wildfires in Southern California was observed moving northeast and eastward into Southern Nevada and Northwestern Arizona.

Figure 258. NOAA's HMS-Smoke text product from 10:20 PST on June 16, 2024.

Summary

On June 16, 2024, meteorological, fire, and smoke conditions likely contributed to smoke transport into the Clark County area, which subsequently enhanced ozone production. Specifically,

- A broad upper-level trough of low pressure enhanced atmospheric mixing and strengthened the low-level southwesterly winds.
- Moderate southwesterly pre-frontal winds at the surface and in the lower levels of the atmosphere transported near-surface and ground-level smoke from the Post Fire in southern California into the Clark County region.
- Atmospheric mixing up to 3,500 m likely facilitated mixing of aloft smoke to the surface.

7.2.4 Surface Impacts

Smoke from the Post Fire spread over Clark County on June 16, 2024. Figure 259 and Figure 260 show photos looking toward the north, northeast, south, and northwest from the M Resort Hotel. Webcam images show increasingly smoky conditions from June 15 to June 16. The incoming smoke was a newsworthy occurrence, as reported on by the local Fox News channel. Their article from June 16, 2024, said "Clark County issues air quality advisory for wildfire smoke," and reported an air quality

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alert for June 16 and June 17 due to the Post Fire in California, which was causing smoke to drift into the valley.[61]

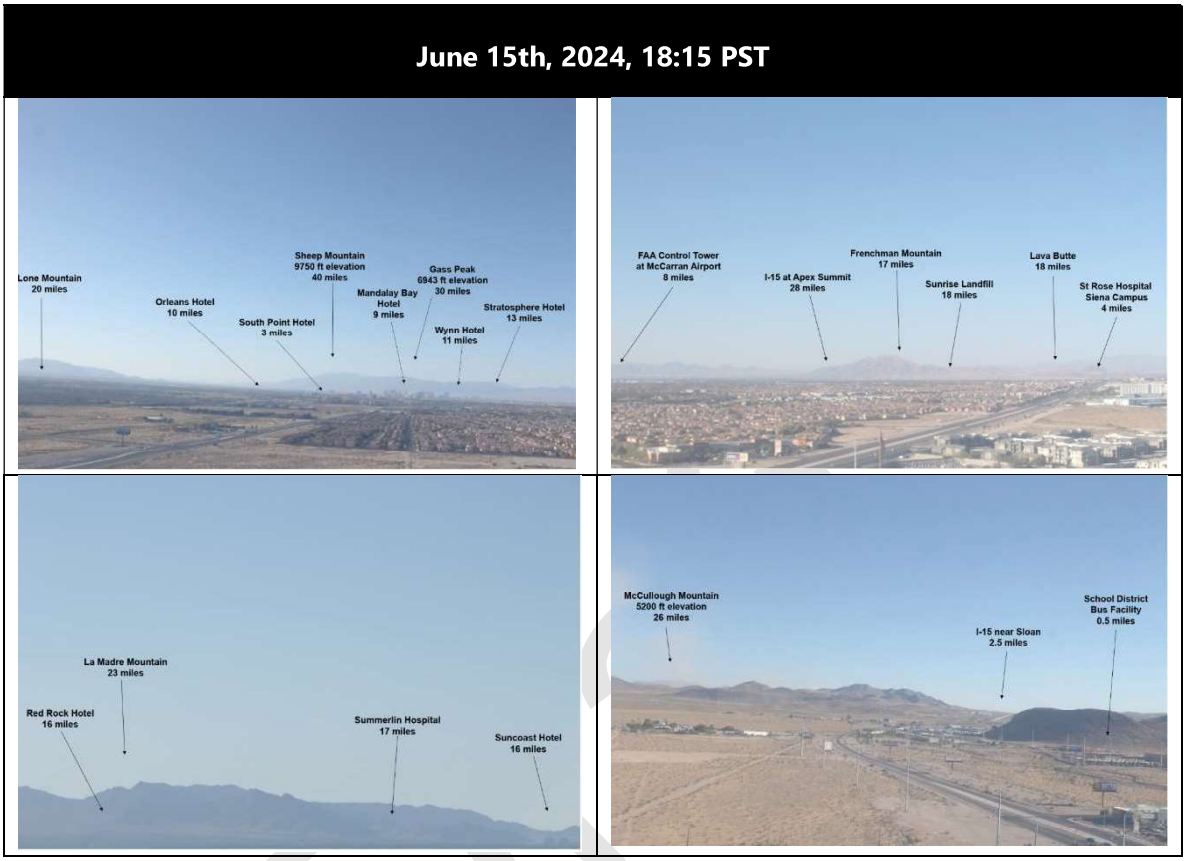

Figure 259. Webcam images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) views from the M Resort Hotel in Clark County, NV, on June 15, 2024, at 18:15 PST.

[61] https://www.fox5vegas.com/2024/06/16/clark-county-issues-air-quality-advisory-wildfire-smoke/

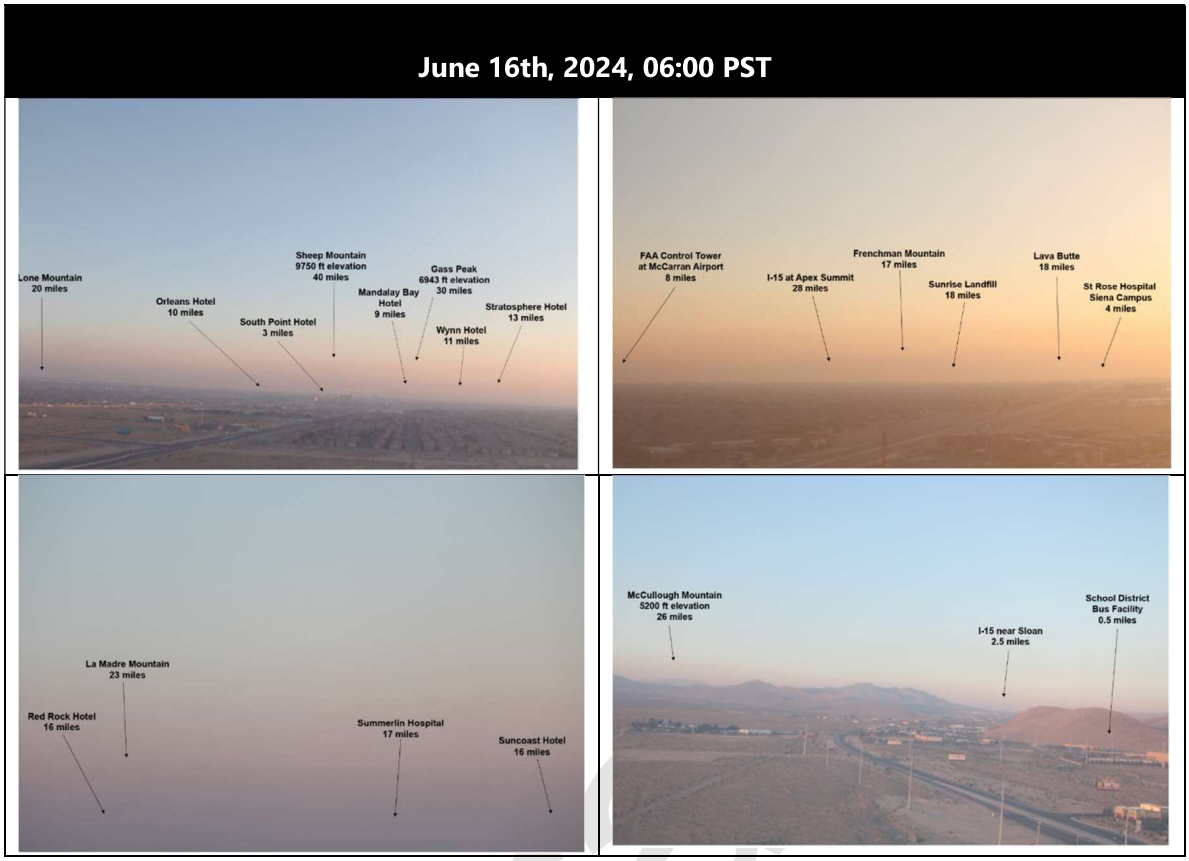

Figure 260. Webcam images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) views from the M Resort Hotel in Clark County, NV, on June 16, 2024, at 06:00 PST.

$PM_{2.5}$ and CO concentrations were enhanced in Clark County during the early morning and early afternoon of June 16 between 01:00 PST and 13:00 PST as smoke from the Post Fire entered the region and mixed towards the surface. This provides further evidence that wildfire smoke was present as an atypical influence on ozone during the exclusion period.

Figure 261 shows hourly $PM_{2.5}$ at four of the affected sites (Garrett Jr. High*, Joe Neal, Virgin Valley High School*, and Walnut Community Center*) overlaid on the multiyear 10th to 90th percentile hourly concentrations during ozone season (April to September). $PM_{2.5}$ concentrations at all sites rose sharply to a peak as smoke moved into the area, reaching concentrations that far exceeded the 90th percentile concentration. Garrett Jr. High*, Joe Neal, and Walnut Community Center* experienced high $PM_{2.5}$ concentrations between 00:00 PST and 13:00 PST on June 16. Virgin Valley High School* experienced increased $PM_{2.5}$ concentrations between 07:00 PST and 19:00 PST on June 16. Virgin Valley High School* is located approximately 80 miles northeast of Las Vegas. The difference in time between enhanced $PM_{2.5}$ concentrations at Virgin Valley High School* compared to all other sites in the Las Vegas area is consistent with westerly smoke moving across the county.

Figure 262 shows hourly CO concentrations at Walnut Community Center* during June 16 overlaid onto the seasonal 10th to 90th percentile range. During the morning of June 16, CO concentrations peaked at or above the 90th percentile concentration from 01:00 PST to 05:00 PST and 08:00 PST to 14:00 PST and remained above the seasonal median from 01:00 PST to 14:00 PST, concurrent with enhanced $PM_{2.5}$ concentrations.

The ratio of $PM_{2.5}$-to-PM_{10} concentrations was examined to determine if wildfire smoke entered Clark County on or before the atypical event. Enhanced $PM_{2.5}$-to-PM_{10} ratios indicate the presence of wildfire smoke at the surface. Figure 263 shows a time series of $PM_{2.5}$-to-PM_{10} ratios from June 15 through June 18 overlaid onto the 10th to 90th percentile for the following sites: Garrett Jr. High*, Joe Neal, Virgin Valley High School*, and Walnut Community Center*. Concurrent with enhanced $PM_{2.5}$ and CO concentrations, $PM_{2.5}$-to-PM_{10} ratios exceeded the 6-year hourly average and the 90th percentile at all sites. The ratio reached approximately 0.7 at the Las Vegas sites (Garrett Jr. High*, Joe Neal, and Walnut Community Center*) and 0.55 at Virgin Valley High School*. This is indicative of wildfire smoke entering the area. These observations provide evidence that wildfire smoke entered Clark County on June 16 containing enhanced $PM_{2.5}$ which increased $PM_{2.5}$-to-PM_{10} ratios during the atypical ozone event on June 16.

The concurrence of widespread enhanced $PM_{2.5}$ and CO concentrations and $PM_{2.5}$-to-PM_{10} ratios, and webcam images in Clark County during the early hours of June 16 provide evidence that surface-level smoke was present in Clark County during the atypical event.

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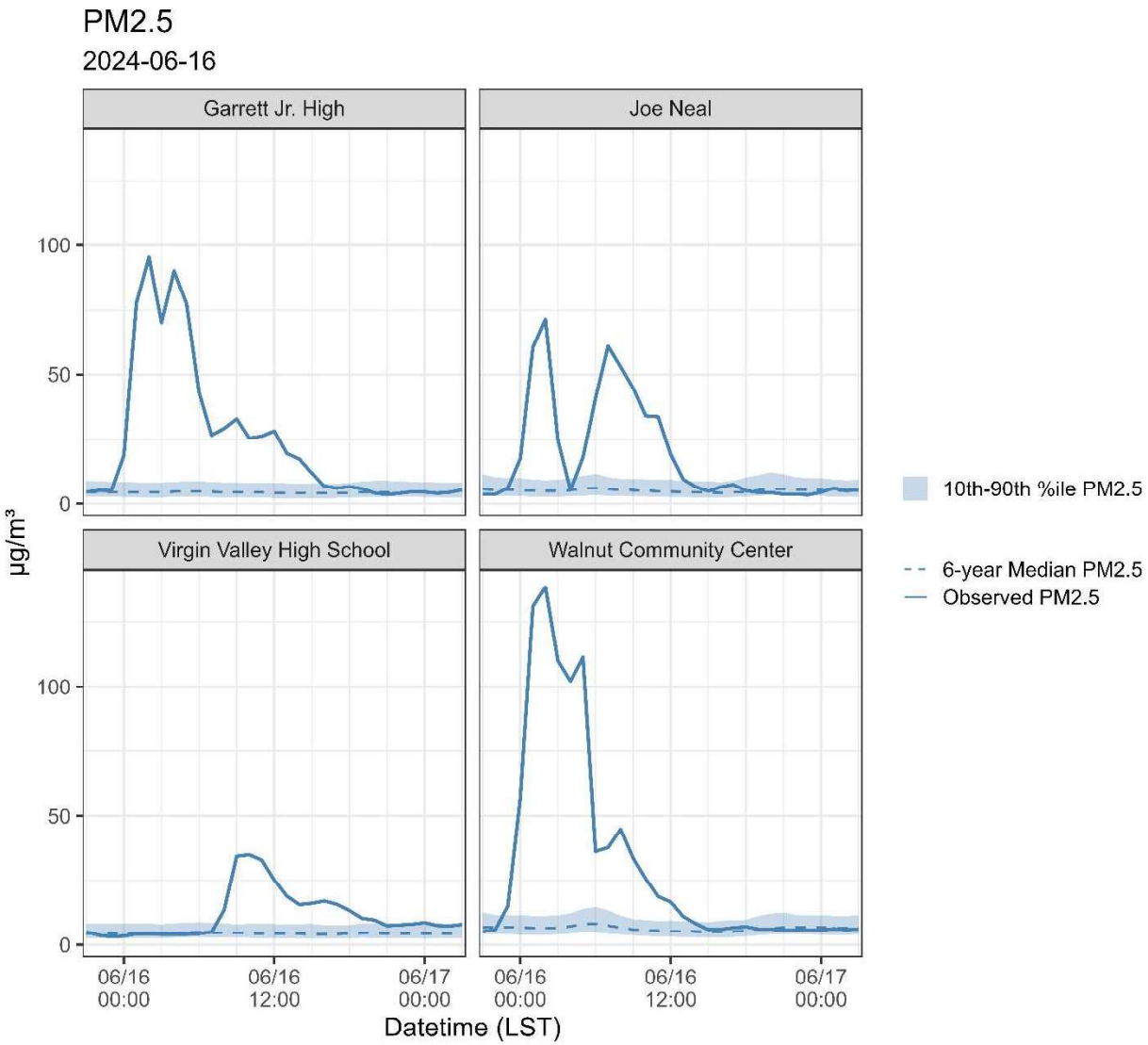

Figure 261. Hourly $PM_{2.5}$ measurements overlaid on the 10th-to-90th percentile diurnal concentration at Garrett Jr. High* (AQS site code 320030602), Joe Neal (AQS site code 320030075), Virgin Valley High School* (AQS site code 320030024), and Walnut Community Center* (AQS site code 320032003). The 10th-to-90th percentile concentration is calculated across the ozone production season (April-September) of 2019-2024 at Joe Neal and 2021-2024 for all other sites.

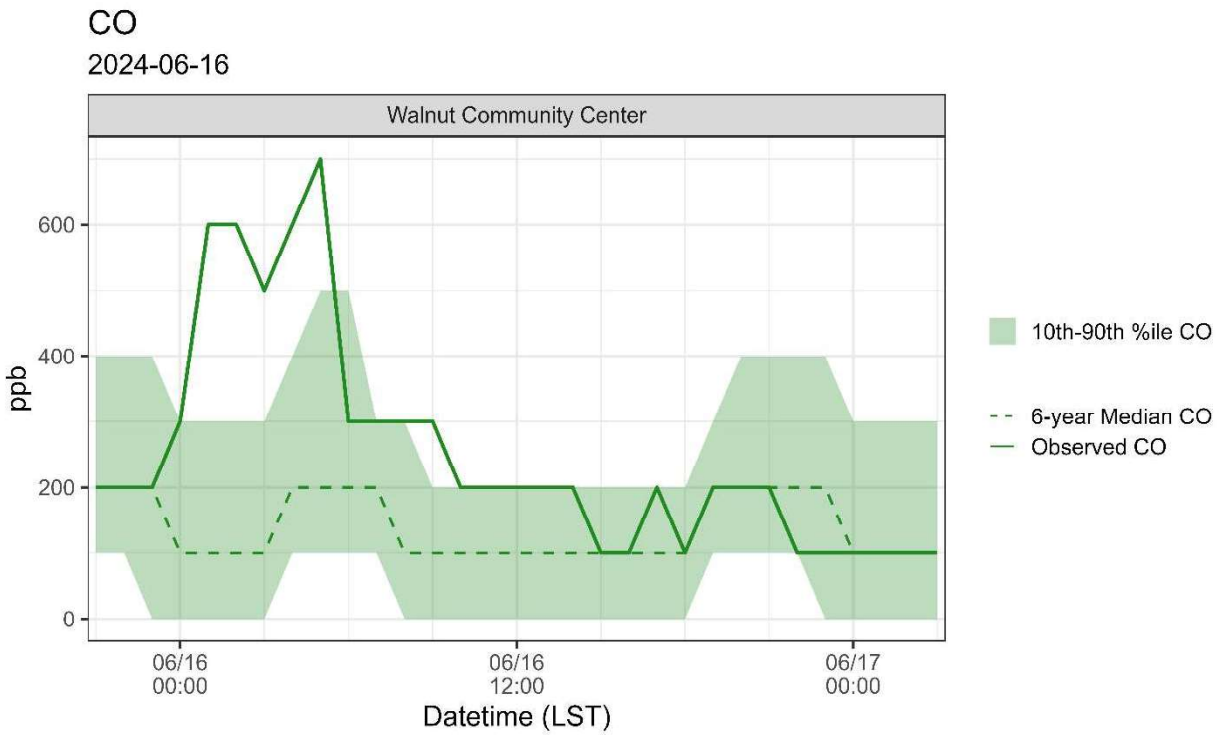

Figure 262. Hourly CO measurements overlaid on the 10th-to-90th percentile diurnal concentration at Walnut Community Center* (AQS site code 320032003). The 10th-to-90th percentile concentration is calculated across the ozone production season (April-September) of 2021-2024.

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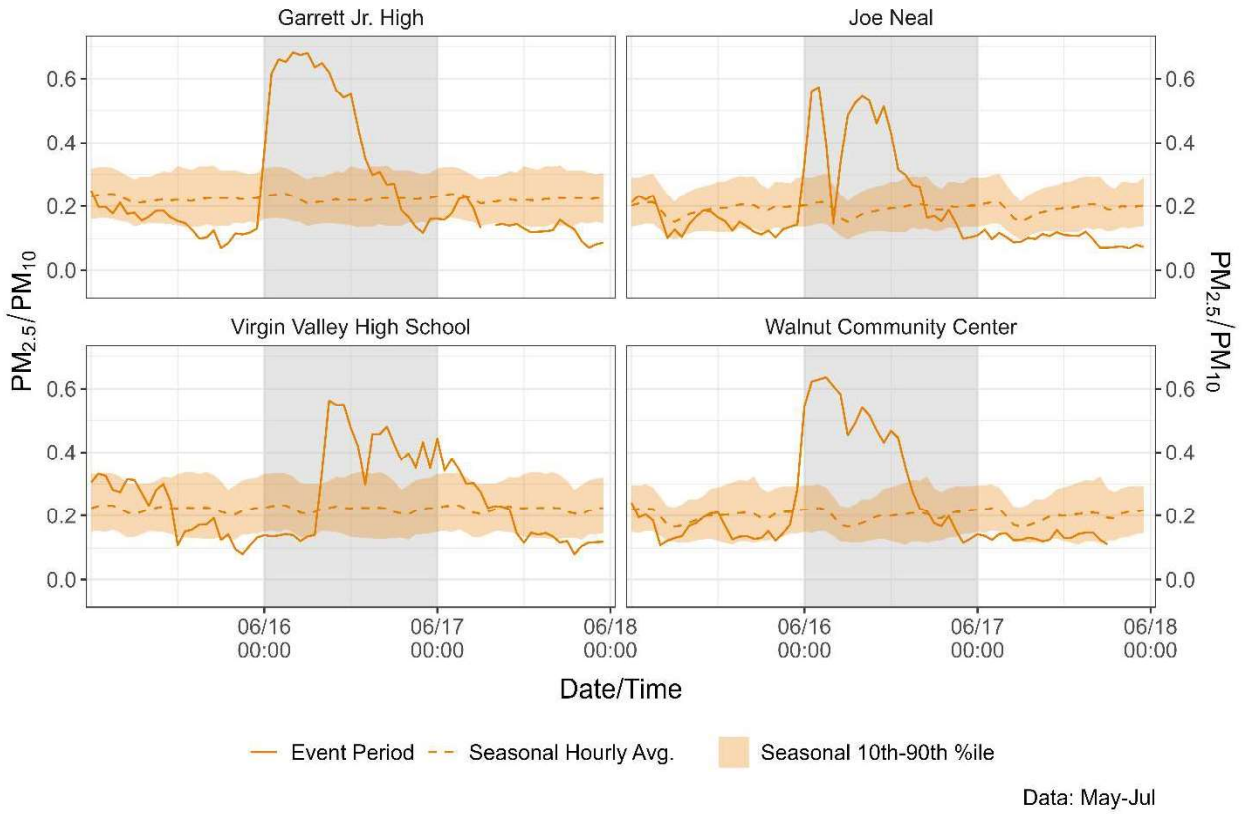

Figure 263. Ratio of $PM_{2.5}$-to-PM_{10} concentrations during the event period overlaid on the 10th-to-90th percentile diurnal concentrations at Garrett Jr. High* (AQS site code 320030602), Joe Neal (AQS site code 320030075), Virgin Valley High School* (AQS site code 320030024), and Walnut Community Center* (AQS site code 320032003). The 10th-to-90th percentile concentration is calculated across the ozone production season (April-September) of 2019-2024 at Joe Neal and 2021-2024 for all other sites.

7.2.5 Event Statistics

Table 64 summarizes concentrations of ozone, $PM_{2.5}$, and CO on the exclusion day, as well as the percentile rank of the observation compared to the previous six-years of data (2019-2024). Joe Neal was the only site with six years of data for comparison. Apex* had two years of data, and Garrett Jr. High*, Virgin Valley High School*, and Walnut Community center* each had four years of data. MDA8 ozone concentrations ranged from the 95th to 100th percentiles on June 16.

24-hr $PM_{2.5}$ concentrations ranged from the 98th-99th percentiles. As shown in Figure 261, hourly concentrations well above the seasonal median and 90th percentile were measured for over half of the day at each site.

CO concentrations were only available for Walnut Community Center* and included four years of data. At this site, the CO 1-hr daily max was higher than typical ozone season values at 700 ppb in the 70th percentile.

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Table 64. Percentile of pollution concentration on exclusion day compared with most recent six years (2019-2024). The percentile rank is calculated across the ozone production season (April 1 – September 30) of 2019-2024. Sites that have less than six years of data available for a given parameter are indicated with an asterisk.

Date	Site Name	Site Code	Ozone		$PM_{2.5}$		CO	
			Ozone MDA8 (ppb)	Percent Rank	$PM_{2.5}$ 24-hr average ($\mu g/m^3$)	Percent Rank	CO 1-hr Daily Max (ppb)	Percent Rank
6/16/2024	Apex	320030025	72	100.0%*	--	--	--	--
	Garrett Jr. High	320030602	77	100.0%*	30.5	99.9%*	--	--
	Joe Neal	320030075	71	95.3%	22.7	99.3%	--	--
	Virgin Valley High School	320030024	77	99.9%*	13.1	98.3%*	--	--
	Walnut Community Center	320032003	74	98.0%*	39.0	99.6%*	700	70.8%*

7.3 July 9-12, 2024

7.3.1 Event Summary

The unrepresentative ozone event took place from July 9-12, 2024, and affected the following seven sites in Clark County, NV: Green Valley, Joe Neal, Palo Verde, Paul Meyer, SM Youth Camp, Walnut Community Center*, and Walter Johnson. Figure 264 shows the time series of hourly ozone and statistical median overlaid onto the 10th to 90th percentile concentrations at the exceeding sites on the day before, the day of, and the day after the atypical ozone event.

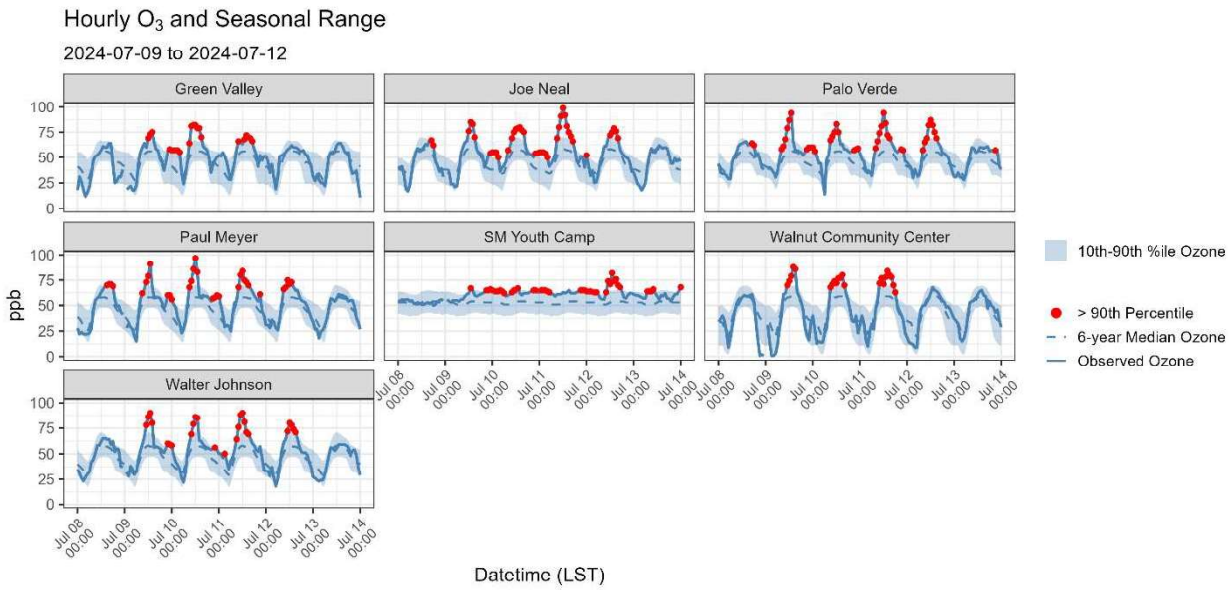

Figure 264. Hourly ozone concentrations (ppb) compared to 6-year ozone season (April 1 – September 30) hourly medians and 10th-to-90th percentiles. Red points indicate hourly ozone concentrations that exceeded the 90th percentile. Note: the Walnut Community Center site only includes data from June 1, 2021, and onwards.

Daily peak ozone concentrations at most sites were recorded at approximately 12:00 PST, with ozone returning to normal seasonal concentrations briefly during the early morning hours each day. Ozone concentrations at the Joe Neal, Palo Verde, Paul Meyer, and Walter Johnson sites were above the 6-year 90th percentile from July 9-12, while ozone concentrations above the 90th percentile at Green Valley and Walnut Community Center were only recorded from July 9-11. Ozone concentrations at Green Valley, Joe Neal, Palo Verde, Paul Meyer, Walnut Community Center*, and Walter Johnson returned to typical seasonal concentrations by the evening of July 12, 2024. The MDA8 ozone concentrations at affected sites ranged from 70-82 ppb: 70 ppb at Joe Neal, 71 ppb at Palo Verde, 72

ppb at Walnut Community Center*, and 71 ppb at Walter Johnson on July 9; 74 ppb at Green Valley and 73 ppb at Paul Meyer on July 10; and 72 ppb at SM Youth Camp on July 12.

Smoke from wildfires located east of Clark County in Utah and west of Clark County in southern California – as well as numerous fires burning in northern California, southern Oregon, northern Nevada, and Baja California in Mexico – were identified as contributors to this event. Evidence includes (1) HMS smoke perimeters over the county; (2) HYSPLIT trajectories and meteorological analysis showing accumulation of smoke in Clark County; (3) visible smoke in camera images and news coverage; and (4) synchronous enhancement of $PM_{2.5}$, CO, NO_2 concentrations, as well as enhanced $PM_{2.5}$-to-PM_{10} ratios that aligned with ozone concentration enhancement. This combination of evidence indicates that this is an unrepresentative event for base and future design value ozone assessments.

7.3.2 Identification of Wildfire(s)

Fires east of Clark County in Utah and multiple fires west and north of Clark County in California and Oregon were active during the days before and during the July 9-12 ozone event (Figure 265 and Figure 267). To the east, the Silver King Fire (Figure 265 and Figure 267), which began about eight miles northwest of Marysvale, UT, in Fishlake National Forest, was detected on July 5 and grew from 800 to 1,700 acres from July 8 through July 13.[62] The Deer Springs Fire located about eight miles North of Kanab, UT, and was the largest fire in Utah during the 2024 season. It was reported as 0% contained on July 9.[63] The Deer Springs Fire reached full containment on July 30. The Lake Fire in Santa Barbara, CA, began on July 5 and was contained on August 4. The Lake Fire burned 38,664 acres and was the 5th largest fire in California in 2024. The Wilder Fire near the Idaho and Nevada border had burned more than 16,830 acres by July 8 and was not contained until July 13. The Shelly Fire (Figure 266 and Figure 268), which began in Siskiyou county in northern California on July 3, was contained on August 8, and burned 15,520 acres. The Salt Creek Fire (Figure 266 and Figure 268), which began on July 7 10 miles east of Eagle Point, OR, was contained on July 22 and burned 4,100 acres.[64] Over a dozen fires were also actively burning in northern Baja California, Mexico (Figure 266 and Figure 269).[65] These were all identified as contributing to the smoke plumes blanketing the western United States before and during the atypical ozone event.

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[62] https://marysvale.gov/wp-content/uploads/2024/08/Silver_King_Burned_Area_Report_Public-2-1.pdf
[63] https://app.watchduty.org/i/25010
[64] https://www.kdrv.com/news/firewatch/salt-creek-fire-100-contained/article_e57852d2-3cb8-11ef-aa63-1b70e0a342cd.html
[65] https://mx.usembassy.gov/fire-alert-u-s-consulate-tijuana-mexico/#:~:text=Event%3A%20Mexican%20authorities%20are%20responding%20to%20dozens%20of,to%20dry%20weather%20conditions%20and%20Santa%20Ana%20winds

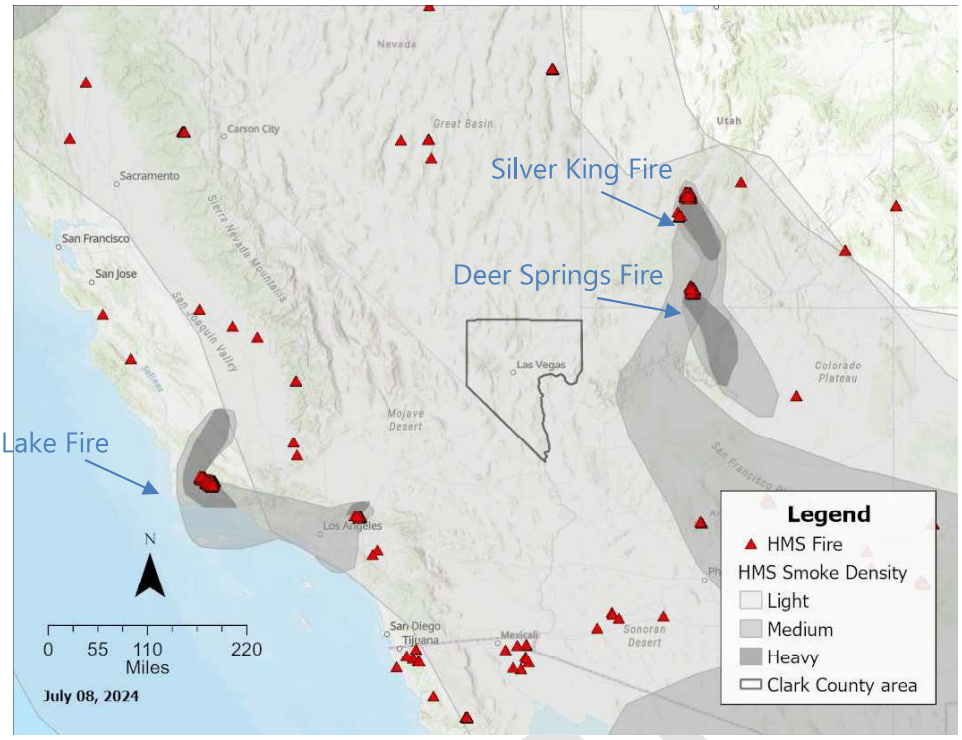

Figure 265. Regional view of HMS fire detections (red triangles) and smoke density (grey contours) on July 8, 2024.

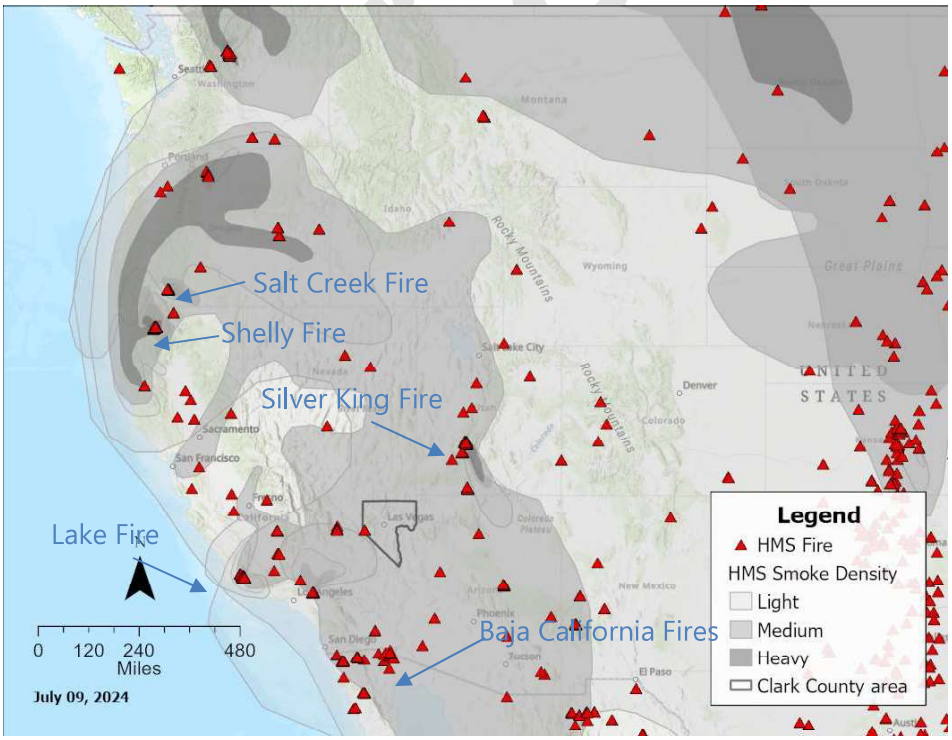

Figure 266. Western U.S. view of HMS fire detections and smoke density on July 9, 2024.

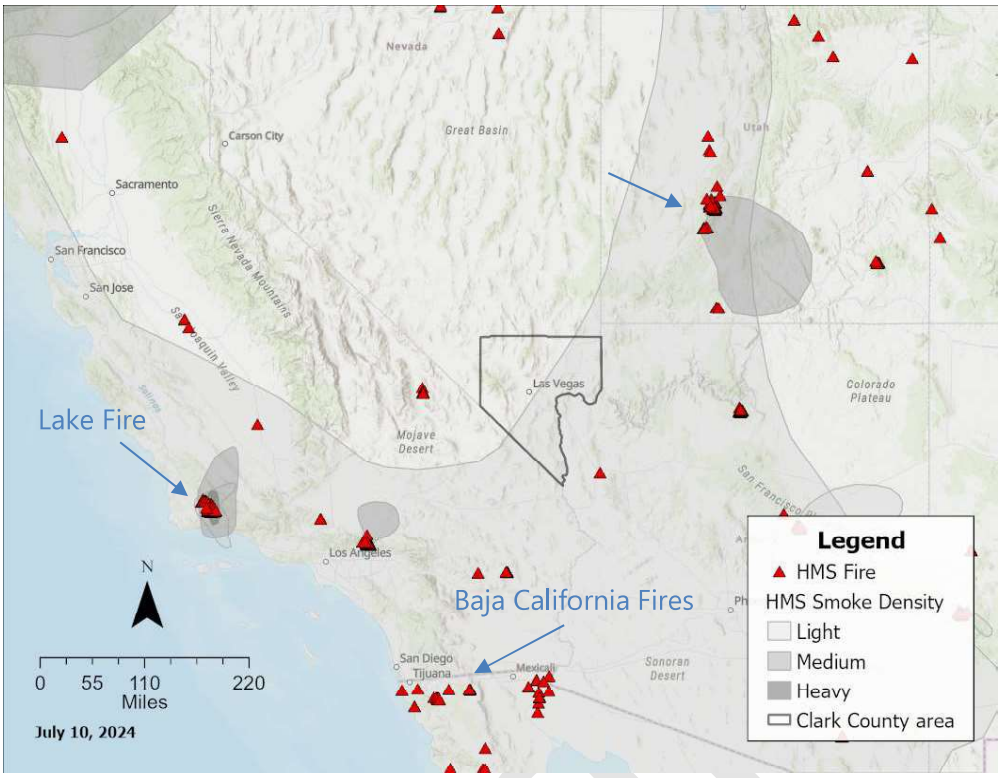

Figure 267. Regional view of HMS fire detections and smoke density on July 10, 2024.

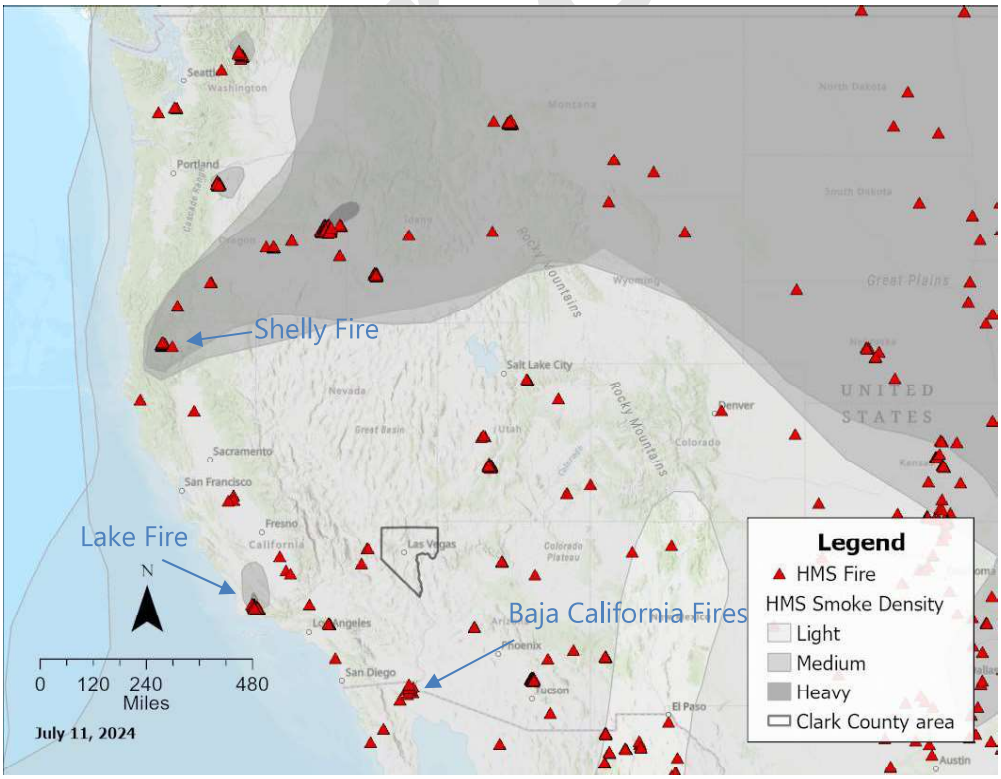

Figure 268. Western U.S. view of HMS fire detections and smoke density on July 11, 2024.

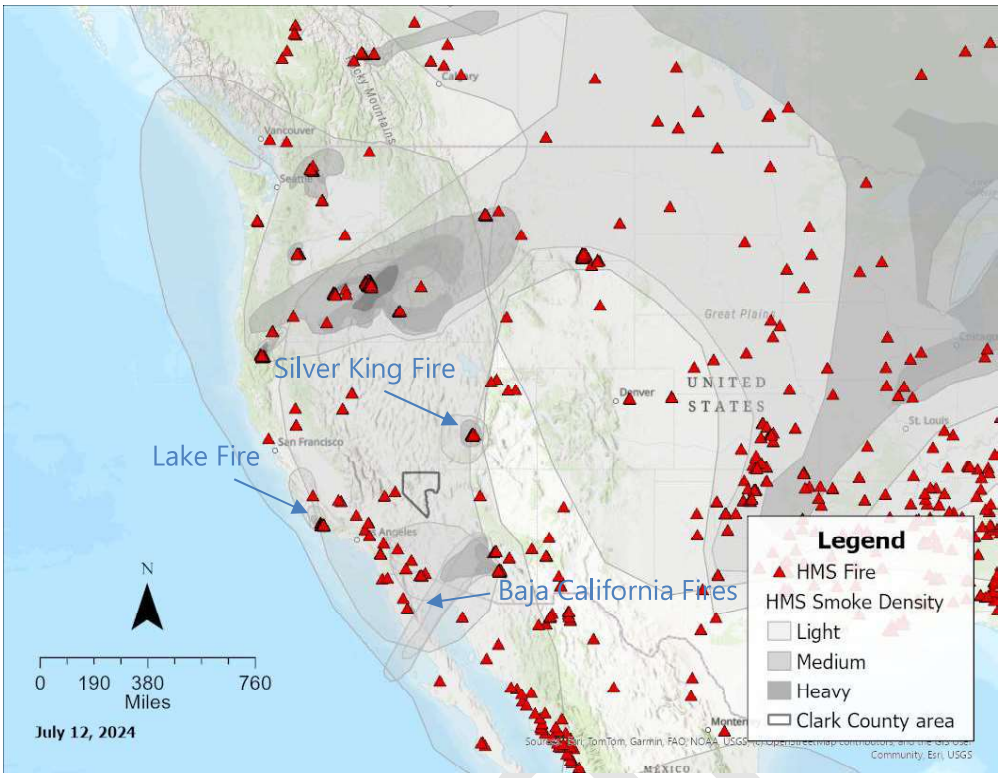

Figure 269. Continental view of HMS fire detections and smoke density on July 12, 2024.

7.3.3 Meteorological Analysis

HRRR-Smoke Model Output

The High-Resolution Rapid Refresh Smoke (HRRR-Smoke) model is a three-dimensional coupled weather-smoke model developed for real-time smoke prediction over flat and complex terrain. The model is run on a 3-km horizontal grid spacing at 50 vertical levels. It assimilates surface and upper-air meteorological and smoke data every hour, including fire radiative power data from VIIRS and MODIS satellites. Taking all these parameters into consideration, it produces hourly operational surface and aloft smoke forecasts that are widely used by air quality forecasters in the United States.

Figure 270 through Figure 273 show archived HRRR-Smoke forecast products for July 9-12, initialized at either 16:00 or 22:00 PST two days prior, depending on availability. The model output predicted near-surface smoke in the Clark County area in the following concentration ranges each day:

- Between 20 and 30 µg/m^3 of smoke were forecast at the surface 11:00 PST on July 9.
- Between 6 and 8 µg/m^3 of smoke were forecast at the surface 05:00 PST on July 10.
- Between 4 and 12 µg/m^3 of smoke were forecast at the surface 04:00 PST on July 11.
- Between 4 and 8 µg/m^3 of smoke were forecast at the surface 04:00 PST on July 12.

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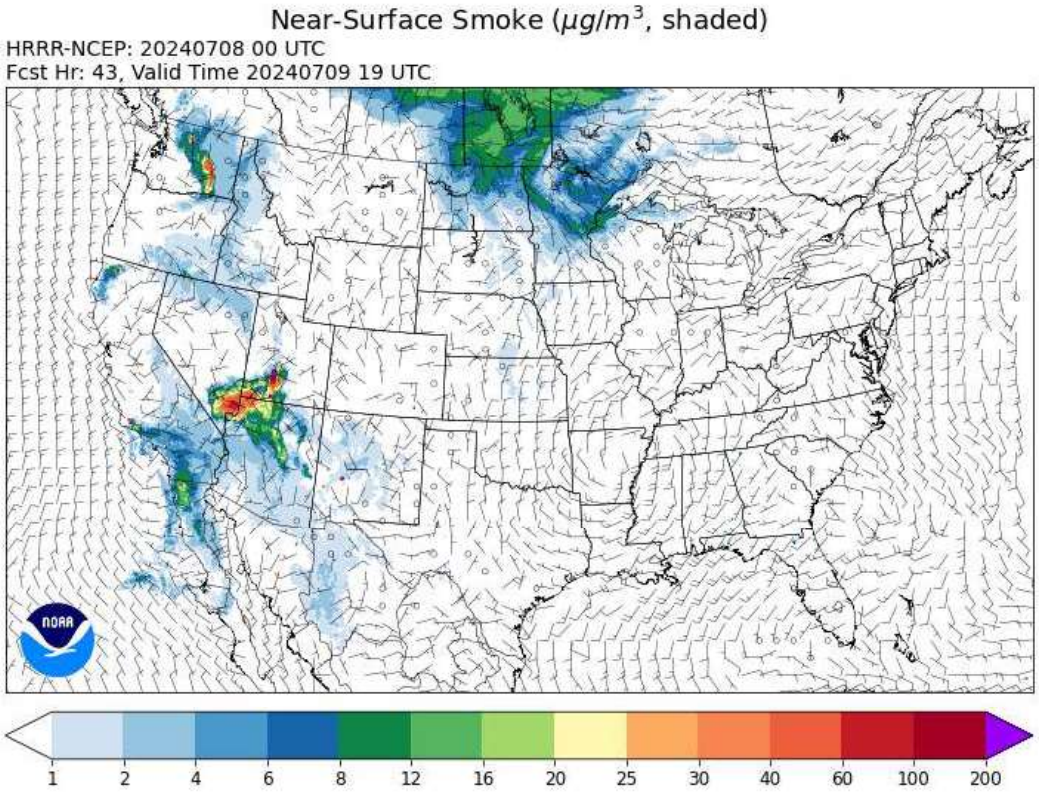

Figure 270. Model prediction (initialized 00 UTC July 8) of near-surface smoke (µg/m^3) at 11:00 PST on July 9, 2024, showed near-surface smoke over southern Nevada. Image courtesy of NOAA's Global Systems Laboratory.

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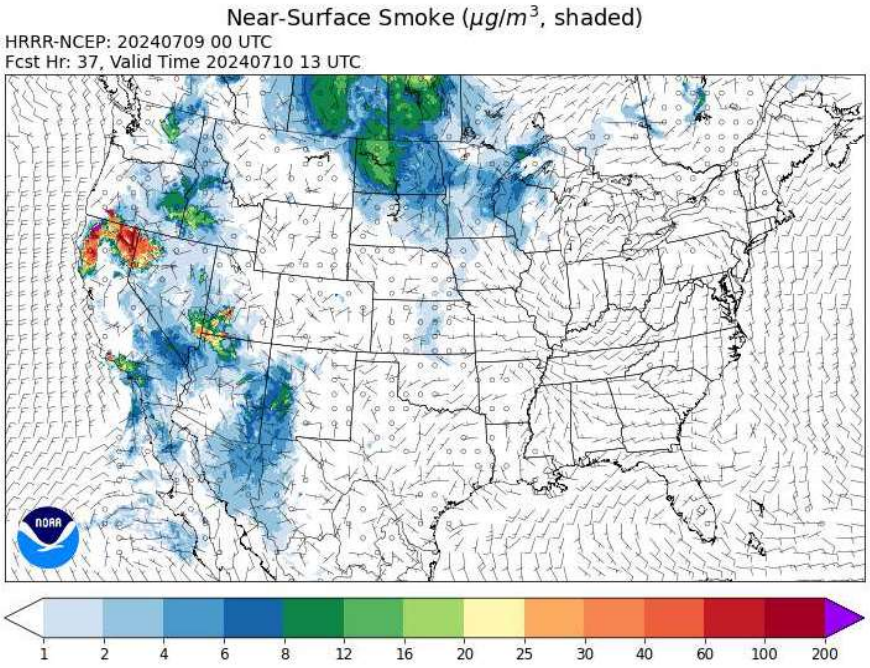

Figure 271. Model prediction (initialized 00 UTC July 9) of near-surface smoke (µg/m³) at 05:00 PST on July 10, 2024, showed near-surface smoke over southern Nevada. Image courtesy of NOAA's Global Systems Laboratory.

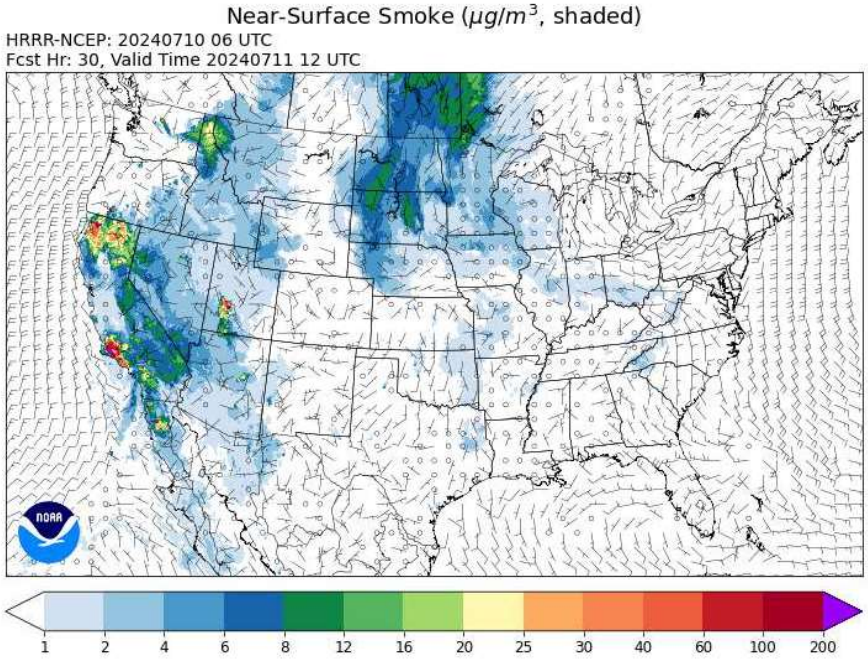

Figure 272. Model prediction (initialized 06 UTC July 10) of near-surface smoke (µg/m³) at 04:00 PST on July 11, 2024, showed near-surface smoke over southern Nevada. Image courtesy of NOAA's Global Systems Laboratory.

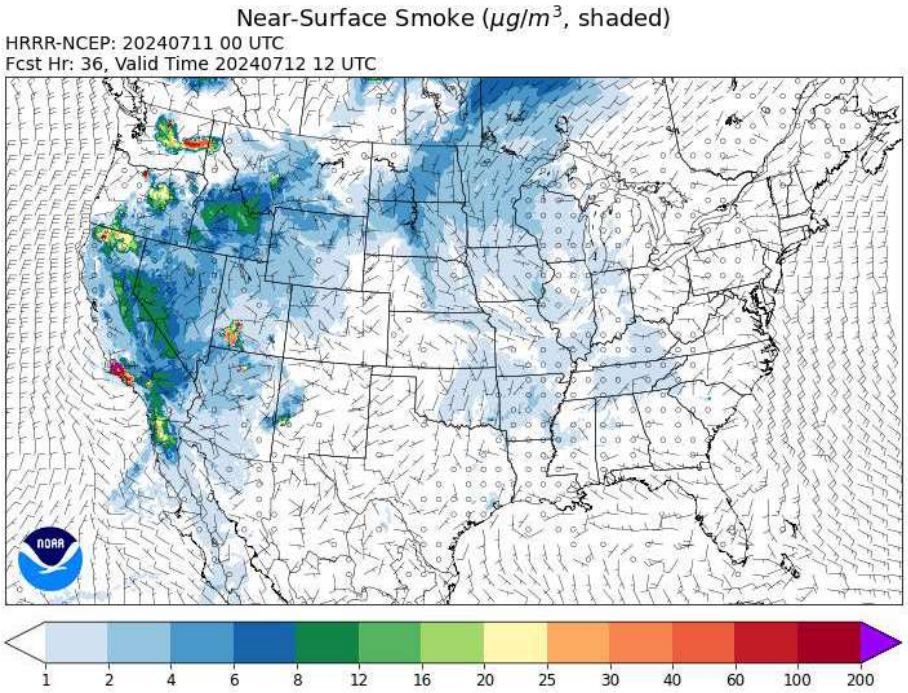

Figure 273. Model prediction (initialized 00 UTC July 11) of near-surface smoke (µg/m^3) at 04:00 PST on July 12, 2024, showed near-surface smoke over southern Nevada. Image courtesy of NOAA's Global Systems Laboratory.

Upper-Level Weather Patterns

The height of the 500-millibar (mb) pressure level AGL as well as the curvature of the 500-mb height field can be useful in discerning the potential for ozone production on the synoptic (large) scale. Low pressure aloft is generally conducive to cloud development and precipitation, as cool temperatures in the mid-levels promote atmospheric mixing and instability. Areas of aloft low pressure generally coincide with decreased ozone development. Alternatively, high pressure aloft is normally indicative of a warm, dry air mass in the mid-levels of the atmosphere. Those warm and dry mid-level conditions often promote sunny skies and increase the potential for ozone development. The contour plots of geopotential height at 500 mb (approximately 18,000 feet) from July 9-12, 2024, shown in Figure 274 through Figure 277 show a strong ridge of upper-level high pressure over southern Nevada.

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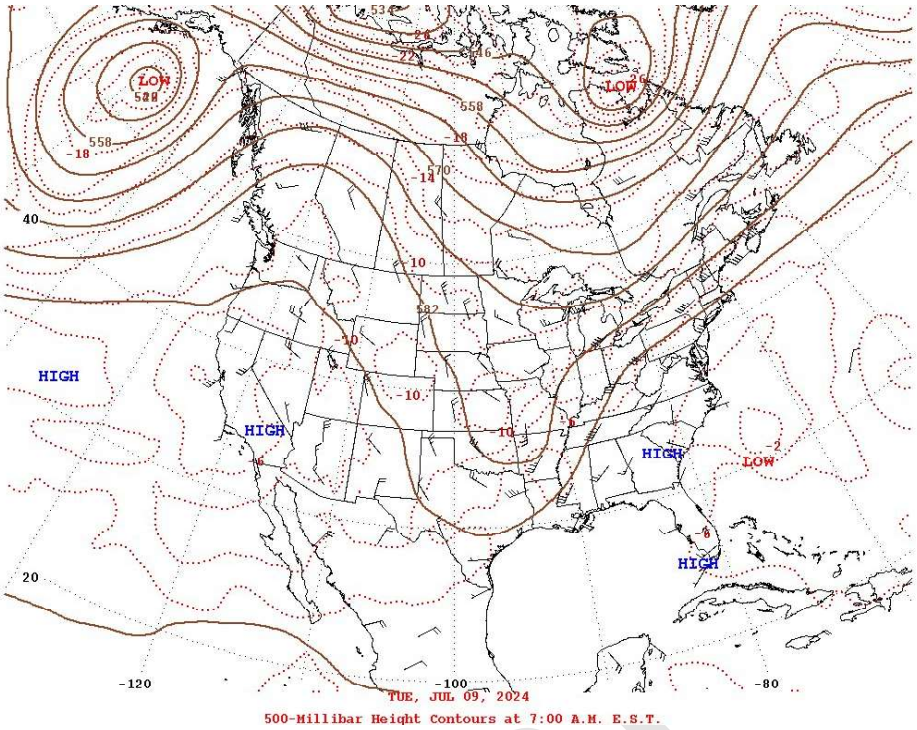

Figure 274. 500-mb heights, winds, and temperatures at 04:00 PST on July 9, 2024. Image courtesy of NOAA's Weather Prediction Center.

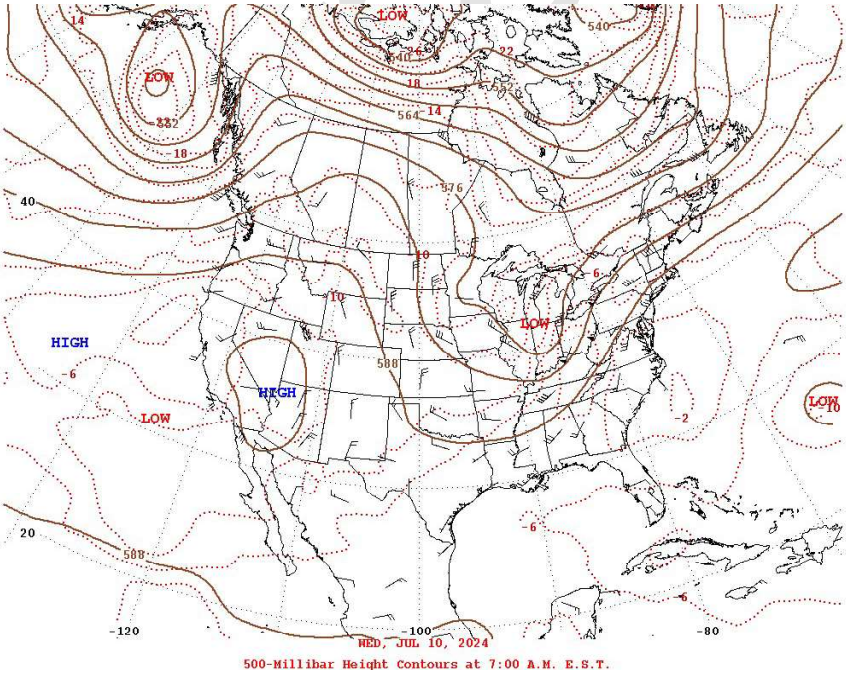

Figure 275. 500-mb heights, winds, and temperatures at 04:00 PST on July 10, 2024. Image courtesy of NOAA's Weather Prediction Center.

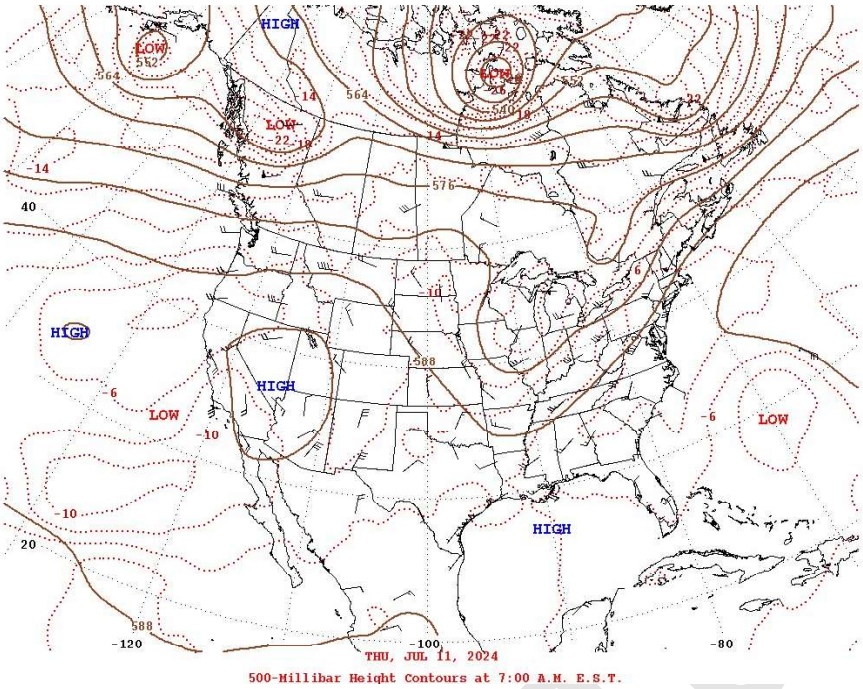

Figure 276. 500-mb heights, winds, and temperatures at 04:00 PST on July 11, 2024. Image courtesy of NOAA's Weather Prediction Center.

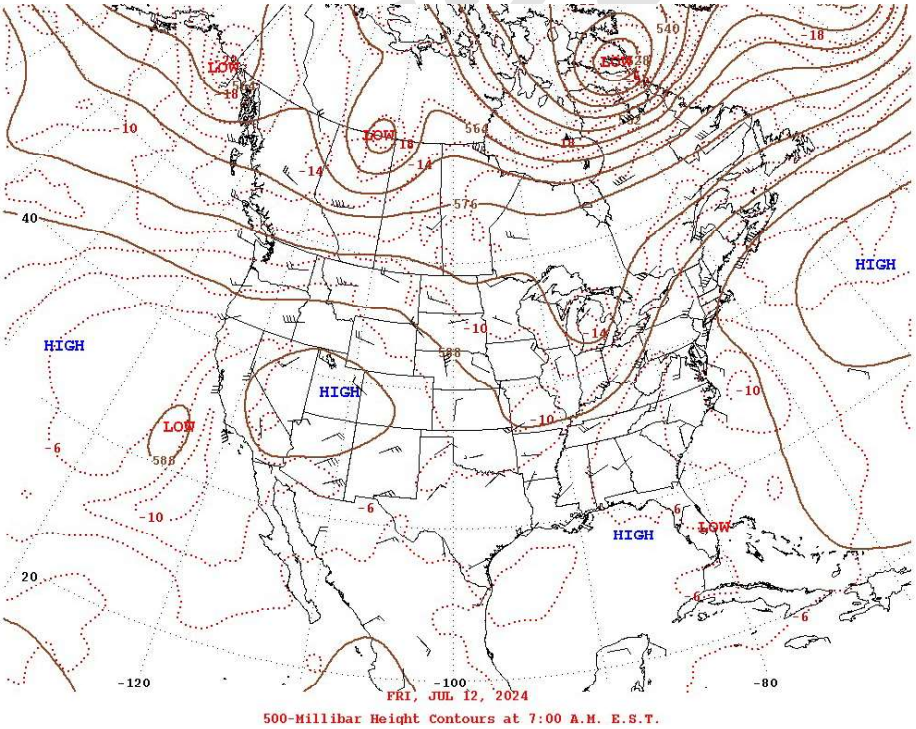

Figure 277. 500-mb heights, winds, and temperatures at 04:00 PST on July 12, 2024. Image courtesy of NOAA's Weather Prediction Center.

The pronounced upper-level high pressure produced mostly sunny skies and very hot temperatures in the Clark County region on each of these days, providing the ultraviolet radiation needed for the photochemical reactions that produce ozone. Additionally, this upper-level ridge confined smoke from regional fires to the mid- and lower-levels of the atmosphere.

Surface Weather Patterns

Surface pressure patterns can indicate whether conditions at ground level are conducive to pollutant transport and accumulation, as well as ozone formation. Surface high pressure generally indicates sinking air and increased stability, which can limit atmospheric mixing and increase ozone production. Conversely, surface low pressure can indicate rising air and increased atmospheric mixing, which can help reduce ozone formation. However, in the desert during the summer, surface low pressure can also be indicative of rising air due to very warm surface temperatures. This is known as a *thermal trough*. The increase in ozone production from hot temperatures can sometimes balance out the potential for air quality to improve due to enhanced atmospheric mixing in the vicinity of a weak surface low. Additionally, enhanced mixing can bring aloft smoke to the surface, further supporting ozone development.

Surface pressure patterns also indicate the potential for wind. When lines of constant pressure (isobars) are packed closely together (strong pressure gradient), there is higher potential for stronger wind and increased dispersion. Alternatively, when isobars are spaced farther apart (weak pressure gradient), periods of light winds and reduced dispersion are more likely. The orientation of the pressure gradient influences the direction of surface winds.

Figure 278 and Figure 279 show a thermal trough of low pressure at the surface, centered over the far southern corner of Nevada each afternoon on July 9 and 10 due to hot temperatures and rising thermals over the Desert Southwest. Concurrently, higher surface pressure was observed over the cool waters of the eastern Pacific. This weak west-to-east pressure gradient resulted in light southwesterly winds in Clark County each afternoon from July 9-10. Due to the weak pressure gradient over Clark County, winds from July 9-12 were generally light through the morning and midday hours, reducing dispersion and allowing smoke and other pollutants to accumulate and linger over the region. The observed pressure patterns from July 11-12 were very similar to those observed from July 9-10 (Figure 278 and Figure 279), with a thermal trough of low pressure over southern Nevada and a weak onshore pressure gradient.

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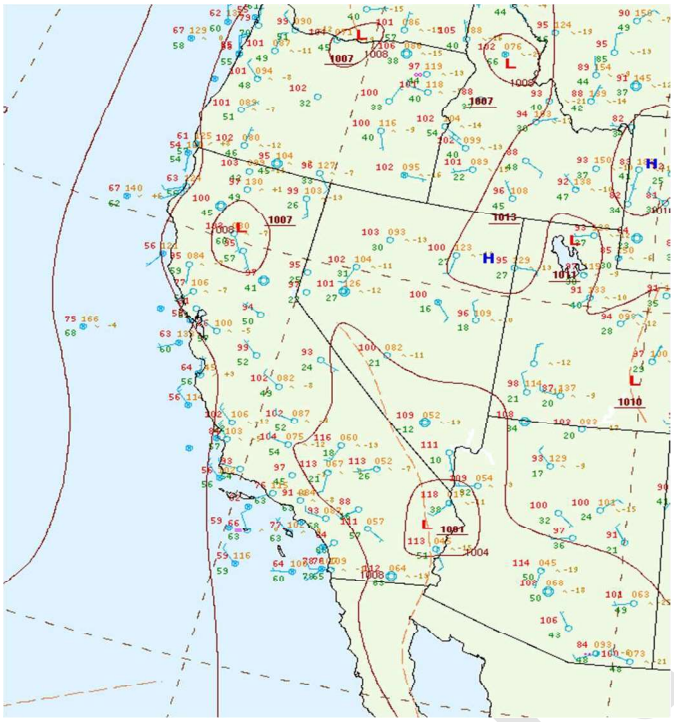

Figure 278. Surface weather conditions at 13:00 PST on July 9, 2024. Image courtesy of NOAA's Weather Prediction Center.

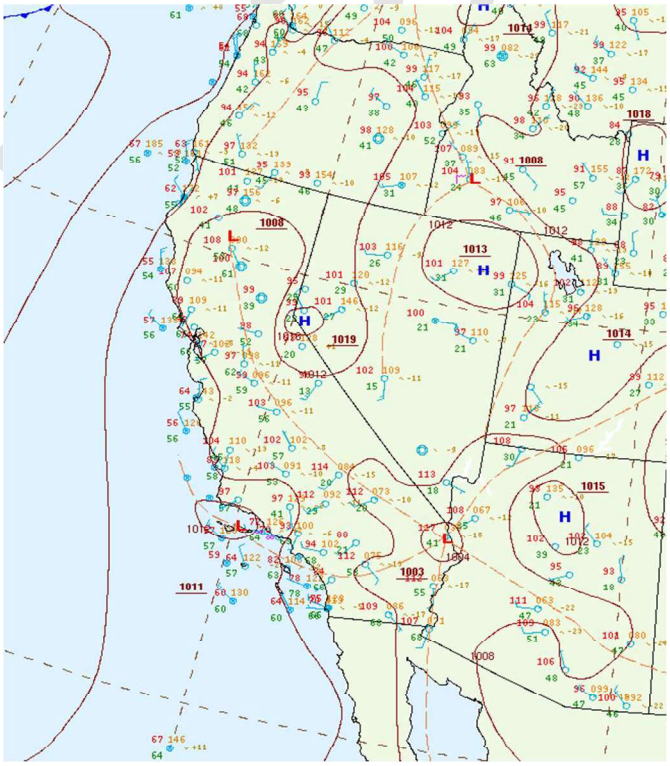

Figure 279. Surface weather conditions at 13:00 PST on July 10, 2024. Image courtesy of NOAA's Weather Prediction Center.

Table 65 confirms that the above-normal heights aloft were associated with hot surface temperatures that aided ozone development. In addition, wind speeds averaged 6 mph or less each day, limiting pollutant dispersion over the nonattainment area.

Table 65. Maximum surface temperatures, average wind speeds, and average wind directions at Las Vegas-Harry Reid International Airport (KLAS) on July 9-12, 2024.

Date	Maximum Temperatures (°F)	Average Wind Speed (mph)	Average Wind Direction (degrees)
July 9, 2024	118	5	248
July 10, 2024	118	6	230
July 11, 2024	117	6	179
July 12, 2024	115	6	148

Vertical Temperature Profiles and Mixing Heights

Soundings are one of the most useful tools to determine how deeply the atmosphere mixes each afternoon, and whether mixing could be deep enough to bring aloft smoke to the ground level. When determining mixing height from soundings, meteorologists compare the observed change of temperature with height (lapse rates) with the background grid of dry adiabats. Dry adiabats follow the dry adiabatic lapse rate, a decrease of roughly 10°C per kilometer. If the observed temperature lapse rate parallels the dry adiabats from the surface upward, vertical mixing can be inferred from the surface to the height where the observed lapse rate is no longer parallel to the dry adiabats. And while deep mixing normally helps ozone concentrations plateau during the afternoon due to mixing and dispersion, ozone formation can be enhanced when that mixing transports aloft smoke to the surface.

The units of the x-axes on the soundings in Figure 280 are temperature in degrees Celsius, and the units of the primary y-axes are pressure in millibars, with height in meters also annotated along those axes. The left black vertical trace on each graph represents observed dewpoint temperature, and the right black vertical trace represents observed air temperature. The green, slightly curved diagonal lines that slope downward from left to right are the dry adiabats. If the right black line originating from the surface parallels the green lines, vertical mixing is inferred through that layer, and that layer is called the boundary layer. The boundary layer is the layer of air that can freely mix with air near the surface. The height of the top of the boundary layer is called the mixing height. The panels in Figure 280 show that afternoon mixing heights of more than 5,000 m were observed each afternoon from July 9-12.

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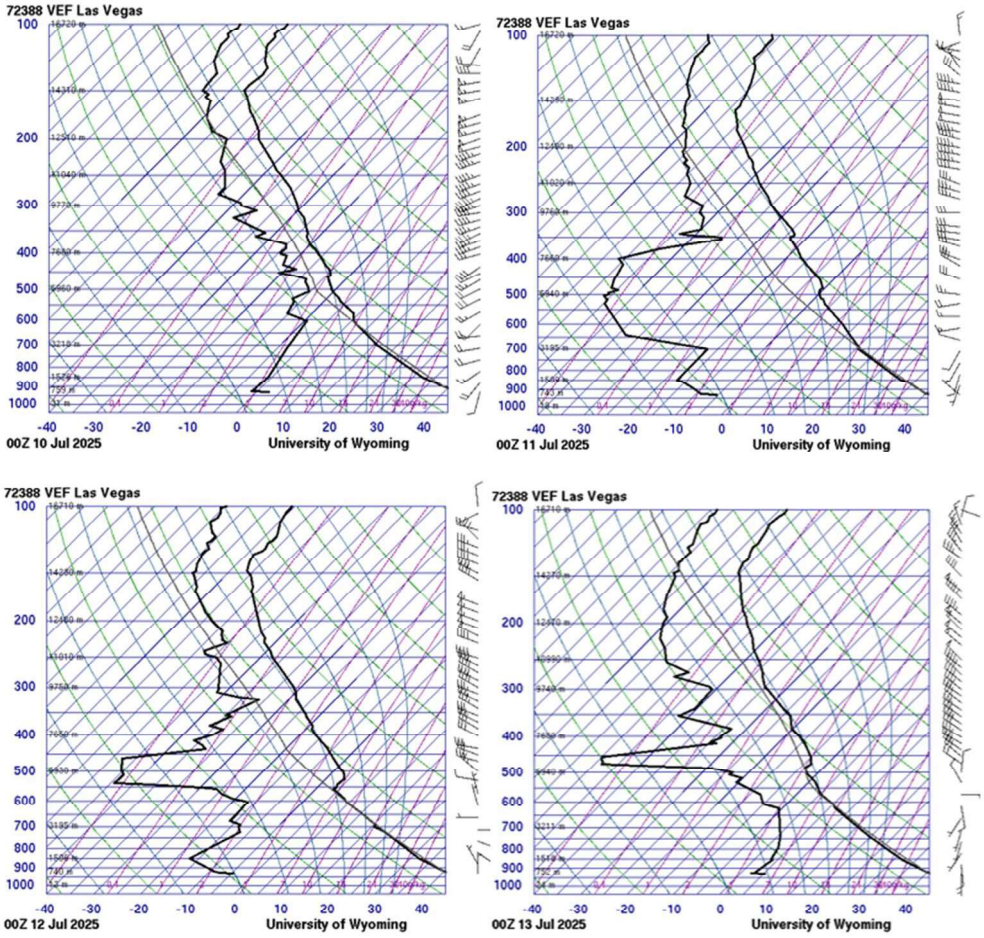

Figure 280. Observed soundings at 16:00 PST on July 9 (top left), July 10, (top right), July 11 (bottom left), and July 12 (bottom right). Images courtesy of the University of Wyoming.

In addition to assessing mixing heights from plots of vertical temperature, meteorologists also used raw vertical temperature data to determine mixing heights each afternoon. Using sounding data at 16:00 PST each day from the KVEF site in Las Vegas, the mixing height was determined to be the height at which aloft potential temperature exceeded the surface potential temperature for each day. Table 66 lists the daily maximum mixing heights observed at 16:00 PST on July 9-12.

Table 66. Maximum mixing heights observed at Las Vegas NWS site KVEF on July 9-12, 2024.

Date	Maximum Mixing Height (m)
July 9, 2024	6,120
July 10, 2024	6,360
July 11, 2024	6,350
July 12, 2024	5,650

Smoke Transport

The mixing heights found in the previous section are not only useful for determining the general potential for mixing of aloft smoke to the surface. These heights can also be used to compute the origins of air masses that arrive in the boundary layer at a specified time using the HYSPLIT model. Initialized near the time of maximum ozone concentrations observed each day, back trajectories were computed for each afternoon from July 9-12. The back trajectories were run for up to 72 hours to determine air mass source regions at three different heights within the boundary layer (i.e., below the mixing height) for each day. These trajectories were overlaid on imagery of satellite smoke and fire detections from the prior days to determine the potential for smoke transport.

July 9, 2024

Back trajectories ending in Las Vegas at 15:00 PST on July 9 are shown originating on July 8 (Figure 281) and July 7 (Figure 282). The HMS fire detections (red triangles) and smoke plumes (gray shading) correspond to the date of the trajectory origin. Date and time stamps indicate air parcel positions along those trajectories.

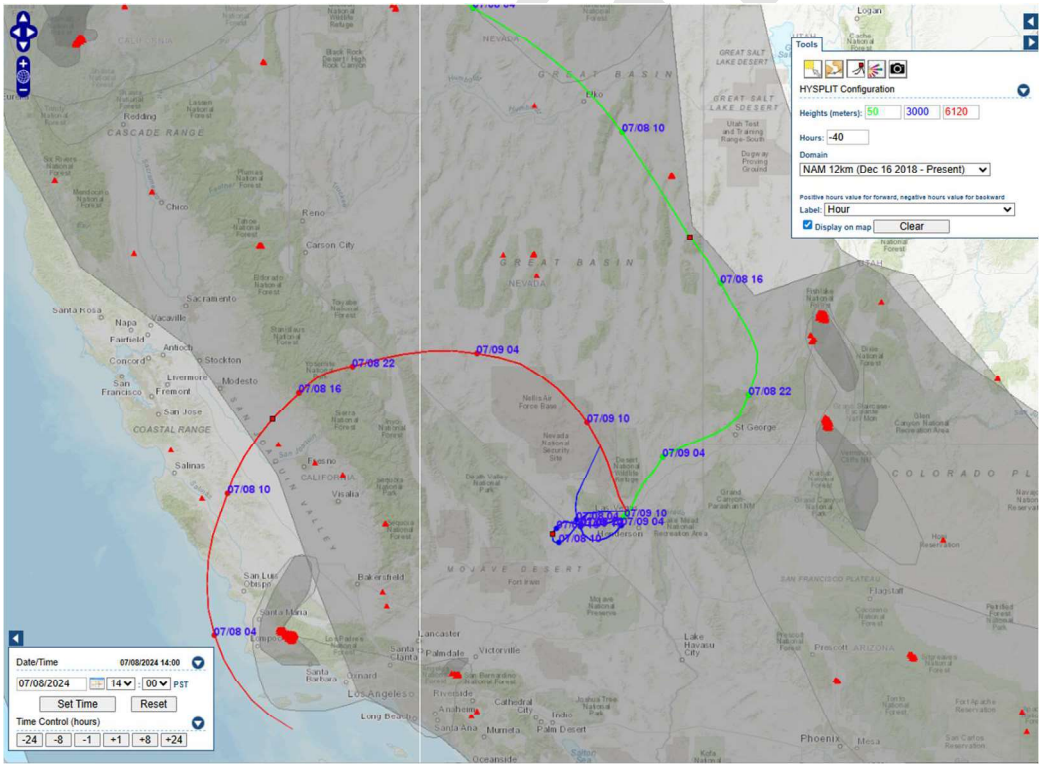

Figure 281. 40-hr boundary-layer back trajectories from the NAM model ending in Las Vegas at 15:00 PST on July 9, 2024, at 50 m (green line), 3,000 m (blue line), and 6,120 m (red line). HMS fires (triangles) and smoke (gray shading) on July 8 are also displayed. Image courtesy of EPA's AirNow-Tech.

As shown in Figure 281, the back trajectory ending in Las Vegas at 15:00 PST on July 9 at 50 m AGL (green line), indicates a transport path within a smoke plume over Nevada and southwestern Utah, which passed near fires observed in southwestern Utah on July 8. Additionally, the back trajectory at 6,120 m AGL (red line) indicates a transport path within a smoke plume over southern Nevada and central California, which passed close to a fire detection near Santa Barbara, CA, on July 8.

Back trajectories extending 72 hours prior to 15:00 PST on July 9 indicate additional smoke transport. Figure 282 shows that the 72-hour back trajectory ending in Las Vegas at 15:00 PST on July 9 at 50 m above ground level (green line) indicates a transport path within a smoke plume and near fire detections over far northern Nevada and southwestern Oregon on July 7.

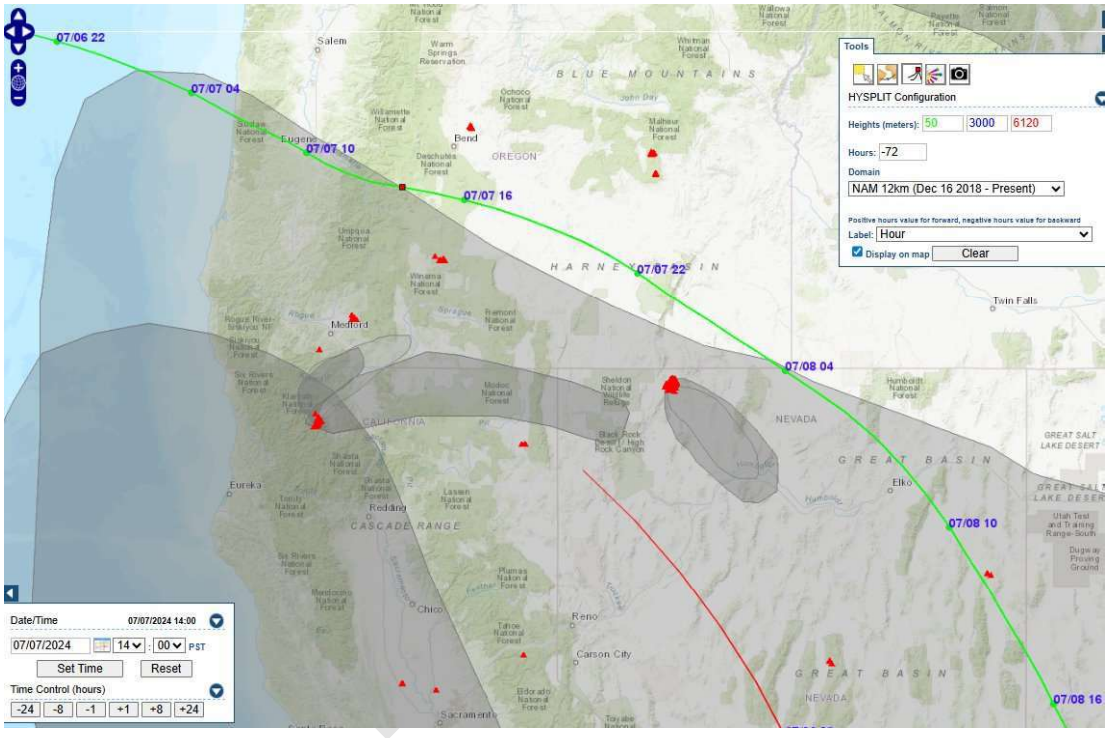

Figure 282. 72-hr boundary-layer back trajectories from the NAM model ending in Las Vegas at 15:00 PST on July 9, 2024, at 50 m (green line), and 6,120 m (red line). HMS fires (triangles) and smoke (gray shading) on July 7 are also displayed. Image courtesy of EPA's AirNow-Tech.

These trajectories provide evidence of direct smoke transport into the Clark County region on July 9 from multiple fires and smoke plumes over the preceding two days. In addition to the trajectories indicating smoke transport into the Clark County area from regional fires, both the HMS smoke analysis (gray shading in Figure 280 through Figure 282) and the NOAA HMS smoke discussion text (Figure 283) indicated smoke directly over Nevada on July 9.

DESCRIPTIVE TEXT NARRATIVE FOR SMOKE/DUST OBSERVED IN SATELLITE IMAGERY

SMOKE:
Canada/United States/Mexico...
A large area of mixed density smoke from wildfires throughout northwestern Canada, northern Washington State, and from eastern Canada continues to be seen today, stretching from eastern Alaska to the North Atlantic and continuing east offshore, and covering most of the US as far south as Baja and northern Mexico. A large area of moderate density smoke was moving east from northeastern British Columbia, northern Alberta, and far southwestern Northwest Territory after having been moving southeastward earlier today over Saskatchewan, southern Manitoba, the northern Plains, Great Lakes, and southeastern Canada, where further wildfire activity was adding to the layer moving east-northeastward out over the North Atlantic. Some is also perhaps becoming entrained in a high pressure area off the Mid-Atlantic coast bringing some of the smoke southward towards the Carolinas and Florida

Western CONUS...
Scattered Wildfire activity from southern California to Oregon and Utah was helping to create another area of light to moderate density smoke that was covering an area from southern Washington State to northwestern Mexico. A couple wildfires in southern California were producing moderate smoke moving mainly northward to northeastward, while smoke from northern California was seen moving multiple directions and a wildfire in central Utah was producing thick smoke moving south-southeast. Remnant smoke from previous days was seen in a ring around Nevada and extending southward across northwestern Mexico, with the thickest remnant smoke seen arcing from the Oregon/Idaho/Washington triple point westward to the coast then south along the Oregon coast to offshore of northern California. There could be minor contributions from the area mentioned above, but this area does appear to be distinct from that large area.

Figure 283. NOAA's HMS Smoke text product from 8:22 p.m. PST July 9, 2024.

July 10, 2024

Figure 284 displays back trajectories within the mixed layer ending in Las Vegas on July 10, originating at 21:00 PST on July 8 and running through 13:00 PST on July 10. The HMS fire detections (red triangles) and smoke plumes (gray shading) correspond to July 9. Date and time stamps indicate air parcel positions along those trajectories.

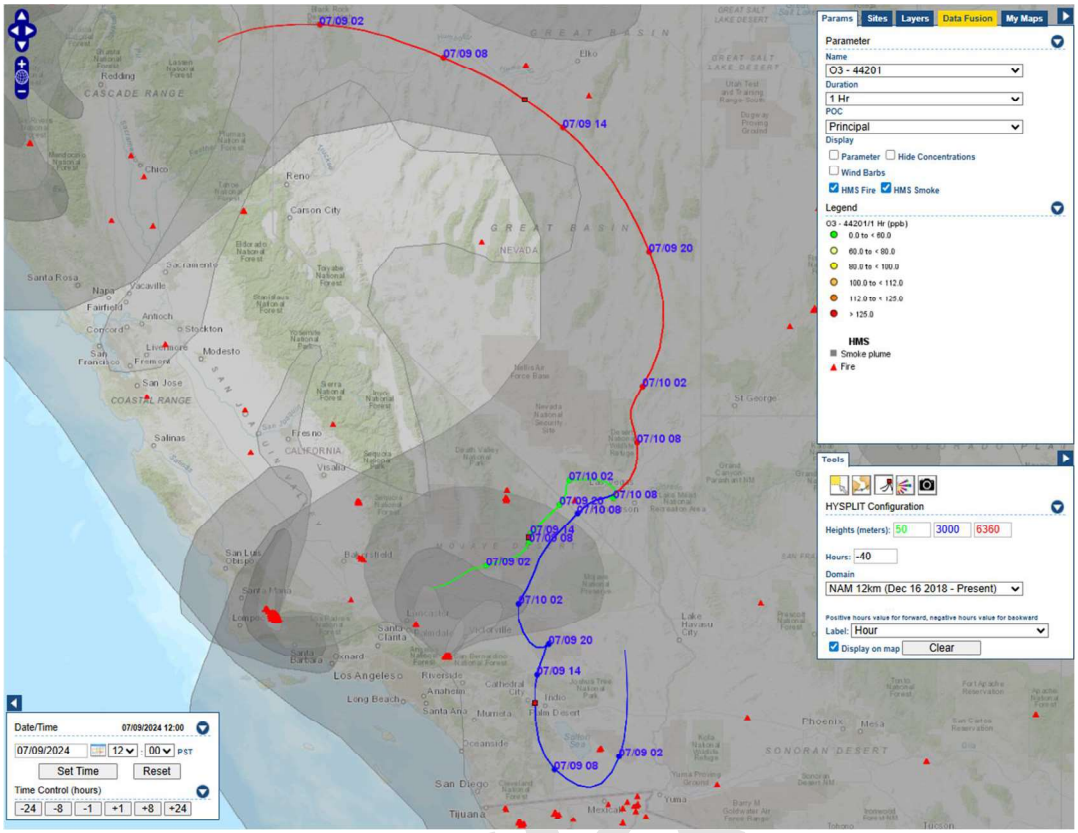

Figure 284. 40-hr boundary-layer back trajectories from the NAM model ending at 13:00 PST on July 10, 2024, at 50 m (green line), 3,000 m (blue line), and 6,360 m (red line). HMS fires (triangles) and smoke (gray shading) on July 9 are also displayed. Image courtesy of EPA's AirNow-Tech.

The back trajectory ending in Las Vegas at 13:00 PST on July 10 at 50 m AGL (green line), indicates a transport path within a dense smoke plume and near several fire detections over southern California on the preceding day (July 9). Additionally, the back trajectory ending at 3,000 m AGL (blue line) indicates a transport path within a smoke plume and near fire detections over far southern California and northern Baja California on July 9. The back trajectory at 6,360 m AGL (red line) indicates a transport path within a smoke plume extending northward through Nevada on July 9.

These back trajectories provide evidence of direct smoke transport into the Clark County region on July 10 from multiple fires and smoke plumes over the preceding day.

July 11, 2024

Figure 285 displays back trajectories within the mixed layer ending in Las Vegas on July 11, originating on July 10. The HMS fire detections (red triangles) and smoke plumes (gray shading) correspond to the date of the trajectory origin. Date and time stamps indicate air parcel positions along those trajectories.

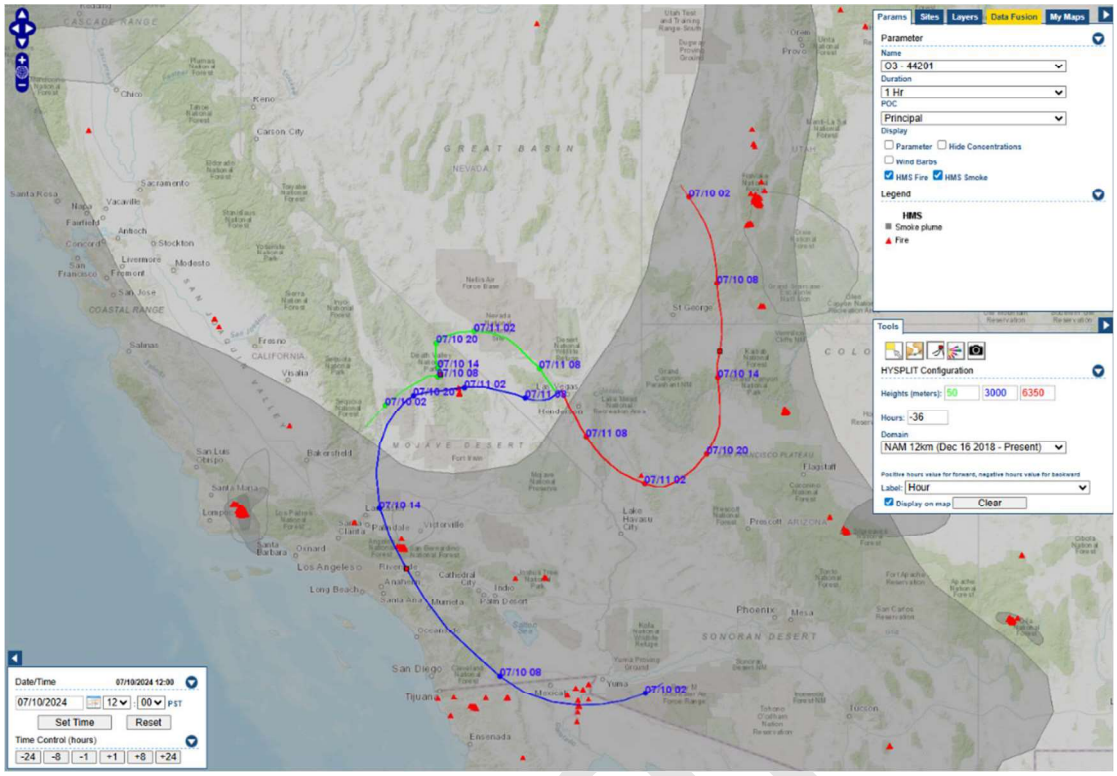

Figure 285. 36-hr boundary-layer backward trajectories from the NAM model ending at 13:00 PST on July 11, 2024, at 50 m (green line), 3,000 m (blue line), and 6,350 m (red line). HMS fires (triangles) and smoke (gray shading) on July 10 are also displayed. Image courtesy of EPA's AirNow-Tech.

As shown in Figure 285, the back trajectory ending in Las Vegas at 13:00 PST on July 11 at 3,000 m AGL (blue line) indicates a transport path within a smoke plume and near a fire detected in east-central California, as well as several fires in northern Baja California, Mexico, on July 10. Furthermore, the back trajectory ending at 6,350 m AGL (red line) indicates a transport path within a smoke plume and near fire detections over southwestern Utah on July 10.

Back trajectories extending 72 hours prior to 13:00 PST on July 11 (Figure 286) indicate additional smoke transport. The back trajectory ending in Las Vegas on July 11 at 50 m (green line) indicates a transport path within a larger smoke plume and within one from a fire located near Santa Barbara, CA, on July 9. Additionally, the back trajectory at 6,350 m AGL (red line) indicates a transport path within a smoke plume extending into northern Nevada and northern California on July 9.

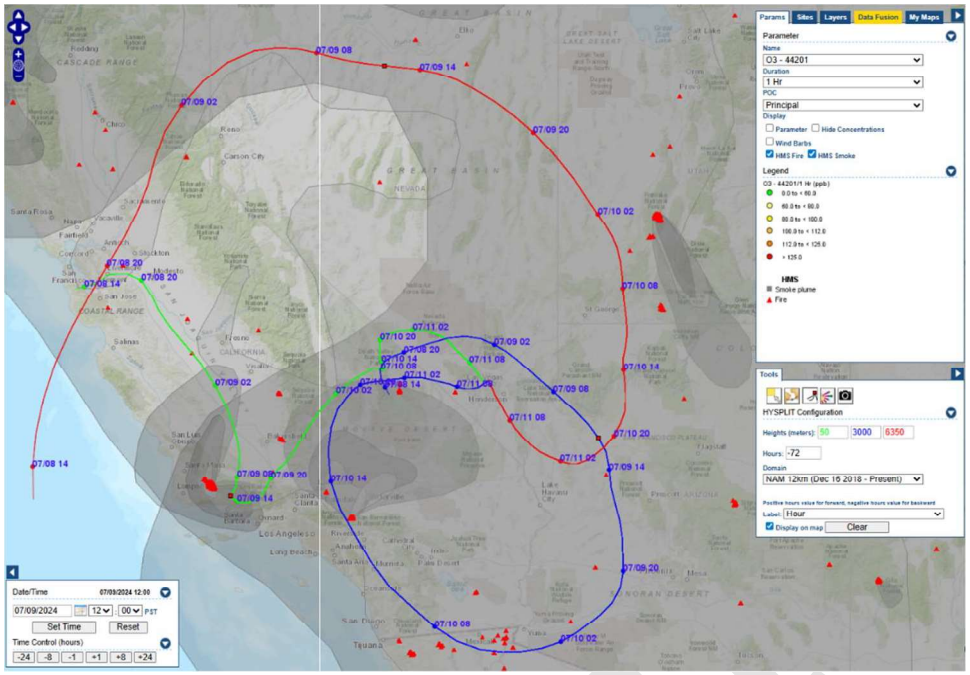

Figure 286. 72-hr boundary-layer backward trajectories from the NAM model ending at 13:00 PST on July 11, 2024, at 50 m (green line), 3,000 m (blue line), and 6,350 m (red line). HMS fires (triangles) and smoke (gray shading) on July 9 are also displayed. Image courtesy of EPA's AirNow-Tech.

These trajectories provide evidence of direct smoke transport into the Clark County region on July 11 from multiple fires and smoke plumes over the preceding two days.

July 12, 2024

Figure 287 displays back trajectories within the mixed layer ending in Las Vegas on July 12, originating on July 11. The HMS fire detections (red triangles) and smoke plumes (gray shading) correspond to the date of the trajectory origin. Date and time stamps indicate air parcel positions along those trajectories.

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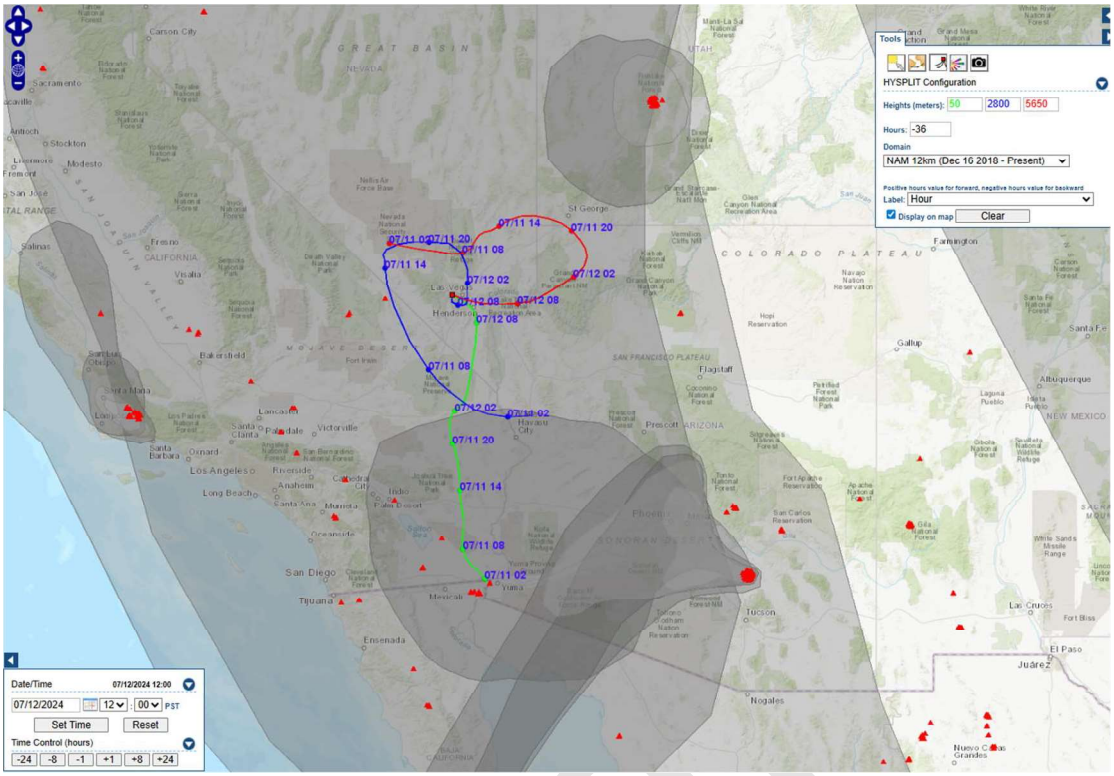

Figure 287. 36-hr boundary-layer backward trajectories from the NAM model ending at 13:00 PST on July 12, 2024, at 50 m (green line), 2,800 m (blue line), and 5,650 m (red line). HMS fires (triangles) and smoke (gray shading) on July 11 are also displayed. Image courtesy of EPA's AirNow-Tech.

The back trajectory ending in Las Vegas at 13:00 PST on July 12 (Figure 287) at 50 m AGL (green line), indicates a transport path originating within a dense smoke plume and near several fires in northern Baja California on July 11. These trajectories provide evidence of direct smoke transport into the Clark County region on July 12 from multiple fires and a dense smoke plume to the south over the preceding day.

Summary

From July 9-12, 2024, meteorological, fire, and smoke conditions likely contributed to smoke transport and accumulation in the Clark County area, which subsequently enhanced ozone production. Specifically,

- Persistent upper-level high pressure produced sunny and very hot conditions, supporting ground-level ozone production.
- A weak surface pressure gradient produced calm-to-light winds in the lower levels of the atmosphere during much of the four-day period, which reduced dispersion and allowed smoke to be gradually transported into the region and then linger for multiple days. In some

cases, a weak onshore pressure gradient generated light southwesterly afternoon winds, which transported smoke from fires in southern California into the Clark County area.

- Mixing heights more than 5,000 m observed each afternoon, driven in part by the extremely high surface temperatures, aided mixing of aloft smoke to the surface. Trajectories at different heights within the mixed layer often showed varying air mass source regions. In some cases, smoke was transported into the Clark County area from multiple directions at multiple heights over the preceding one or two days.
- On all days, a smoke plume was analyzed directly over the Clark County area.

7.3.4 Surface Impacts

Smoke from the fires burning in southwestern Utah, southern and northern California, Oregon, northern Nevada, and Baja California, Mexico, were present in Clark County from July 9-12, 2024. Figure 288 through Figure 291 show photos looking toward the north, northeast, south, and northwest from the M Resort Hotel, where smoke was visible by the afternoon of July 9. In the following days visibility decreased, particularly from the northwest direction as the sky became increasingly hazy due to smoke. The incoming smoke was a newsworthy occurrence, and was reported by the Las Vegas Sun. Their article from July 9, 2024, said "In wildfire season, enhanced by climate change, Las Vegas residents asked to keep informed," and reported that winds helped to drive smoke from the Post Fire in Utah, causing poor air quality over most of Clark County.[66]

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[66] https://lasvegassun.com/news/2024/jul/09/in-wildfire-season-enhanced-by-climate-change-las/

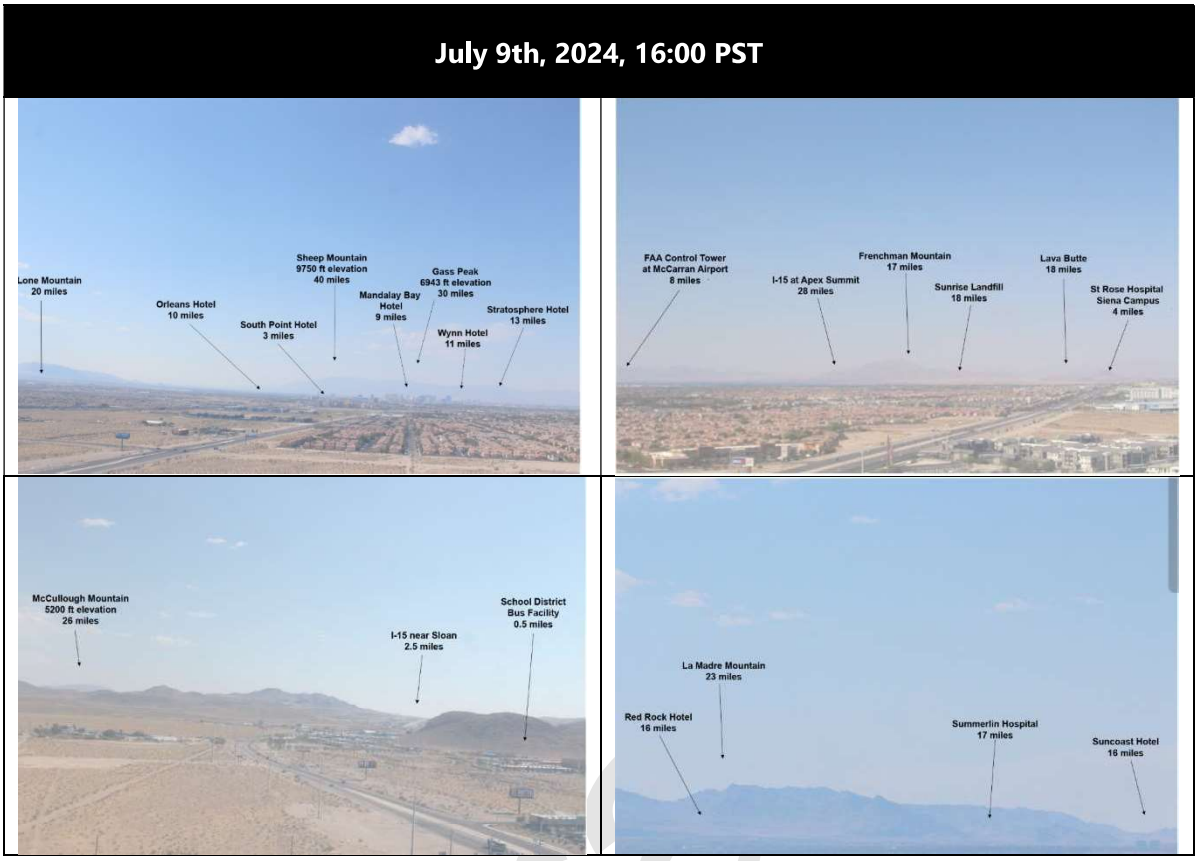

Figure 288. Webcam images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) views from the M Resort Hotel in Clark County, NV, on July 9, 2024, at 16:00 PST.

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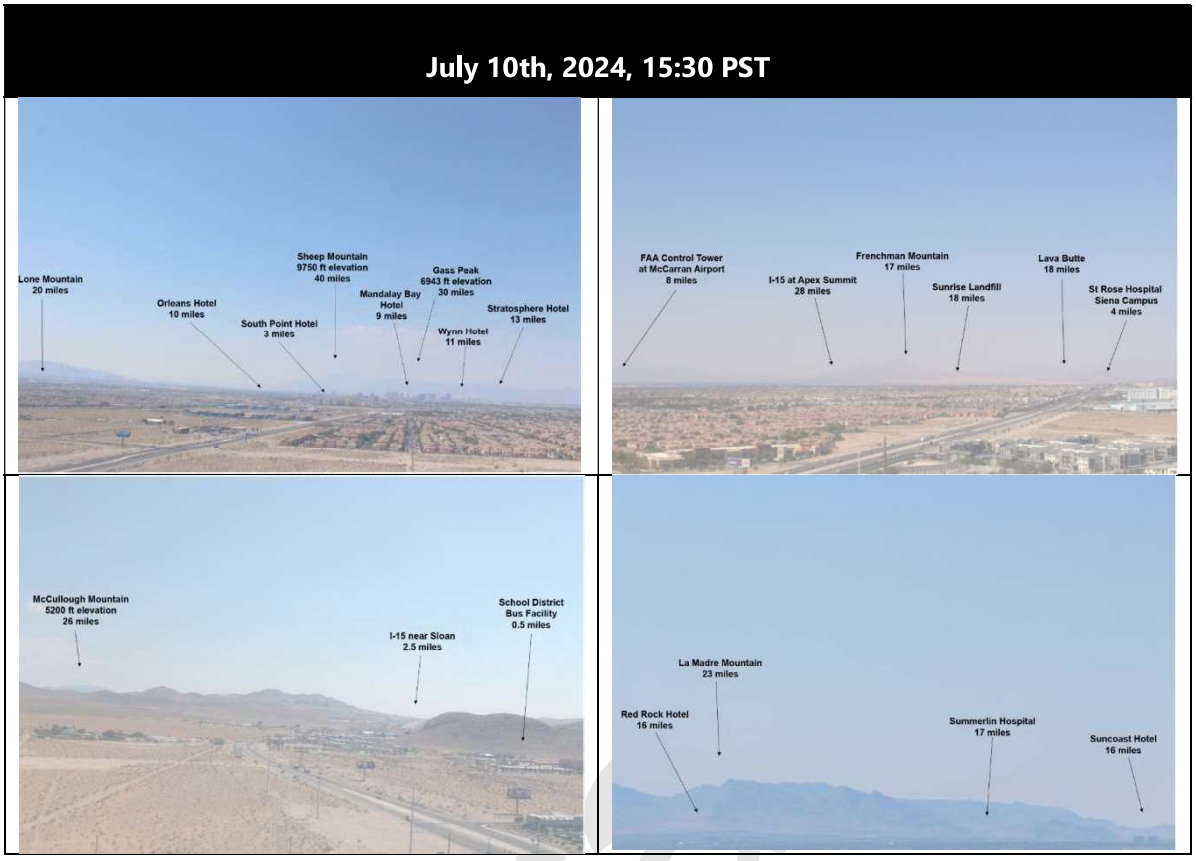

Figure 289. Webcam images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) views from the M Resort Hotel in Clark County, NV, on July 10, 2024, at 15:30 PST.

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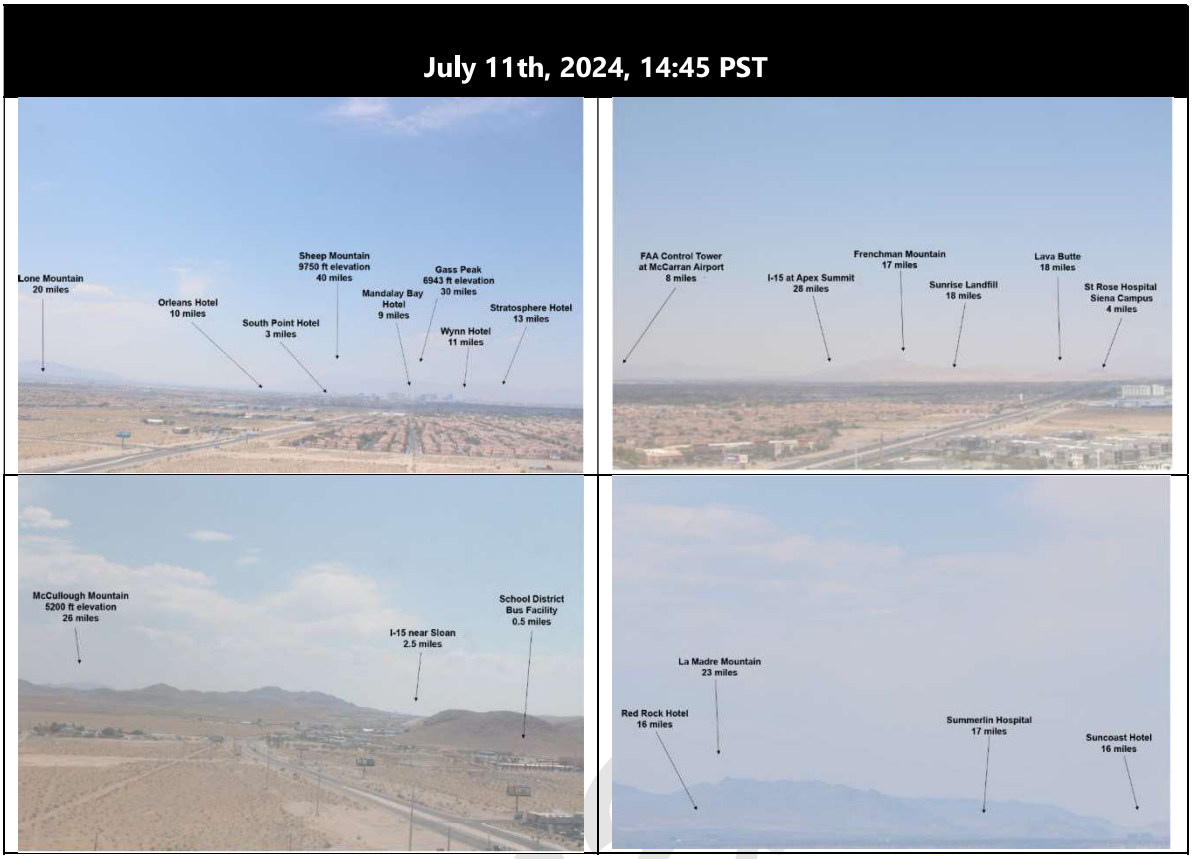

Figure 290. Webcam images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) views from the M Resort Hotel in Clark County, NV, on July 11, 2024, at 14:45 PST.

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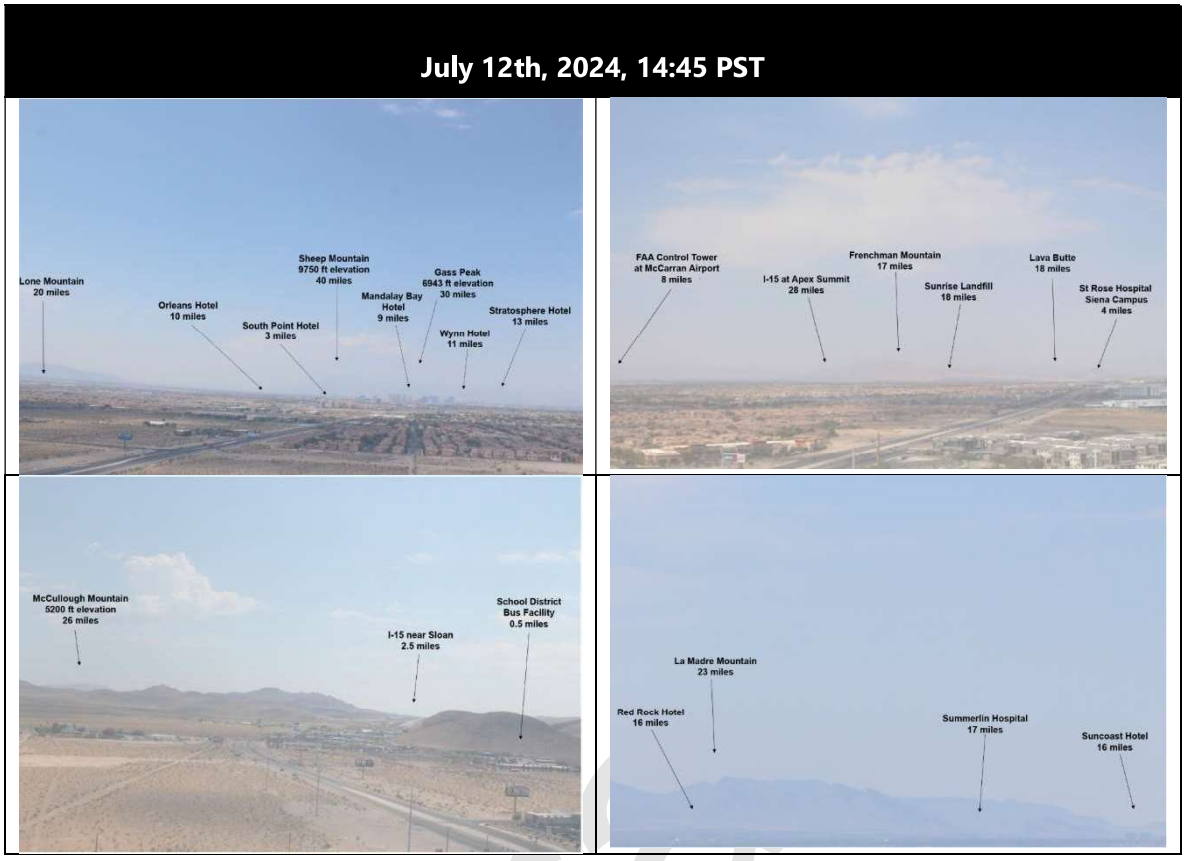

Figure 291. Webcam images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) views from the M Resort Hotel in Clark County, NV, on July 12, 2024, at 14:45 PST.

$PM_{2.5}$, CO, and NO_2 concentrations were enhanced in Clark County from July 9-12 due to smoke from the Post Fire, Silver King Fire, and numerous other fires burning in the western United States and Baja California, Mexico, which entered the region and mixed toward the surface, providing further evidence that wildfire smoke was present as an atypical influence on ozone during the exclusion period.

Figure 292 shows hourly $PM_{2.5}$ concentrations at six of the affected sites (Green Valley, Joe Neal, Palo Verde, Paul Meyer, Walnut Community Center*, and Walter Johnson) overlaid on the 10th to 90th percentile hourly concentrations during ozone season (April to September), calculated using data from 2019-2024. At all six sites, $PM_{2.5}$ concentrations were elevated above the seasonal median concentration throughout the event period. From July 9-12, $PM_{2.5}$ concentrations regularly peaked above the 90th percentile, typically during the morning hours of each day (approximately 09:00 PST). The most notable spike in $PM_{2.5}$ concentrations occurred around 21:00 PST on July 12 at all six sites.

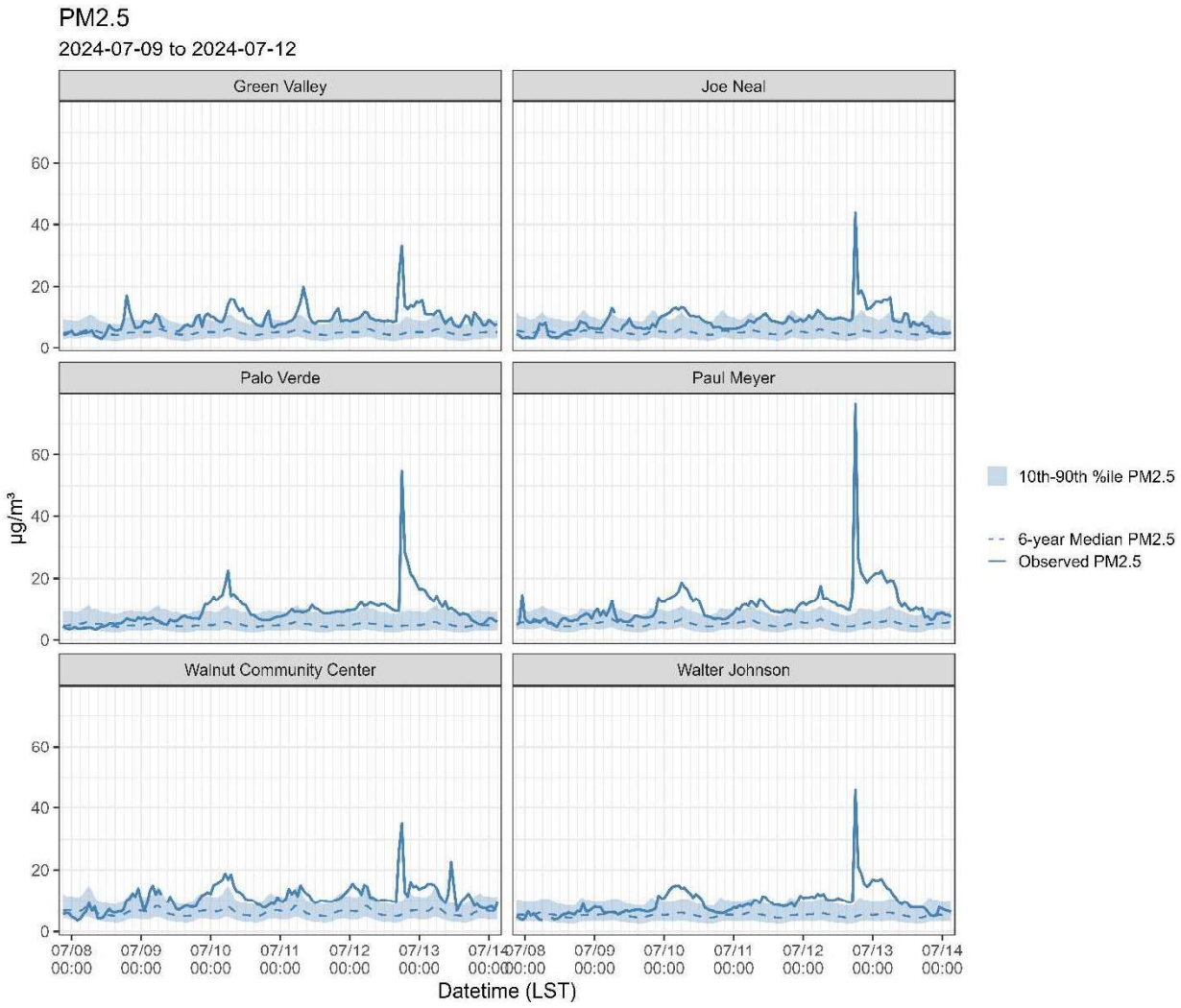

Figure 292. Hourly $PM_{2.5}$ concentrations for July 9 – 13 overlaid on the 10th-to-90th percentile diurnal concentration at Green Valley (AQS site code 320030298), Joe Neal (AQS site code 320030075), Palo Verde (AQS site code 320030073), Paul Meyer (AQS site code 320030043), Walnut Community Center* (AQS site code 320032003), and Walter Johnson (AQS site code 320030071). The 10th-to-90th percentile concentration is calculated across the ozone production season (April-September) of 2019-2024. Note: the Walnut Community Center site only includes data from June 1, 2021, and onwards.

Figure 293 shows hourly CO concentrations at Walnut Community Center* from July 9-12 overlaid onto the multiyear seasonal 10th to 90th percentile ranges. A significant peak in CO concentrations was observed between 18:00 PST on July 8 and 06:00 PST on July 9, which exceeded the multiyear median and 90th percentile concentrations before returning to approximate median concentrations later in the day on July 9. A similar diurnal pattern in CO concentrations also occurred from July 10-12, with slightly lower CO concentrations than on July 8.

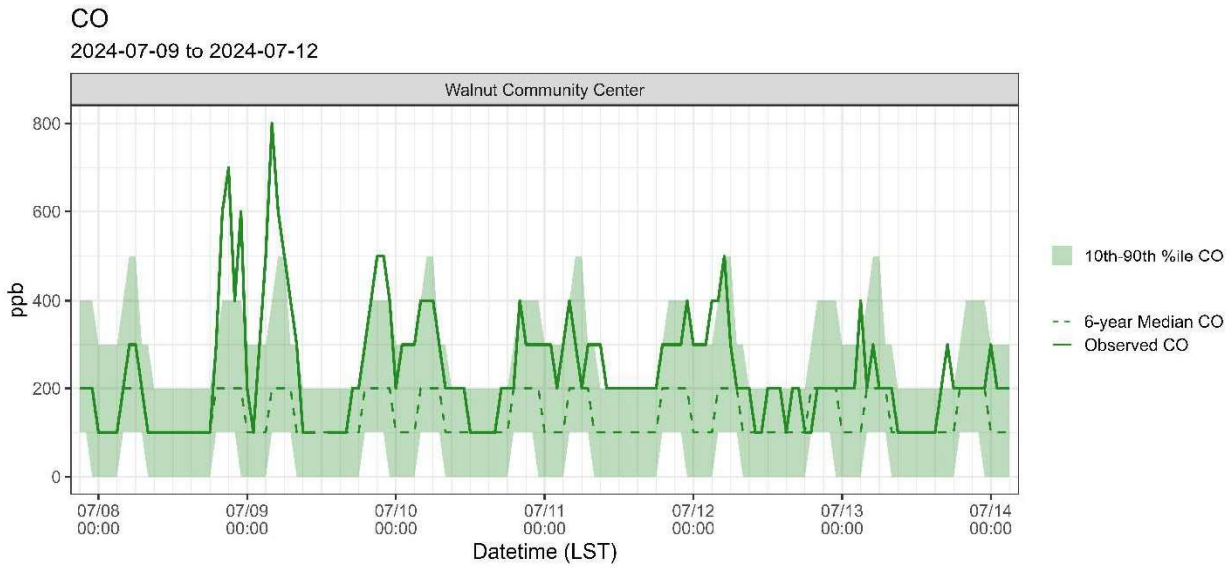

Figure 293. Hourly CO concentrations for July 9 – 13 overlaid on the 10th-to-90th percentile diurnal concentration at Walnut Community Center* (AQS site code 320032003). The 10th-to-90th percentile concentration is calculated across the ozone production season (April-September) of 2021-2024. Note: the Walnut Community Center site only includes data from June 1, 2021, and onwards.

As shown in **Figure 294**, NO_2 concentrations in Clark County were enhanced during some hours from July 9-12, exhibited by hourly concentrations at Walnut Community Center* overlaid onto the multiyear seasonal 10th to 90th percentile range. NO_2 concentrations followed a similar diurnal pattern as CO at Walnut Community Center* during this period. The most significant peak was observed between 18:00 PST on July 8 and 06:00 PST on July 9, exceeding the 6-year median and 90th percentile values; with concentrations returning to typical seasonal values between 09:00 PST and 15:00 PST on July 9. In subsequent days, NO_2 concentrations followed a similar pattern but with slightly lower peak concentrations from July 10-12, relative to July 8-9.

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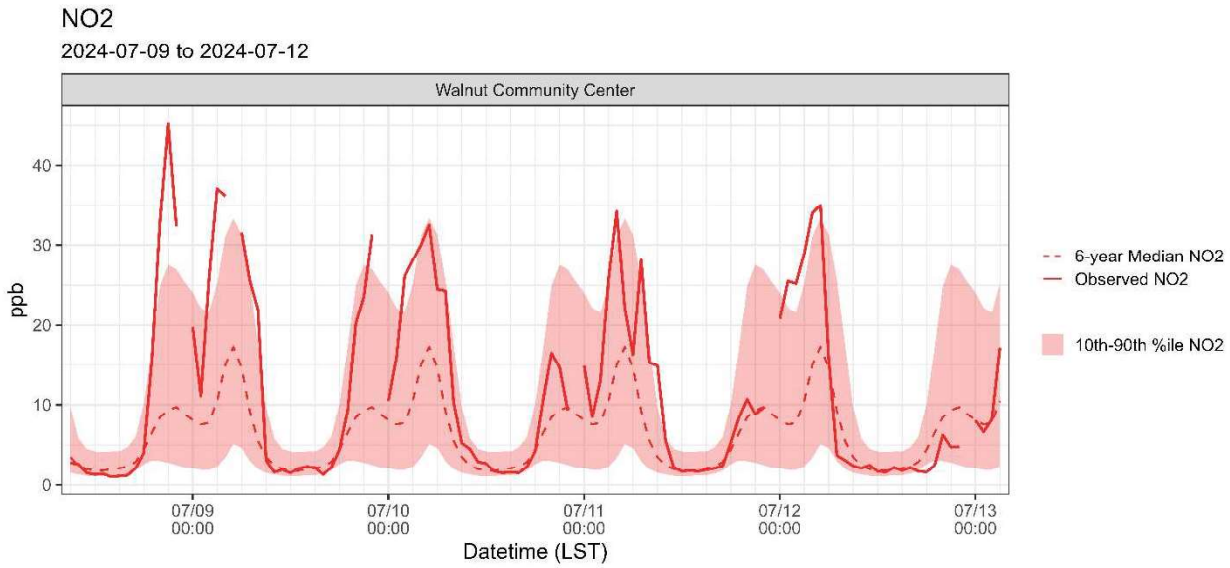

Figure 294. Hourly NO_2 concentrations for July 9-13 overlaid on the 10th-to-90th percentile diurnal concentration at Walnut Community Center* (AQS site code 320032003). The 10th-to-90th percentile concentration is calculated across the ozone production season (April-September) of 2021-2024. Note: the Walnut Community Center site only includes data from June 1, 2021, and onwards.

The ratio of $PM_{2.5}$-to-PM_{10} concentrations was examined to determine if wildfire smoke entered Clark County on or before the atypical event. Enhanced $PM_{2.5}$-to-PM_{10} ratios indicate the presence of wildfire smoke at the surface. Figure 295 shows a time series of $PM_{2.5}$-to-PM_{10} ratios from July 8-13 overlaid onto the 6-year average ratio and 10th to 90th percentile for the following sites: Green Valley, Joe Neal, Palo Verde, Paul Meyer, Walnut Community Center*, and Walter Johnson. At all six sites, the ratio fluctuated and regularly exceeded the 6-year mean and 90th percentile concentrations. Notably, $PM_{2.5}$-to-PM_{10} ratios were elevated above the 90th percentile during the period between 12:00 PST on July 9 and 00:00 PST on July 13, which is indicative of wildfire smoke in the area. Elevated $PM_{2.5}$-to-PM_{10} ratios provide evidence of the presence of wildfire smoke in Clark County during the atypical ozone event from July 9-12.

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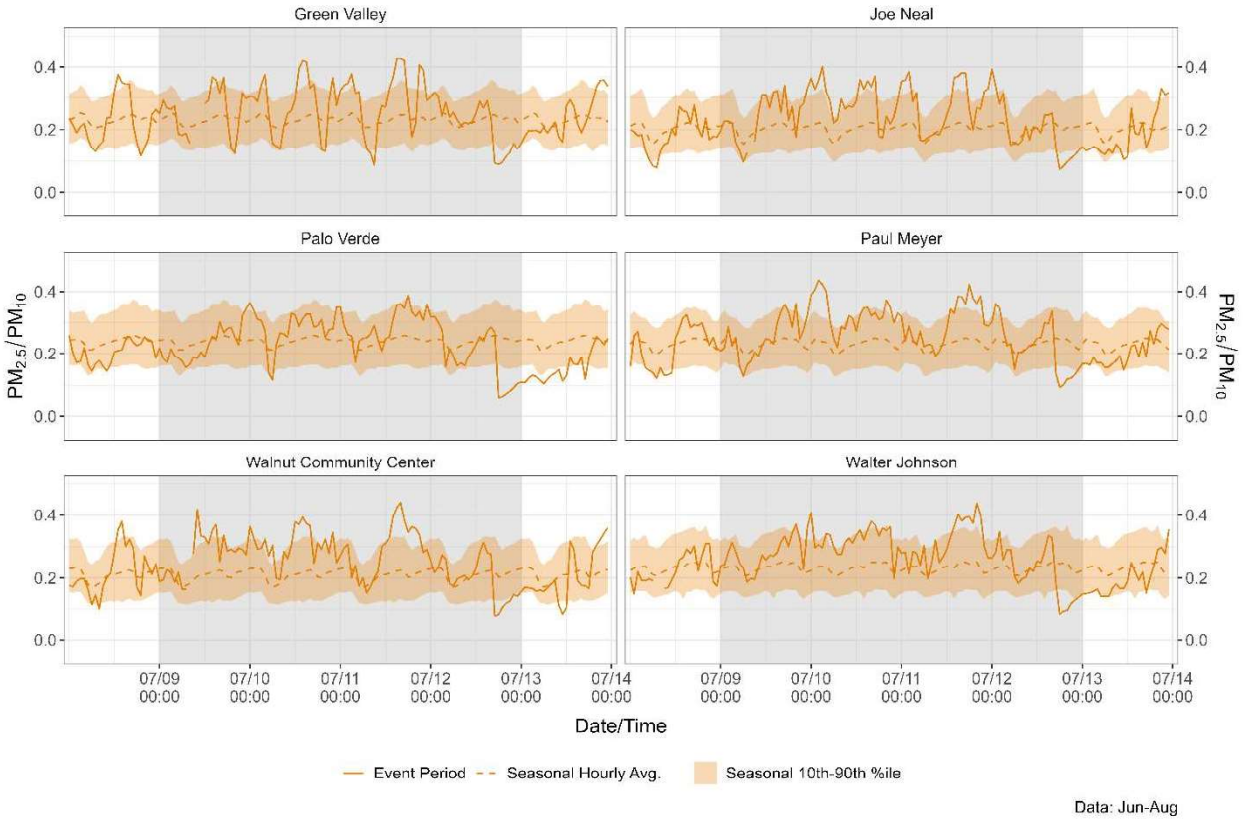

Figure 295. Ratio of $PM_{2.5}$-to-PM_{10} concentrations during the event period (shaded) overlaid on the 10th-to-90th percentile diurnal concentrations at Green Valley (AQS site code 320030298), Joe Neal (AQS site code 320030075), Palo Verde (AQS site code 320030073), Paul Meyer (AQS site code 320030043), Walnut Community Center* (AQS site code 320032003), and Walter Johnson (AQS site code 320030071). The 10th-to-90th percentile concentration is calculated across the ozone production season (April-September) of 2019-2024. Note: the Walnut Community Center site only includes data from June 1, 2021, and onwards.

The concurrence of widespread enhanced $PM_{2.5}$, CO, and NO_2 concentrations, enhanced $PM_{2.5}$-to-PM_{10} ratios, and webcam images in Clark County on July 9-12 provide evidence that surface-level smoke was present in Clark County during the atypical event.

7.3.5 VOC Analysis

VOC samples were collected on July 11 and 12, 2024 during the July 9-12 smoke period. VOC ratios shown in Table 67 were calculated at all sites where data was available (Jerome Mack data for July 11 was unavailable). These ratios were compared with the fire and no fire regimes calculated in Section 7.1.2 and found to all fall within the fire regime for all sites and all ratios except Acetonitrile: Pentane (ACN_PEN) at Jerome Mack on July 12. Jean saw particularly high ratios on July 12 despite being the upwind site during this event, confirming the presence of smoke both upwind and within Clark County.

Table 67. VOC Ratios calculated for July 11 and 12, 2024 from the Jean, Jerome Mack, and Sunrise Acres monitoring sites. These ratios can be compared with the fire and no fire regimes calculated in Section 7.1.2. Ratio abbreviations are defined in Table 61.

Sample Date	Site	ACE_ ACN	ACN_ ACE	ACN_ ACR	ACN_ BZN	ACN_ PEN	ACN_ TOL
7/11/2024	Jean	15.9	0.067	1.1	3.4	0.9	3.4
	Sunrise Acres	25.4	0.054	1.4	3.3	0.3	0.6
7/12/2024	Jerome Mack	10.9	0.039	0.4	3.9	0.1	0.1
	Jean	44.0	0.073	3.2	3.2	3.2	3.2
	Sunrise Acres	16.8	0.055	0.9	3.4	1.0	1.3

7.3.6 Event Statistics

Table 68 summarizes concentrations of ozone, $PM_{2.5}$, CO, and NO_2 on the exclusion days as well as the percentage of the observation compared to the previous six years of data (2019-2024). MDA8 ozone concentrations ranged from the 94th to 99th percentiles for July 9-12.

24-hr $PM_{2.5}$ concentrations ranged from the 81st to 97th percentiles. As shown in Figure 292, $PM_{2.5}$ concentrations were above the seasonal median for all of July 9-12, with concentrations during many hours exceeding the 90th percentile.

CO and NO_2 concentrations are not well represented at the affected sites and in most cases have less than six years of data for comparison. Data from Jerome Mack, which is not an affected site, was thus also included for additional context on enhanced CO and NO_2 observations across the region. CO concentrations were only available from Walnut Community Center* and Jerome Mack and ranged from 400-800 ppb or the 37th-77th percentiles. NO_2 concentrations were only available for Joe Neal, Walnut Community Center*, and Jerome Mack and ranged from 7-41 ppb or the 13th-84th percentiles.

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Table 68. Percentile of pollution concentration on exclusion day compared with most recent six years (2019-2024). The percentile rank is calculated across the ozone production season (April 1 – September 30) of 2019-2024. Sites that have less than six years of data available for a given parameter are indicated with an asterisk. Data from nearby sites not identified for exclusion are shown in italics.

Date	Site Name	Site Code	Ozone		$PM_{2.5}$		CO		NO_2	
			Ozone MDA8 (ppb)	Percent rank	$PM_{2.5}$ 24-hr average ($\mu g/m^3$)	Percent Rank	CO 1-hr daily max (ppb)	Percent Rank	NO_2 1-hr daily max (ppb)	Percent Rank
7/9/2024	Joe Neal	320030075	70	94.1%	7.8	85.0%			17	55.8%
	Palo Verde	320030073	71	97.2%	7.0	86.3%*				
	Walnut Community Center	320032003	72	96.2%*	10.1	84.3%*	800	76.9%*	37	81.7%*
	Walter Johnson	320030071	71	95.2%	7.1	81.1%*				
	Jerome Mack-NCore	*320030540*					*716*	*52.4%*	*35*	*58.3%*
	Green Valley	320030298	74	99.4%	10.2	94.4%				
7/10/2024	Joe Neal	320030075	74	97.6%	9.6	91.5%			7	13.3%
	Paul Meyer	320030043	73	96.9%	11.3	95.3%				
	Walnut Community Center	320032003	73	97.1%*	12.3	92.0%*	400	37.4%*	33	61.8%*
	Walter Johnson	320030071	70	94.1%	10.3	94.0%				
	Jerome Mack-NCore	*320030540*					*675*	*50.4%*	*41*	*84.4%*
7/11/2024	Joe Neal	320030075	82	99.8%	8.6	88.6%			9	20.7%
	Palo Verde	320030073	75	99.4%	9.1	92.5%*				
	Paul Meyer	320030043	72	96.4%	10.4	93.4%				
	Walnut Community Center	320032003	76	98.9%*	11.2	88.4%*	400	37.4%*	34	70.2%*
	Walter Johnson	320030071	75	98.2%	9.1	91.1%*				
	Jerome Mack-NCore	*320030540*			*9.2*	*67.5%*	*558*	*43.8%*	*38*	*71.8%*
7/12/2024	Joe Neal	320030075	70	94.1%	12.5	96.1%			17	55.8%

Date	Site Name	Site Code	Ozone		$PM_{2.5}$		CO		NO_2	
			Ozone MDA8 (ppb)	Percent rank	$PM_{2.5}$ 24-hr average ($\mu g/m^3$)	Percent Rank	CO 1-hr daily max (ppb)	Percent Rank	NO_2 1-hr daily max (ppb)	Percent Rank
	Palo Verde	320030073	74	98.9%	15.1	97.8%*				
	SM Youth Camp	320037771	72	97.2%						
	Walter Johnson	320030071	70	94.1%	13.5	97.1%*				
	Jerome Mack-NCore	*320030540*					*532*	*42.0%*	*41*	*83.5%*

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7.4 July 15-17, 2024

7.4.1 Event Summary

The unrepresentative ozone event took place on July 15 through 17, 2024, and affected the following seven sites in Clark County, Nevada: Green Valley, Joe Neal, Mountain's Edge*, Palo Verde, Paul Meyer, Walnut Community Center*, and Walter Johnson. Time series showing hourly ozone exceeding seasonal medians (calculated using April 1 – September 30, 2019-2024 data, where available) and 10th to 90th percentiles at each site are shown in Figure 296.

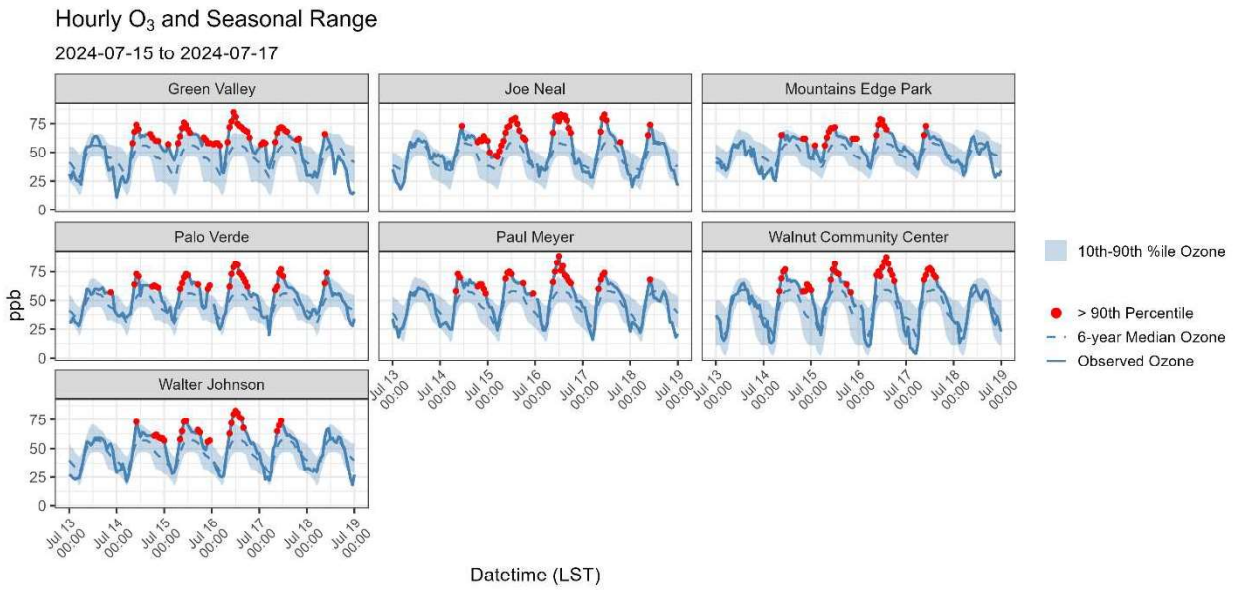

Figure 296. Hourly ozone concentrations (ppb) compared with 6-year* ozone season (April 1 – September 30) hourly medians and 10th-to-90th percentiles. Note: the Mountain's Edge site only includes data from October 1, 2020, and onwards; and the Walnut Community Center only includes data from June 1, 2021, and onwards.

The affected sites began to measure ozone concentrations above the six-year ozone season median and 90th percentile during the late morning of July 14. Elevated ozone concentrations were measured until the evening of July 17, when they returned to typical seasonal levels. From July 15-17, peak daily ozone concentrations were recorded midday; those values were typically above the 6-year ozone season median and 90th percentile. The peak ozone concentrations during this period were recorded at all sites at midday on July 16. The maximum daily 8-hour average (MDA8) concentrations at affected sites ranged from 71-79 ppb.

Large smoke plumes from numerous wildfires in western Canada and wildfires in southern California were identified as likely contributors to this event. Evidence includes (1) NOAA HMS smoke perimeters over Clark County, (2) HYSPLIT trajectories and meteorological analysis showing transport and accumulation of smoke in Clark County, (3) visible smoke in camera images and news coverage, and (4) synchronous enhancement of $PM_{2.5}$, CO, and NO_2 concentrations as well as enhanced $PM_{2.5}$-to-PM_{10} ratios aligned with ozone enhancement. This combination of evidence strongly indicates that this event is unrepresentative for base and future design-value ozone assessments.

7.4.2 Identification of Wildfire(s)

Numerous wildfires were actively burning across the western United States and in western Canada on the days leading up to and during July 15-17, 2024, the exclusion days. By late July, 989 fires were actively burning in Canada, with more than half of those occurring in British Columbia or Alberta.[67] The significant emissions from these fires contributed to regional smoke impacts across large swaths of the United States; this situation was verified for the exclusion days using HMS (**Figure 297 through Figure 299**).[68] To the west of Clark County, the SQF Lightning Complex Fires burned in the Sequoia National Forest in southern California (Figure 298). Those fires started on July 13 and quadrupled in size by July 15. They were contained by September 17, according to Cal Fire. Additionally, multiple fires were active in the Tehachapi Mountains area of Kern County, CA, prior to and during the exclusion days.[69] The White Fire (Figure 297 and Figure 298), which started 11 miles south of the Tehachapi Mountains on July 13, had burned 3,412 acres by July 14. The White Fire eventually burned 5,536 acres and was contained on July 26.[70] The Rancho Fire (Figure 297 and Figure 298), which began north of the Tehachapi Mountains on July 13, had burned 9,590 acres by July 14 and was contained on July 26.[71] Finally, the Hurricane Fire (Figure 297 and Figure 298), which began in San Luis Obispo County on July 13, had burned 12,703 acres[72] and was contained as of July 16.[73][74] Figure 297 shows the western United States on July 15; Figure 298 shows the SQF Lightning Complex Fires on July 16; and Figure 299 shows the continental view on July 17.

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[67] https://scitechdaily.com/smoke-from-hundreds-of-wildfires-darkens-skies-over-canada-and-the-u-s/#:~:text=As%20of%20July%2024%2C%20989%20fires%20actively%20burned,movement%20of%20wildfire%20smoke%20from%20July%2017%E2%80%9324%2C%202024
[68] https://earthobservatory.nasa.gov/images/153106/smoky-skies-across-north-america
[69] https://kerncountyfire.org/16473/three-wildfires-impact-kern-county/
[70] https://www.fire.ca.gov/incidents/2024/7/13/white-fire
[71] https://www.fire.ca.gov/incidents/2024/7/13/rancho-fire
[72] https://www.fire.ca.gov/incidents/2024/7/13/hurricane-fire
[73] https://www.sanluisobispo.com/news/local/article290054829.html
[74] https://www.sfchronicle.com/projects/california-fire-map/hurricane-fire-2024

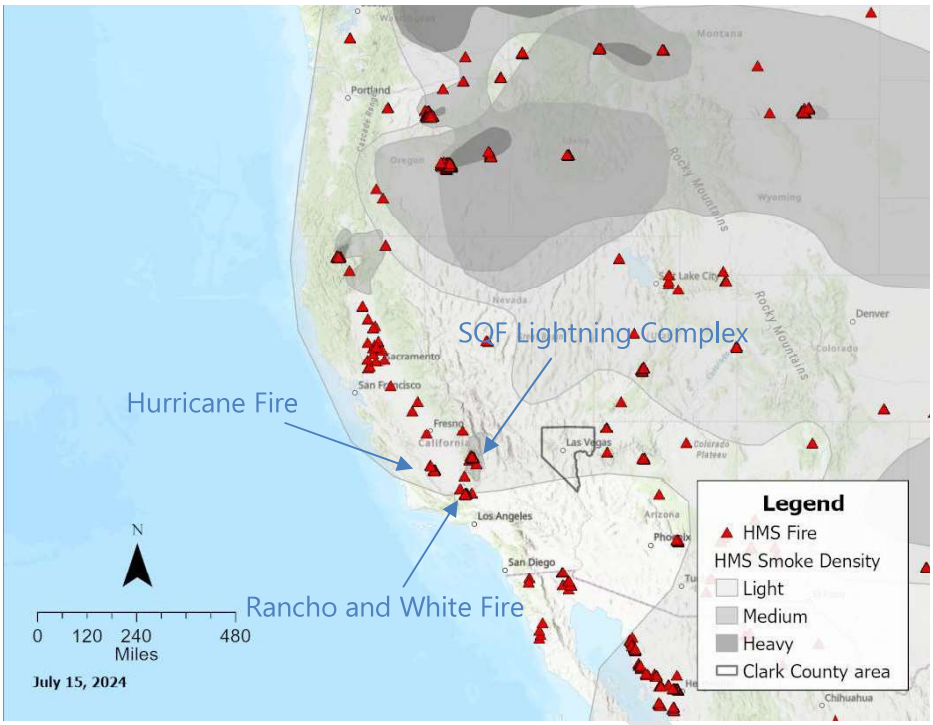

Figure 297. View of the western United States with HMS fire detections (red triangles) and smoke density (grey contours) on July 15, 2024. Clark County is outlined in grey.

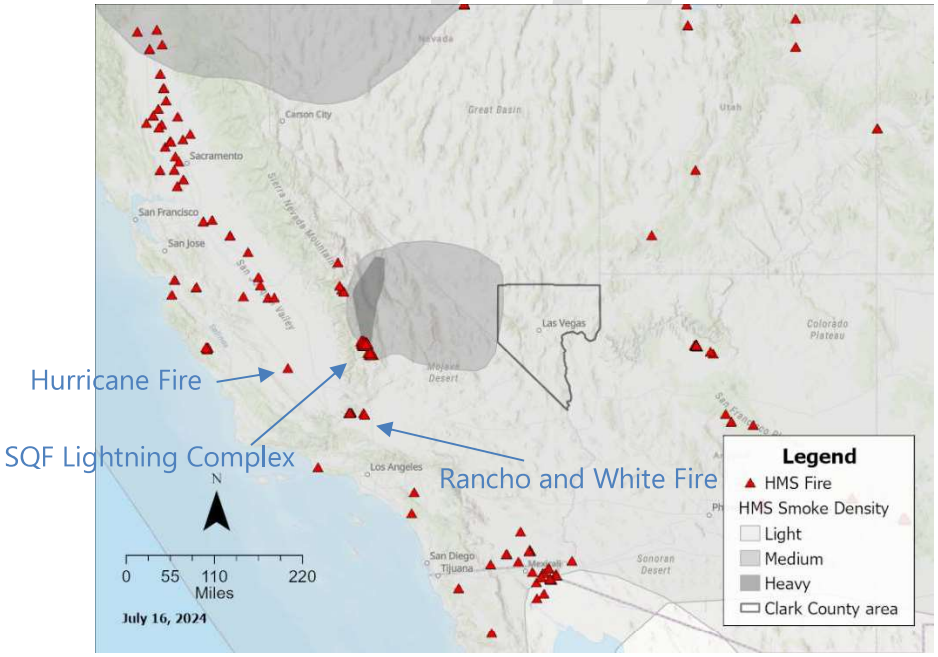

Figure 298. Local view of HMS fire detections (red triangles) and smoke density (grey contours) on July 16, 2024. Clark County is outlined in grey.

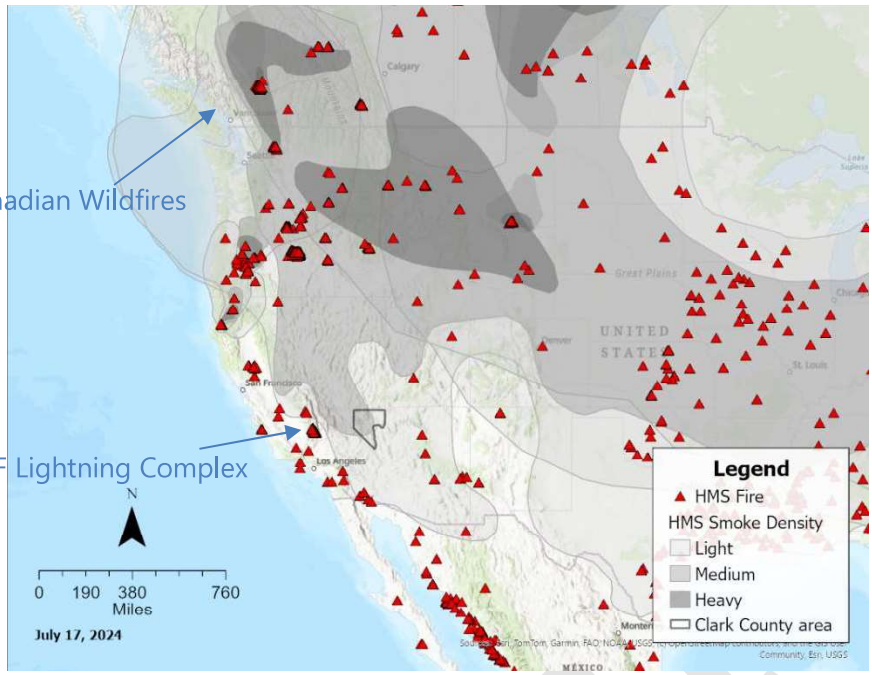

Figure 299. Continental view of HMS fire detections (red triangles) and smoke density (grey contours) on July 17, 2024. Clark County is outlined in grey.

7.4.3 Meteorological Analysis

Upper-Level Weather Patterns

To determine the meteorological conditions during the ozone exceedance period of July 15-17, 2024, an analysis was conducted using observed upper-level weather maps, observed PBL meteorological data, NOAA HMS satellite fire and smoke data, and HYSPLIT paths.

The mean 500 mb winds (approximately 18,000 feet above ground level [AGL]) for the three-day period are shown in Figure 300. A clockwise wind pattern is noted around Colorado and New Mexico, with air entering Clark County from the south-southeast. This clockwise wind pattern is associated with high pressure aloft, which generates subsidence (sinking air) and compressional heating that limits cloud development and yields high surface temperatures.

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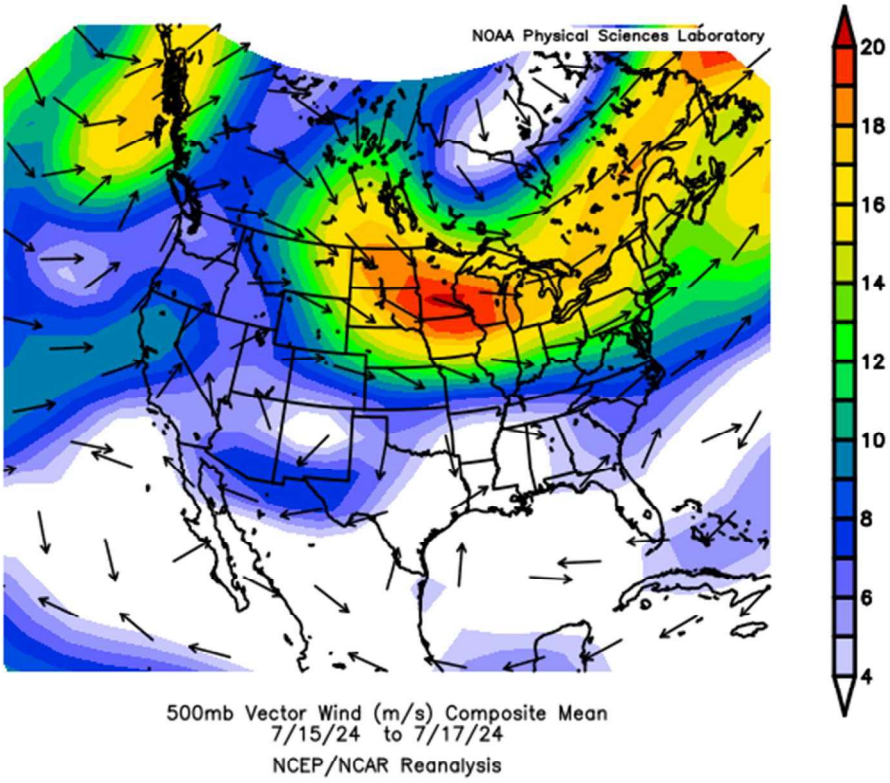

Figure 300. Mean 500 mb winds for July 15-17, 2024. High pressure aloft over Colorado and New Mexico resulted in clockwise flow and south-southeasterly upper-level winds into southern Nevada. Source: NOAA.

Surface Weather Patterns

Table 69 lists pertinent daily weather data from the Harry Reid International Airport (KLAS) for July 15-17. Partly-to-mostly-sunny skies were observed each day with afternoon high temperatures reaching at least 110°F at KLAS. Figure 301 shows the daily average wind speeds and directions in wind rose format from KLAS. Calm-to-light southwesterly winds each day inhibited dispersion of pollutants and ozone precursors present in the Clark County area, while sunny and hot conditions promoted ground-level ozone production.

Table 69. Daily maximum temperatures, average daily wind speed, and average daily wind direction at KLAS for the July 15-17, 2024, period.

Date	Maximum temperature (°F)	Average wind speed (mph)	Average wind direction (deg)
7/15	110	6.0	214
7/16	110	4.9	188
7/17	111	5.1	196

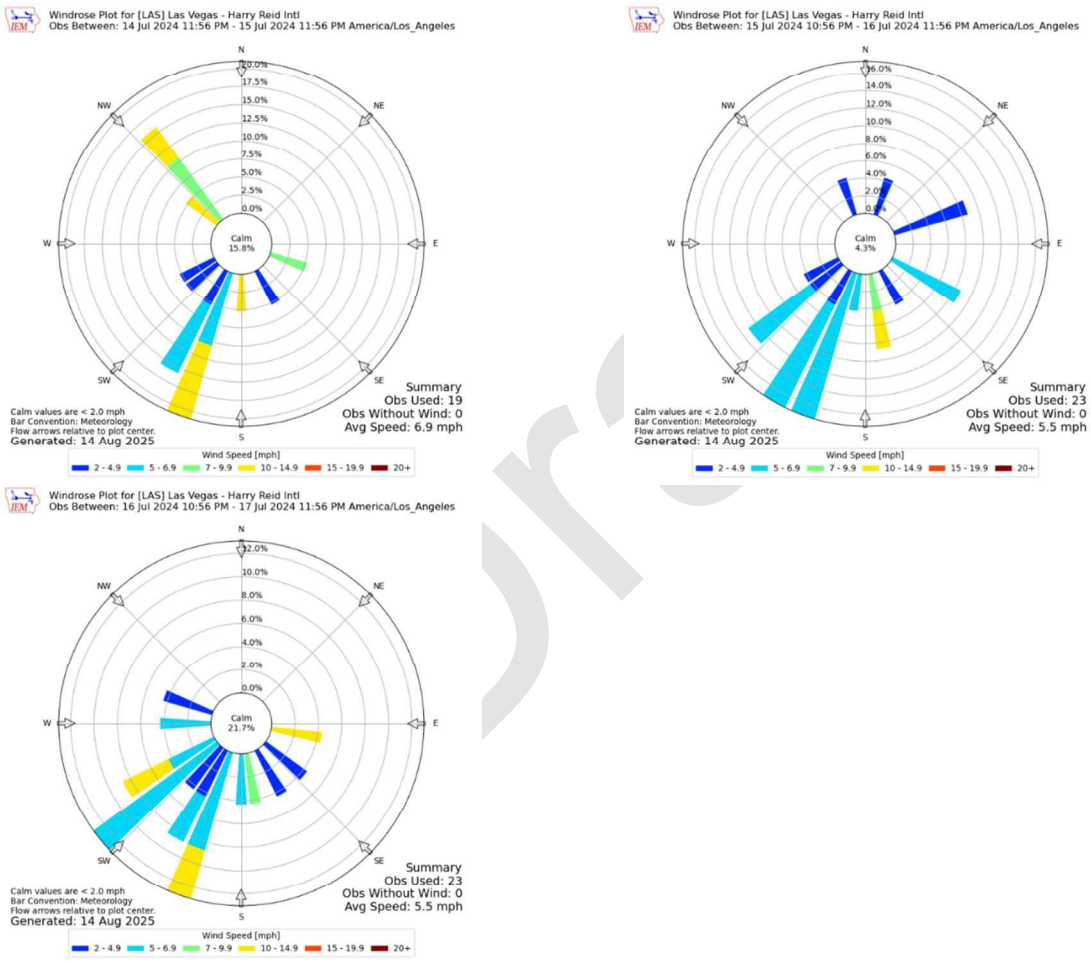

Figure 301. KLAS daily wind roses for July 15-17, 2024, which indicate calm-to-light southwesterly winds inhibiting dispersion of pollutants and ozone precursors throughout the three-day period. Source: Iowa State Mesonet.

Vertical Temperature Profiles and Mixing Heights

PBL heights can provide information on the depth of vertical mixing from the surface to the top of the boundary layer and can also aid in assessing potential transport paths within the boundary layer into southern Nevada. Higher PBL heights often result in deep mixing vertically, allowing upper-level air to be transported to the surface. PBL heights for July 15-17, 2024, were estimated using available data from the Las Vegas upper-air weather station (KVEF) and the Jerome Mack ceilometer. Table 70 lists the estimated PBL heights and their corresponding data source.

Table 70. Estimated PBL heights for Clark County for the July 15-17, 2024, period.

Date	Estimated PBL (meters)	Data Source
7/15	4,270	04:00 PST KVEF sounding
7/16	2,180	Jerome Mack ceilometer
7/17	5,000	16:00 PST KVEF sounding

NOAA HMS satellite fire detections and smoke plumes were examined to determine whether smoke was present over southern Nevada from July 15-17, 2024. As shown in Figure 302, NOAA identified smoke over a large portion of Canada and the contiguous United States (CONUS), including southern Nevada, each day. Furthermore, the NOAA smoke discussions (Figure 304 and Figure 307 in the following section) for each day highlighted the source of the large plume of smoke originating from fires across Canada and portions of the United States. Given the persistent clockwise flow around the 500 mb high shown in Figure 300, conditions were favorable for transport from the large smoke plume into Clark County.

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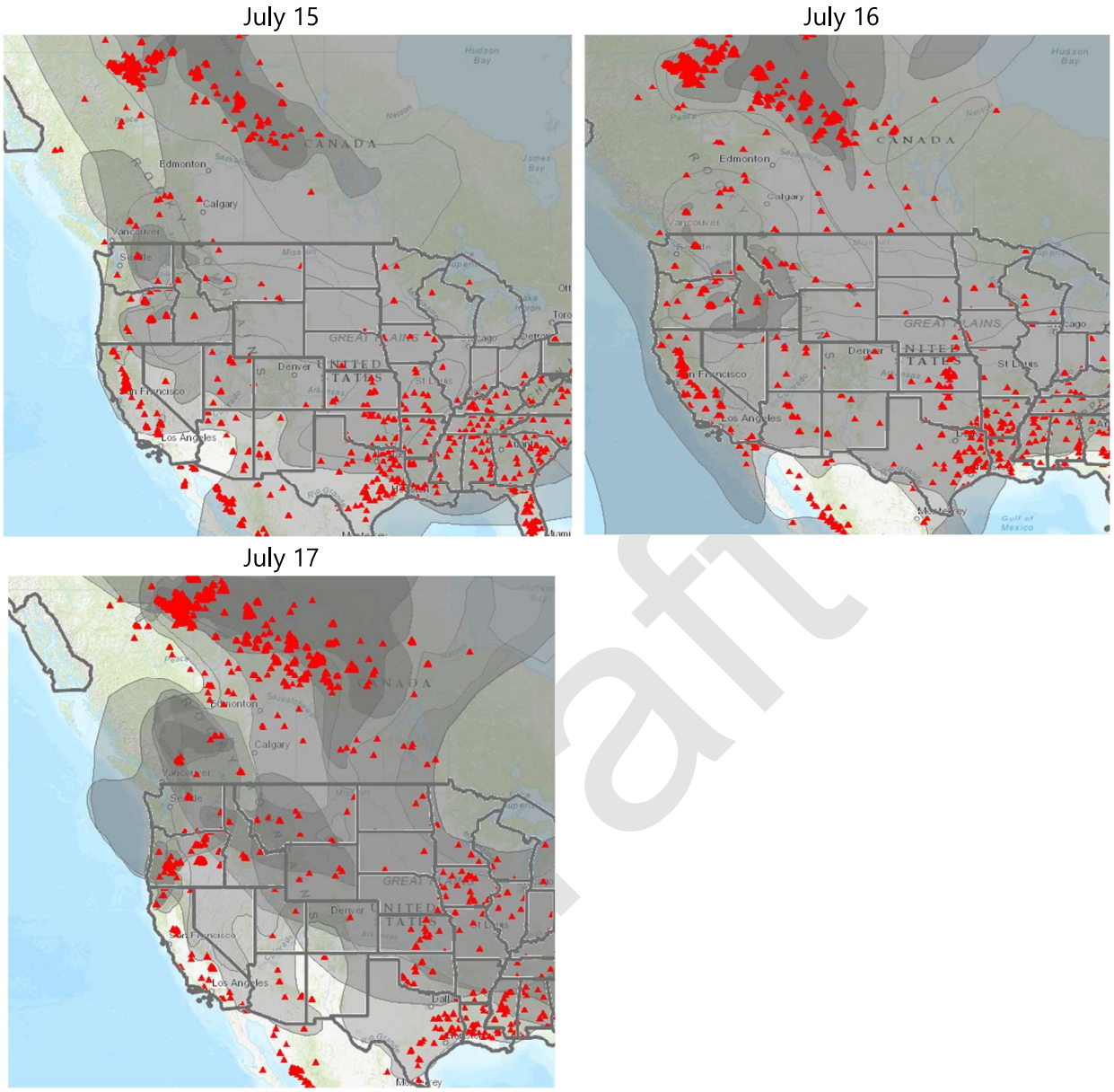

Figure 302. NOAA HMS smoke analysis (grey contours) and satellite fire detections (red triangles) for July 15-17, 2024. Source: AirNow-Tech.

Smoke Transport

Evidence of this large smoke plume being transported into southern Nevada was found using HYSPLIT and HMS. For July 15, a 72-hour back trajectory analysis was used that ended at 16:00 PST. NOAA HMS smoke plumes and satellite fire detections from 72 hours prior (i.e., July 12) were overlaid onto the HYSPLIT back trajectories. All transport paths within the PBL shown in **Figure 303** intersected analyzed smoke from July 12, with the 4,200 m AGL path originating from northern Texas and southwestern Oklahoma. Additionally, the prevailing back trajectory at 4,200 m AGL followed a

similar pattern to the 500 mb wind flow shown in Figure 300. According to the NOAA smoke discussion on July 12, the source of the smoke over Texas and Oklahoma was from wildfires burning in western Canada (Figure 304).

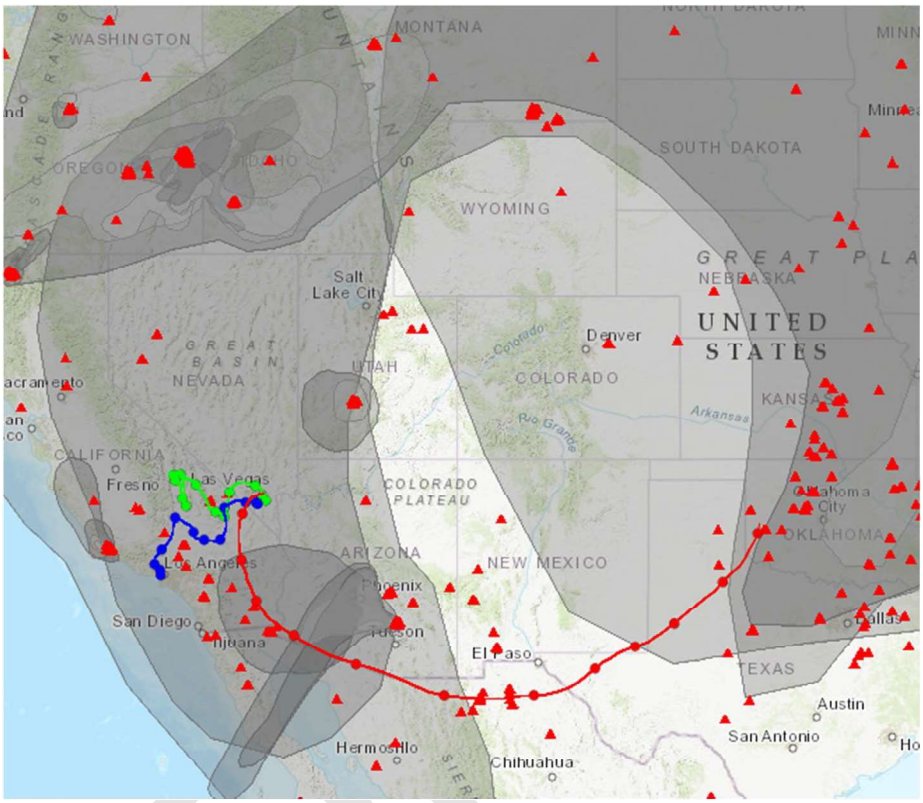

Figure 303. 72-hour back trajectory analysis (green – 50 m AGL, blue – 2,100 m AGL, red – 4,200 m AGL) ending at 16:00 PST on July 15. The 4,200 m AGL path intersects NOAA-analyzed smoke (grey contours) and is near fires (red triangles) detected by satellites on July 12. Source: AirNow-Tech.

Friday, July 12, 2024

DESCRIPTIVE TEXT NARRATIVE FOR SMOKE/DUST OBSERVED IN SATELLITE IMAGERY THROUGH 1350Z July 12, 2024

SMOKE:
Northeastern British Columbia/Alberta/US Northwest/US Central Plains
Light to heavy density smoke emanating from the ongoing fires in Northeastern British Columbia and eastern Alberta, were observed dispersing over large portions of the US/Canadia interior/Atlantic Seaboard. One segment of the light to medium density smoke shifted Southwards into Washington state, Oregon, Montana, and through the Central plains towards Dallas, Texas. Another segment of smoke blew across the Canadian interior until reaching Newfoundland and Labrador, from where it dispersed outwards into the Labrador Sea/Atlantic Ocean.

Figure 304. Smoke discussion valid 05:50 PST July 12, which mentions a large plume of smoke from Canadian fires covering the Central Plains and Texas. Source: NOAA.

Along with the broad smoke plume covering southern Nevada, an additional source of smoke was identified on July 16. For this date, a 24-hour HYSPLIT back trajectory was assessed, with transport paths within the PBL intersecting HMS-analyzed smoke from the previous day. Additionally, all transport paths shown in Figure 305 were near a cluster of satellite fire detections in the Tehachapi Mountains in southern California on July 15. This transport path shows evidence of smoke transport into Clark County.

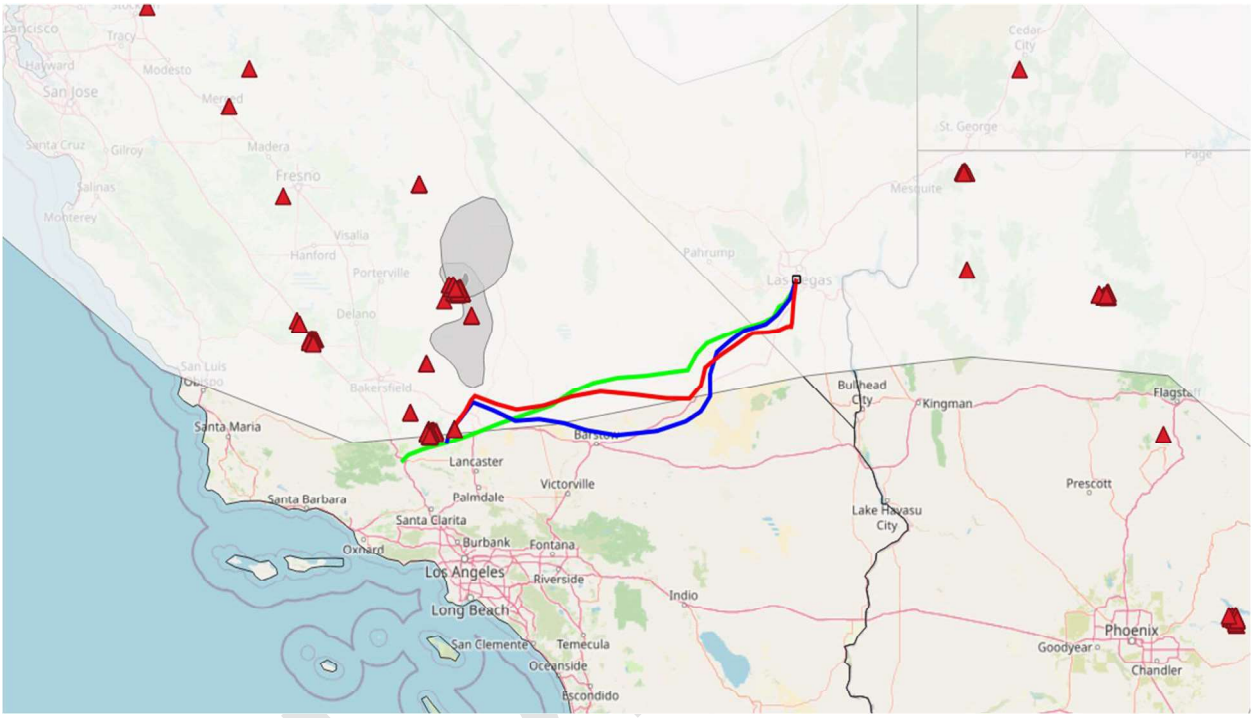

Figure 305. 24-hour back trajectory analysis ending at 16:00 PST on July 16. Transport paths (red – 10 m AGL, blue – 1,100 m AGL, and green – 2,180 m AGL) intersect NOAA-analyzed smoke (light grey contour) and are near fires (red triangles) detected by satellites on July 15. Source: NOAA.

A similar transport path was found within the PBL for the July 17 HYSPLIT analysis. Using a 48-hour back trajectory ending at 11:00 PST, the 10 m AGL and 2,500 m AGL transport paths intersected a NOAA-analyzed smoke plume from July 15. Furthermore, both paths shown in Figure 306 were near fires detected by satellites on July 15 in the Tehachapi Mountains, suggesting additional smoke was able to reach Clark County, in conjunction with the broad continental smoke plume analyzed in the NOAA smoke discussion shown in Figure 307.

Figure 306. 48-hour back trajectory analysis (green – 10 m AGL, blue – 2,500 m AGL, red – 5,000 m AGL) ending at 11:00 PST on July 17. The 10 m AGL and 2,500 m AGL transport paths intersected a NOAA-analyzed smoke plume from July 15 and were near fires detected by satellites on July 15 in the Tehachapi Mountains. Source: AirNow-Tech.

Wednesday, July 17, 2024

DESCRIPTIVE TEXT NARRATIVE FOR SMOKE/DUST OBSERVED IN SATELLITE IMAGERY
THROUGH 0030Z July 18, 2024

SMOKE:
Canada/United States/Pacific Northwest/Pacific Ocean/Atlantic Ocean...
A significant amount of mixed density smoke attributed to a combination of seasonal fire activity in the United States and numerous wildfires throughout northern Canada, Washington State, Oregon, California, Idaho, Montana, Wyoming and Utah continued to be seen throughout today covering an extensive area including northern Canada, the majority of the Continental United States and parts of the Pacific Ocean off the coast of the Northern Pacific. This mixed density smoke was seen extending east through the entirety of Canada from the Northwest Territories into the Labrador Sea before extending further east into the Northern Atlantic Ocean. Areas of moderate density smoke were seen moving east from the central region of the Northwest Territories into northeast Alberta, reaching central Saskatchewan. Areas of the moderate smoke progressed further south into the U.S., completely covering the northern Central Plains and the Midwest regions with a mass of heavy density smoke seen within the northern Western U.S. region. This heavy density smoke originating from the wildfires present in northern Canada was seen extending east-southeast within the larger area of moderate smoke within Canada, however, the thick smoke remained within the boundaries of the central parts of the Northwest Territories and Saskatchewan and northern Alberta. Several wildfires within the Pacific Northwest were seen emitting plumes of moderate to thick density smoke that continues to accumulate into the larger mass of thick density smoke seen moving east-southeast through Oregon, Idaho, Montana and Wyoming.

Figure 307. Smoke discussion valid 16:30 PST July 17, which mentions a large plume of smoke from Canadian and United States fires covering most of CONUS. Source: NOAA.

Summary

Based on the prevailing weather conditions and back trajectory analysis, there is evidence that supports smoke enhancing ozone development in Clark County from July 15-17, 2024. Specifically:

- Upper-level high pressure east of southern Nevada producing a clockwise wind pattern aloft, capable of transporting smoke into Clark County. Furthermore, the upper-level high generated periods of sunshine and hot surface temperatures conducive to ozone formation.
- Light surface winds throughout the three-day period inhibiting dispersion of pollutants and ozone precursors in Clark County.
- PBL heights revealing deep vertical mixing capable of mixing aloft air (including any aloft pollutants) down to the surface, and HYSPLIT back trajectory analysis within the PBL finding evidence of smoke transport. Potential sources for smoke entering Clark County include Canadian fires, as well as fires in southern California and other portions of the United States.

7.4.4 Surface Impacts

Smoke from Canadian wildfires and southern California wildfires spread over Clark County beginning on July 14, 2024. Figure 308 through Figure 311 show photos taken from the M Resort Hotel looking to the north, northeast, south, and northwest. Smoke is visible to the north in the afternoon of July 14 (Figure 308). Visibility becomes worse on July 15, and smoke is visible throughout the day from the north-facing webcams (Figure 309). The incoming smoke was a news-worthy occurrence reported on by the local FOX news network; their forecast report on July 16 mentions elevated levels of wildfire smoke.[75]

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[75] https://www.fox5vegas.com/2024/07/16/forecast-outlook-7162024/

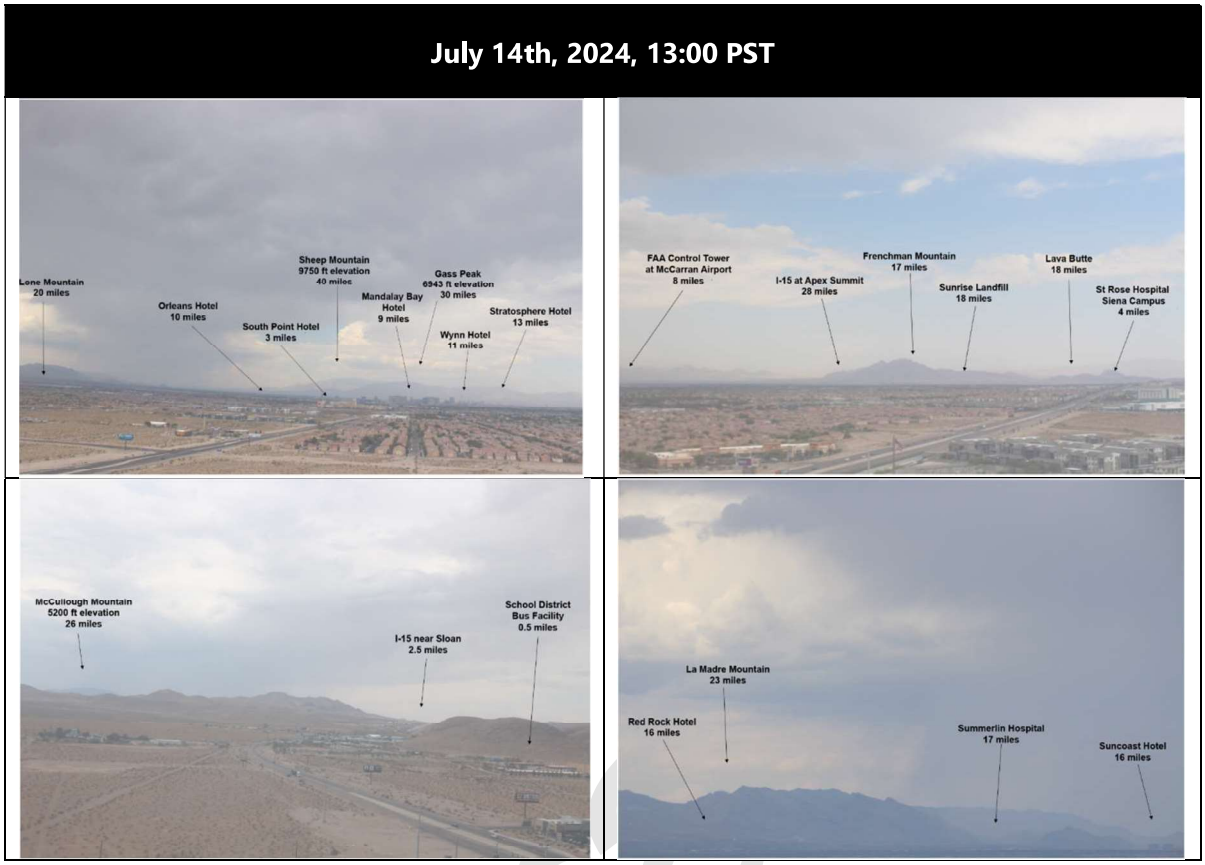

Figure 308. Webcam images showing the views to the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) as taken from the M Resort Hotel in Clark County, NV, on July 14, 2024, at 13:00 PST.

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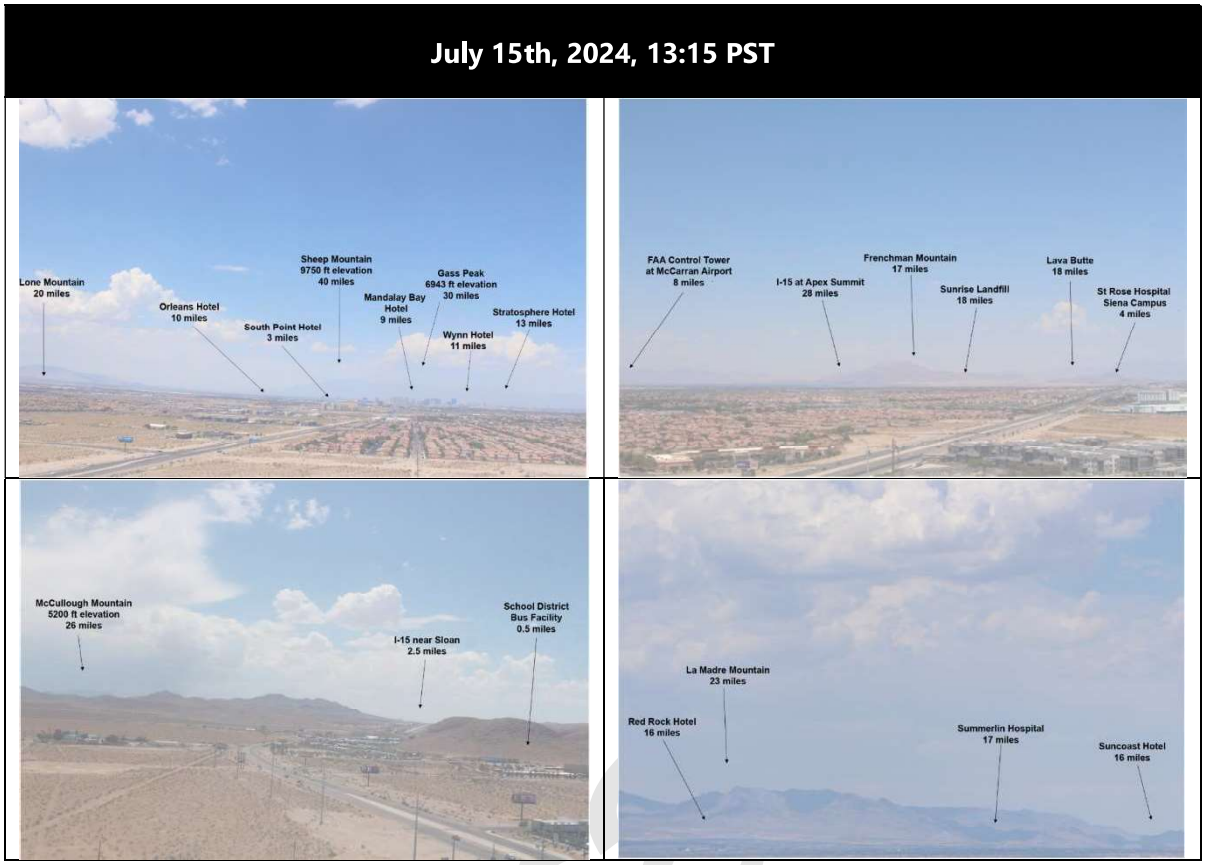

Figure 309. Webcam images showing the views to the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) as taken from the M Resort Hotel in Clark County, NV, on July 15, 2024, at 13:15 PST.

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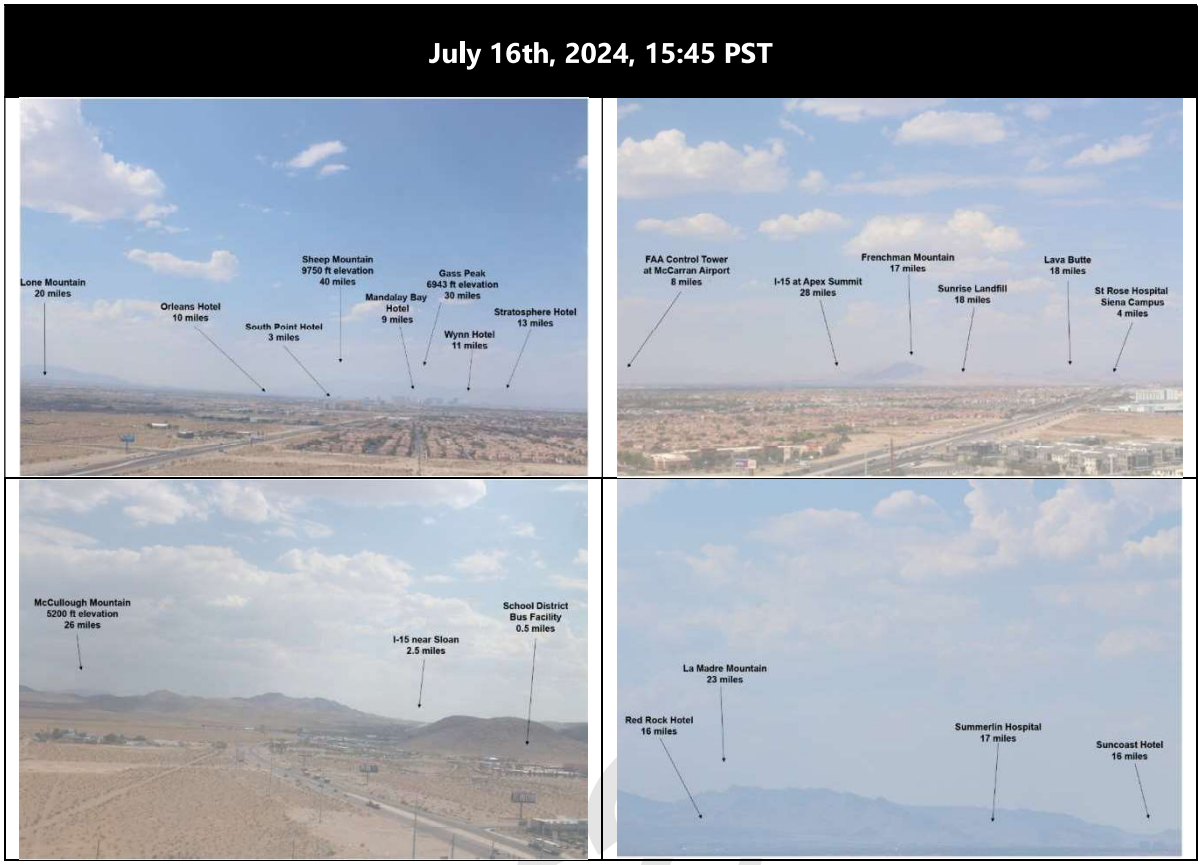

Figure 310. Webcam images showing the views to the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) as taken from the M Resort Hotel in Clark County, NV, on July 16, 2024, at 15:45 PST.

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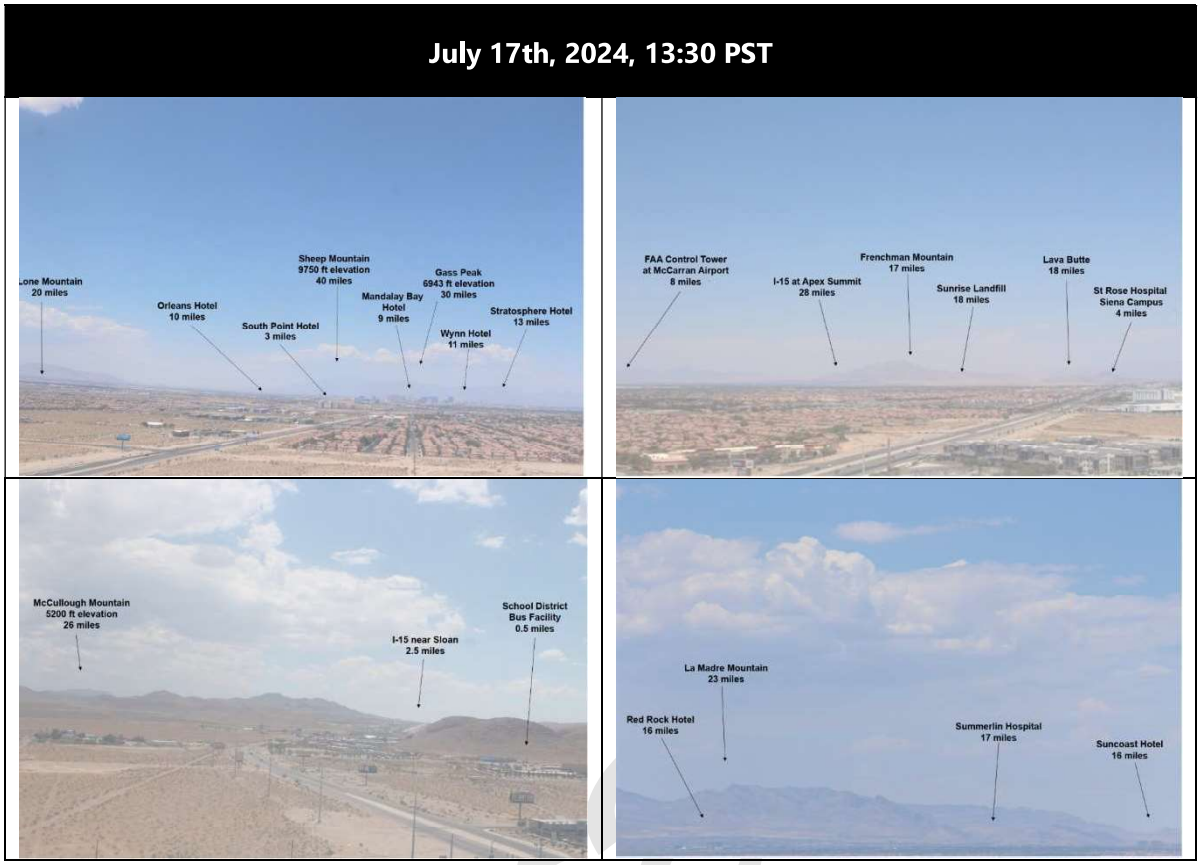

Figure 311. Webcam images showing the views to the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) as taken from the M Resort Hotel in Clark County, NV, on July 17, 2024, at 13:30 PST.

$PM_{2.5}$, CO, and NO_2 concentrations were enhanced in Clark County from July 15-17 as smoke from western Canadian wildfires and southern California wildfires entered the region and mixed towards the surface. Such heightened concentrations were further evidence that wildfire smoke was present as an atypical influence on ozone during the exclusion period.

Figure 312 shows hourly $PM_{2.5}$ concentrations at the seven affected sites (Green Valley, Joe Neal, Mountain's Edge*, Palo Verde, Paul Meyer, Walnut Community Center*, and Walter Johnson) overlaid on the 10th to 90th percentile hourly concentrations during ozone season (April to September), calculated using data from 2019-2024, where available. At all seven sites, $PM_{2.5}$ concentrations were elevated above the multiyear seasonal median $PM_{2.5}$ concentration for the entirety of July 15-17. $PM_{2.5}$ concentrations above the 90th percentile were recorded at all sites between 12:00 and 15:00 PST on July 16, with sites recording sustained high concentrations during this event starting as early as 02:00 PST on July 16. High $PM_{2.5}$ concentrations were also observed between 00:00 and 12:00 PST on July 17, with peak values occurring at approximately 06:00 PST during this period, which exceeded the 90th percentile concentration at four sites.

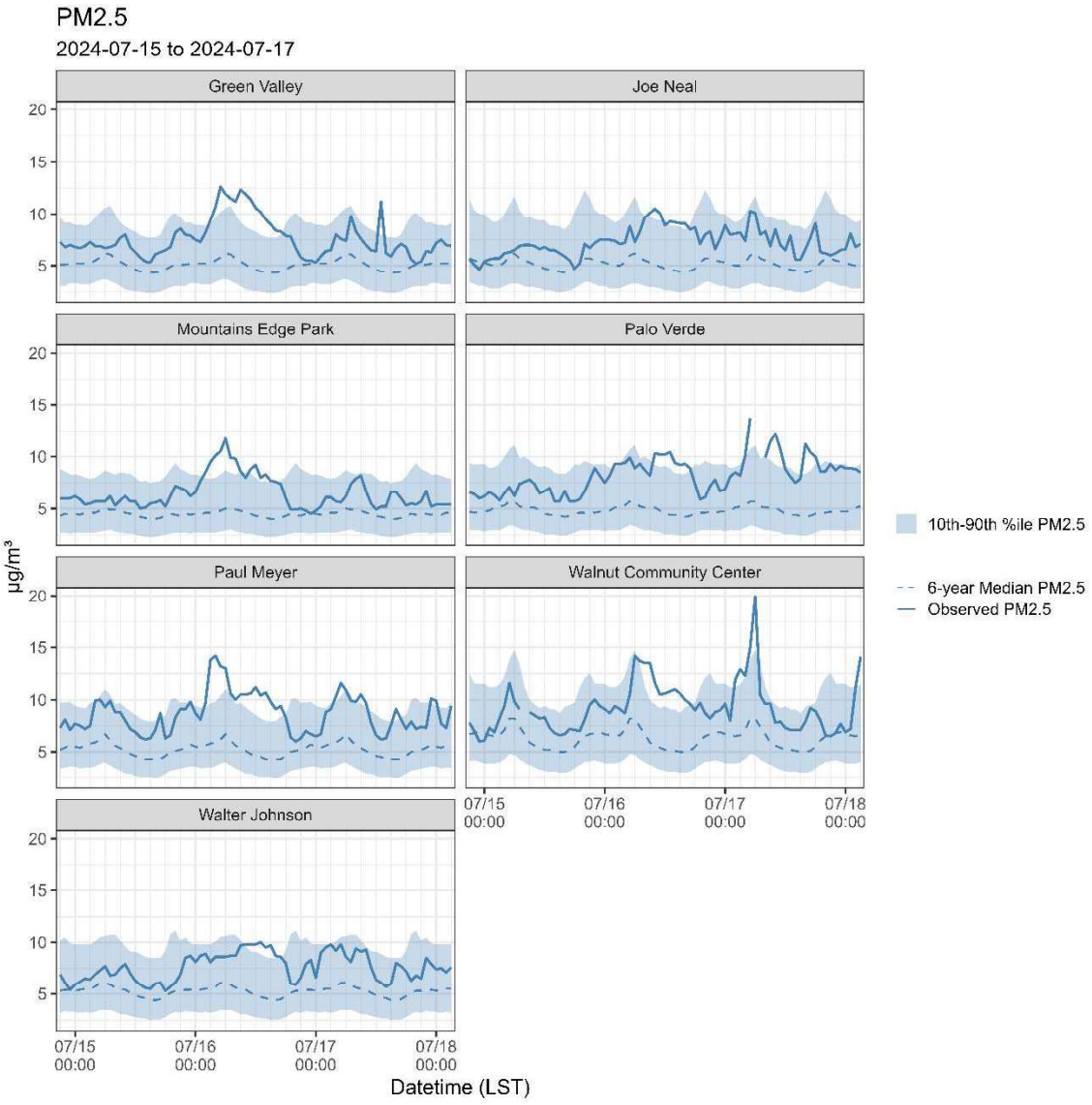

Figure 312. Hourly $PM_{2.5}$ measurements overlaid on the 10th-to-90th percentile diurnal concentration at Green Valley (AQS site code 320030298), Joe Neal (AQS site code 320030075), Mountain's Edge* (AQS Site Code 320030044), Palo Verde (AQS site code 320030073), Paul Meyer (AQS site code 320030043), Walnut Community Center* (AQS site code 320032003), and Walter Johnson (AQS site code 320030071). The 10th-to-90th percentile concentration is calculated across the ozone production season (April-September) for 2019-2024 Note: the Mountain's Edge site only includes data from October 1, 2020, and onwards; and the Walnut Community Center only includes data from June 1, 2021, and onwards.

Figure 313 shows hourly CO concentrations at Walnut Community Center* for July 15-17 plotted with the 6-year seasonal 10th to 90th percentile range of diurnal concentration. CO concentrations followed a typical diurnal pattern, with peak concentrations during the late night and early morning (00:00 to 06:00 PST) that were elevated above the seasonal median and at or slightly below the 90th percentile. Enhanced CO concentrations are indicative of the presence of smoke.

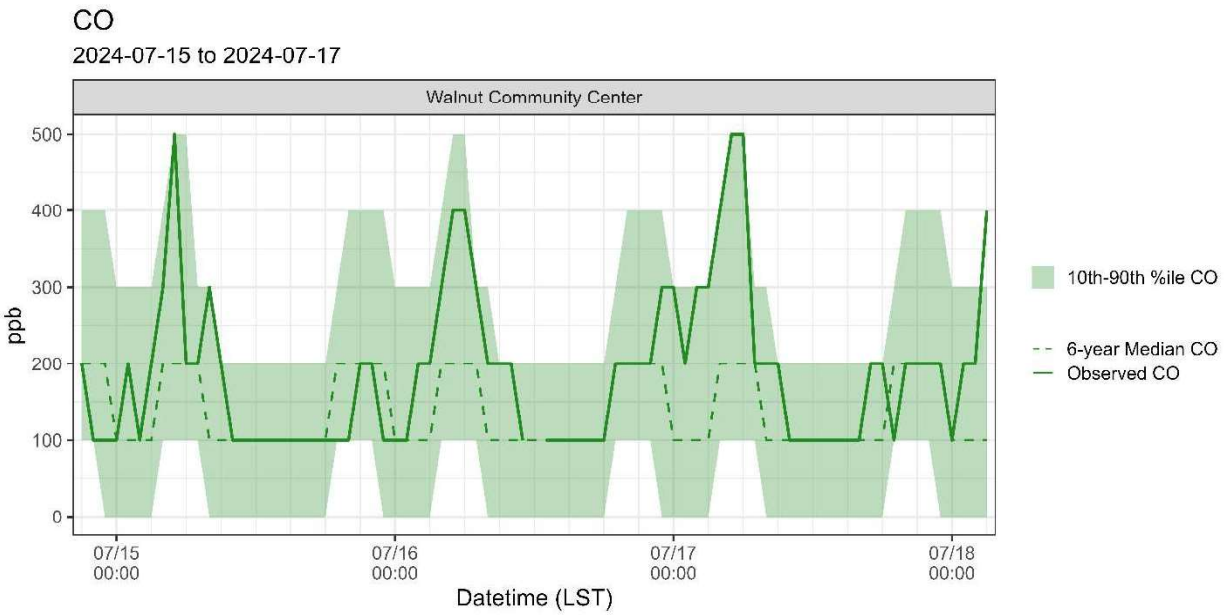

Figure 313. Hourly CO measurements overlaid on the 10th-to-90th percentile diurnal concentration at Walnut Community Center* (AQS site code 320032003). The 10th-to 90th percentile concentration is calculated across the ozone production season (April-September) for 2021-2024. Note: the Walnut Community Center only includes data from June 1, 2021, and onwards.

NO_2 concentrations in Clark County were also enhanced for the period of July 15-17; such enhancements are indicative of ozone precursor transport. Figure 314 shows hourly concentrations at Walnut Community Center* alongside the multiyear seasonal 10th to 90th percentile range of diurnal concentration. NO_2 concentrations followed a similar diurnal pattern as CO during this period, with peak concentrations between 00:00 and 06:00 PST each day. These peak concentrations were above the multiyear seasonal median and typically at or slightly below the 90th percentile. The exception to that trend occurred on July 17 at 02:00-03:00 PST, when the concentration exceeded the 90th percentile. During this time, enhanced NO_2, $PM_{2.5}$, and CO concentrations occurred at similar times each day.

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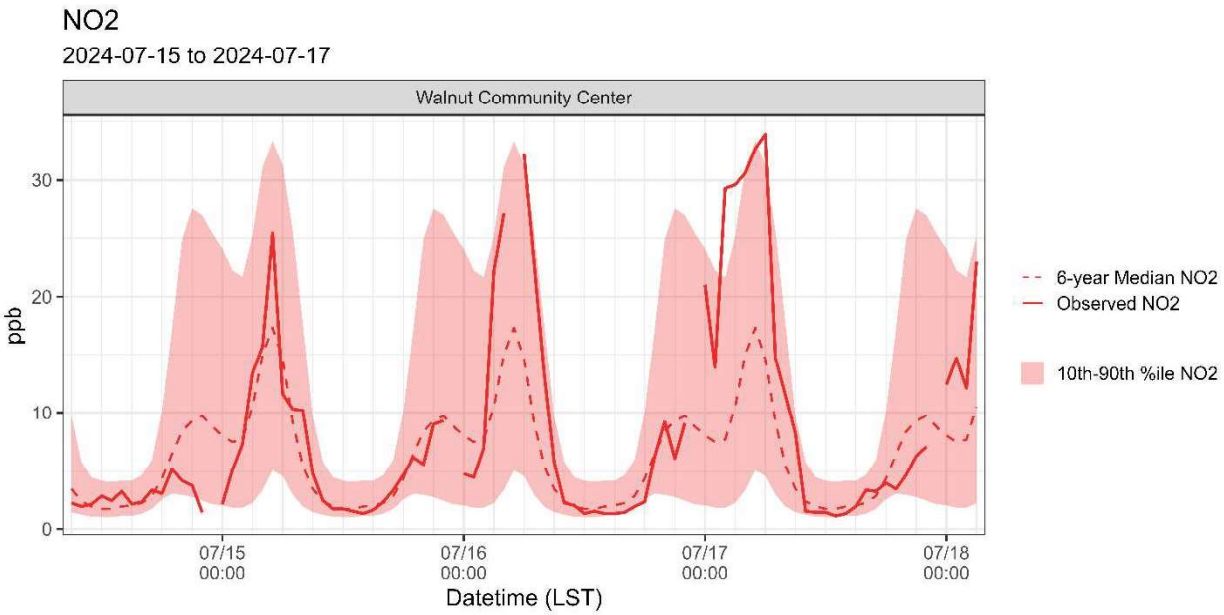

Figure 314. Hourly NO_2 measurements overlaid on the 10th-to-90th percentile diurnal concentration at Walnut Community Center* (AQS site code 320032003). The 10th-to-90th percentile concentration is calculated across the ozone production season (April-September) for 2021-2024. Note: the Walnut Community Center only includes data from June 1, 2021, and onwards.

During wildfire events, the ratio of $PM_{2.5}$-to-PM_{10} concentrations increases. This ratio was therefore also examined to determine whether wildfire smoke entered Clark County on or before the exclusion dates. Figure 315 shows a time series of the ratio of $PM_{2.5}$-to-PM_{10} concentrations from July 14-18, with the six-year average ratio and the 10th to 90th percentile shown for the following sites: Green Valley, Joe Neal, Mountain's Edge*, Palo Verde, Paul Meyer, Walnut Community Center*, and Walter Johnson. At all seven sites, this ratio fluctuated significantly and regularly exceeded the six-year mean and, at most sites, the 90th percentile concentrations. The ratio was the most elevated between 09:00 PST July 15 and 03:00 PST July 17. During that window, the sites measured values between 0.3 and 0.4, which are indicative of wildfire smoke entering the area. These observations of enhanced $PM_{2.5}$ that increased the $PM_{2.5}$-to-PM_{10} ratio provide evidence that wildfire smoke was present in Clark County from July 15-17.

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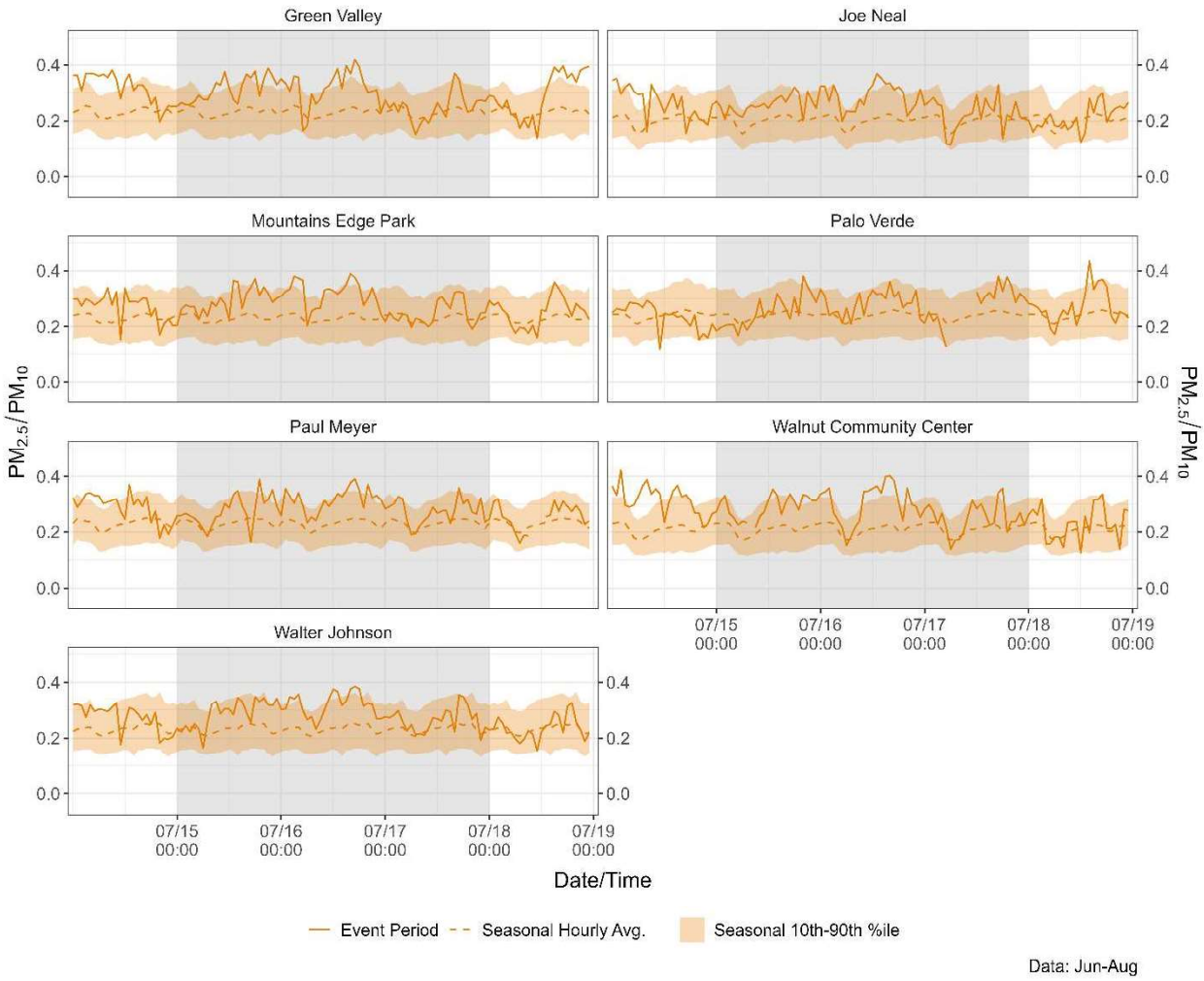

Figure 315. Ratio of $PM_{2.5}$-to-PM_{10} concentrations during the event period overlaid on the 10th-to-90th percentile diurnal concentrations at Green Valley (AQS site code 320030298), Joe Neal (AQS site code 320030075), Mountain's Edge* (AQS Site Code 320030044), Palo Verde (AQS site code 320030073), Paul Meyer (AQS site code 320030043), Walnut Community Center* (AQS site code 320032003), and Walter Johnson (AQS site code 320030071). The 10th-to-90th percentile concentration is calculated across the ozone production season (April-September) for 2019-2024. Note: the Mountain's Edge site only includes data from October 1, 2020, and onwards; and the Walnut Community Center only includes data from June 1, 2021, and onwards.

The concurrence of enhanced $PM_{2.5}$, CO, NO_2, and $PM_{2.5}$-to-PM_{10} ratio in Clark County for July 15-17, in addition to the analysis of meteorological conditions and smoke imagery, provides strong evidence that surface-level smoke was present in Clark County during the exclusion period. This combined evidence suggests that wildfires in California and numerous wildfires in Canada provided an atypical source of ozone and ozone precursors that resulted in enhanced ozone concentrations from July 15-17.

7.4.5 VOC Analysis

VOC samples were collected on July 16 and 17, 2024 during the July 15-17 smoke period. VOC ratios shown in Table 71 were calculated at all sites. These ratios were compared with the fire and no fire regimes calculated in Section 7.1.2 and found to all fall within the fire regime for all sites and all ratios. All sites saw high ratios for each species during this event, confirming the presence of smoke both upwind and within Clark County.

Table 71. VOC Ratios calculated for July 16 and 17, 2024 from the Jean, Jerome Mack, and Sunrise Acres monitoring sites. These ratios can be compared with the fire and no fire regimes calculated in Section 7.1.2. Ratio abbreviations are defined in Table 61.

Sample Date	Site	ACE_ ACN	ACN_ ACE	ACN_ ACR	ACN_ BZN	ACN_ PEN	ACN_ TOL
7/16/2024	Jerome Mack	23.3	0.061	1.4	3.4	1.0	3.4
	Jean	46.0	0.070	3.2	3.2	3.2	3.2
	Sunrise Acres	19.0	0.062	1.2	3.4	1.0	1.4
7/17/2024	Jerome Mack	44.0	0.070	3.1	3.1	1.1	3.1
	Jean	63.0	0.051	3.2	3.2	0.1	3.2
	Sunrise Acres	56.0	0.054	3.0	3.0	0.3	0.7

7.4.6 Event Statistics

Table 72 summarizes the concentrations of ozone, $PM_{2.5}$, CO, and NO_2 on the exclusion days as well as the percentage rank of the observation compared with the previous six years of data (i.e., from 2019-2024 or years available if site sampling started after 2019). Ozone MDA8 concentrations ranged from the 95th to 99th percentile on July 15-17.

24-hour $PM_{2.5}$ concentrations were high, ranging from the 69th to 92nd percentile, at the affected sites. As shown in Figure 312, $PM_{2.5}$ concentrations remained above the seasonal median for the entire period and peaked above the seasonal 90th percentile at each site during this period.

CO and NO_2 concentrations are not well represented at the affected sites; in most cases, there are less than six years' worth of data for comparison. Data from Jerome Mack, which is not an affected site, was therefore included for additional context on enhanced CO and NO_2 observations across the region. CO concentrations were at or below average seasonal values and ranged from 300-500 ppb or the 25th-50th percentile. NO_2 concentrations were scattered and ranged from 7-34 ppb or the

16th-69th percentile. While the max 1-hour NO2 concentrations are not extremely high for this event, the concentrations over the entire period are higher than normal as shown in **Figure 314**.

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Table 72. Percentile of pollution concentration on an exclusion day compared with most recent six years' worth of data (i.e., from 2019-2024). The percentile rank is calculated across the ozone production season (April 1 – September 30) for 2019-2024. Sites that have less than six years of data available for a given parameter are indicated with an asterisk. Data from nearby sites not identified for exclusion are indicated in italics.

Date	Site Name	Site Code	Ozone		$PM_{2.5}$		CO		NO_2	
			Ozone MDA8 (ppb)	Percent Rank	$PM_{2.5}$ 24-hr average ($\mu g/m^3$)	Percent Rank	CO 1-hr daily max (ppb)	Percent Rank	NO_2 1-hr daily max (ppb)	Percent Rank
7/15/2024	Joe Neal	320030075	74	97.6%	6.3	71.3%			7	15.7%
7/15/2024	Walnut Community Center	320032003	71	94.9%*	8.2	69.4%*	500	49.6%*	25	35.8%*
7/15/2024	*Jerome Mack-NCore*	*320030540*					*373*	*30.7%*	*28*	*36.2%*
7/16/2024	Green Valley	320030298	75	99.7%	9.2	91.8%				
7/16/2024	Joe Neal	320030075	79	99.5%	8.4	87.8%			9	23.6%
7/16/2024	Mountain's Edge	320030044	71	96.4%*	7.8	92.2%*				
7/16/2024	Palo Verde	320030073	74	98.9%	8.7	91.9%*				
7/16/2024	Paul Meyer	320030043	76	98.7%	9.8	91.7%				
7/16/2024	Walnut Community Center	320032003	78	99.5%*	10.4	85.3%*	400	37.4%*	32	61.1%*
7/16/2024	Walter Johnson	320030071	75	98.2%	8.6	89.3%*				
7/16/2024	*Jerome Mack-NCore*	*320030540*					*457*	*36.5%*	*30*	*39.3%*
7/17/2024	Joe Neal	320030075	71	95.3%	7.5	83.3%			10	25.7%
7/17/2024	Walnut Community Center	320032003	71	94.9%*	9.4	79.7%*	500	49.6%*	34	68.8%*
7/17/2024	*Jerome Mack-NCore*	*320030540*			*8.0*	*60.4%*	*300*	*25.1%*	*35*	*58.3%*

7.5 July 24-25, 2024

7.5.1 Event Summary

The unrepresentative ozone event took place on July 24 and 25, 2024 and affected the following nine sites in Clark County, NV: Apex*, Garrett Jr. High School*, Green Valley, Joe Neal, Mountain's Edge*, Palo Verde, Paul Meyer, SM Youth Camp, and Walnut Community Center*. Figure 316 shows the time series of hourly ozone exceeding seasonal medians (calculated using April 1 – September 30, 2019-2024 data, where available) and 10th to 90th percentiles at each site.

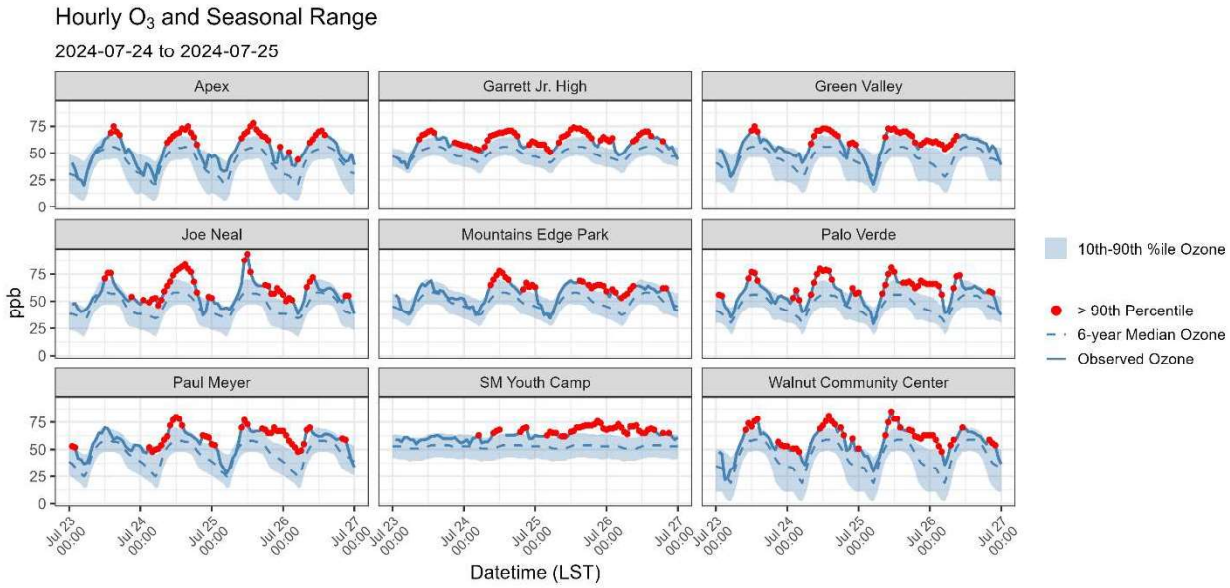

Figure 316. Hourly ozone concentrations (ppb) compared to 6-year ozone season (April 1 – September 30) hourly medians and 10th-to-90th percentiles. Note: the Apex site only includes data from June 1, 2023, and onwards; the Garrett Jr. High site only includes data from April 1, 2021, and onwards; the Mountain's Edge site only includes data from October 1, 2020, and onwards; and the Walnut Community Center site only includes data from June 1, 2021, and onwards.

Ozone concentrations at the affected sites were consistently higher than the seasonal median and 90th percentile concentrations on July 24-25. Ozone concentrations followed a typical diurnal pattern at the Apex*, Garrett Jr. High*, Green Valley, Joe Neal, Mountain's Edge*, Palo Verde, Paul Meyer, and Walnut Community Center* sites. At these sites, ozone concentrations reached daily highs at 12:00 PST and fell during the early morning between 00:00 and 06:00 PST. Ozone concentrations at the SM Youth Camp site did not follow a typical diurnal pattern, likely because the site is at an isolated, rural location in the Spring Mountains outside of Las Vegas, but concentrations at the site were consistently above the 90th percentile throughout the event. The maximum daily 8-hour average

(MDA8) concentrations at the affected sites ranged from 70-77 ppb: 70 ppb at Green Valley, 77 ppb at Joe Neal, 71 ppb at Mountain's Edge*, 73 ppb at Palo Verde, 71 ppb at Paul Meyer, and 72 ppb at Walnut Community Center* on July 24; and 70 ppb at Apex*, 71 ppb at Garrett Jr. High*, and 72 ppb at SM Youth Camp on July 25.

Wildfires in California were identified as major contributors to this event, as were numerous fires in Canada, Alaska, and the Pacific Northwest. Evidence includes (1) smoke perimeters over Clark County from NOAA's HMS, (2) HYSPLIT model back trajectories and meteorological analysis showing transport and accumulation of smoke in Clark County, (3) visible smoke in camera images, and (4) synchronous enhancement of $PM_{2.5}$ concentrations, as well as enhanced $PM_{2.5}$-to-PM_{10} ratios aligned with ozone enhancement. This combination of evidence strongly indicates that this is an unrepresentative event for base and future design value ozone assessments.

7.5.2 Identification of Wildfire(s)

Numerous wildfires were actively burning across the western United States and in northern Canada on the days leading up to and on July 24-25, 2024, the exclusion days. To the west of Clark County, the 2024 SQF Lightning Complex, which began on July 13 in the Sequoia National Forest (**Figure 317**), continued to grow and included the Acorn, Packsaddle, and Trout Fires.[76] On July 25, the California Department of Forestry and Fire Protection (CAL FIRE)reported that the complex had burned 32,376 acres. In northern California, the Shelly Fire, which began in Siskiyou County on July 3, continued to burn. The Shelly Fire was contained on August 8 and eventually burned 15,520 acres.[77] Additionally, many fires in northern Canada, Alaska, and the Pacific Northwest were contributing to extensive smoke transport across the west coast as far south as Mexico (**Figure 318**). The significant smoke emissions from these wildfires contributed to regional smoke, which was verified for the exclusion days through visualization of NOAA's HMS products.

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[76] SQF Lightning fire explodes in size inside Sequoia National Forest - ABC30 Fresno
[77] https://www.fire.ca.gov/incidents/2024/7/3/shelly-fire

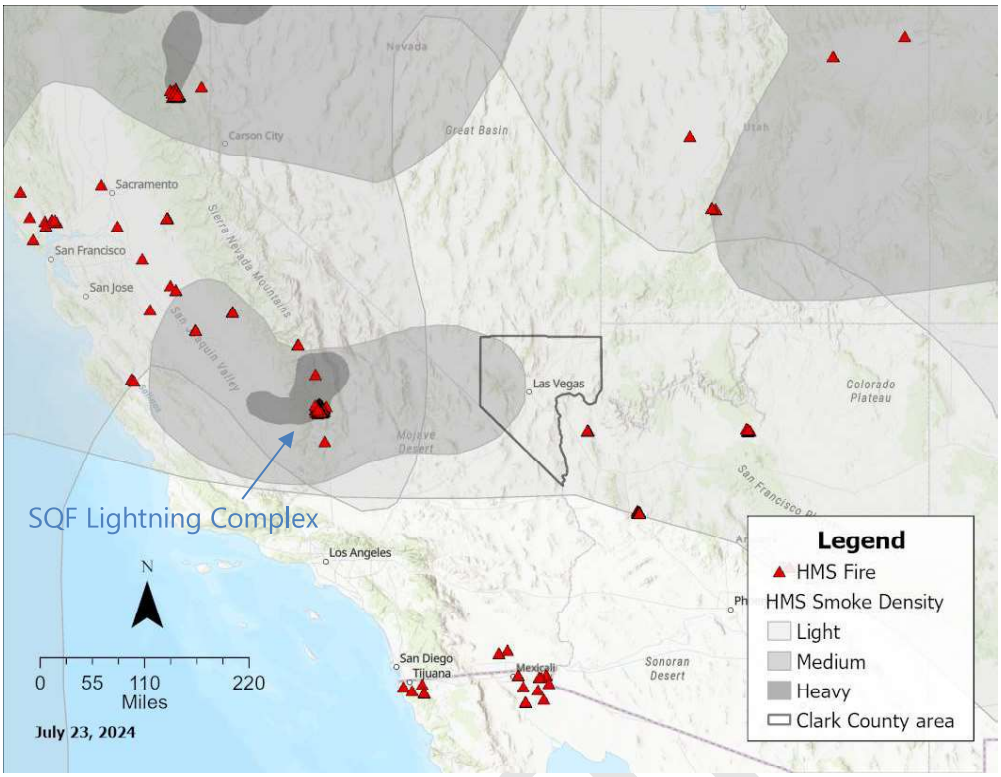

Figure 317. Local view of HMS fire detections (red triangles) and smoke density (grey contours) on July 23, 2024. Clark County is outlined in grey.

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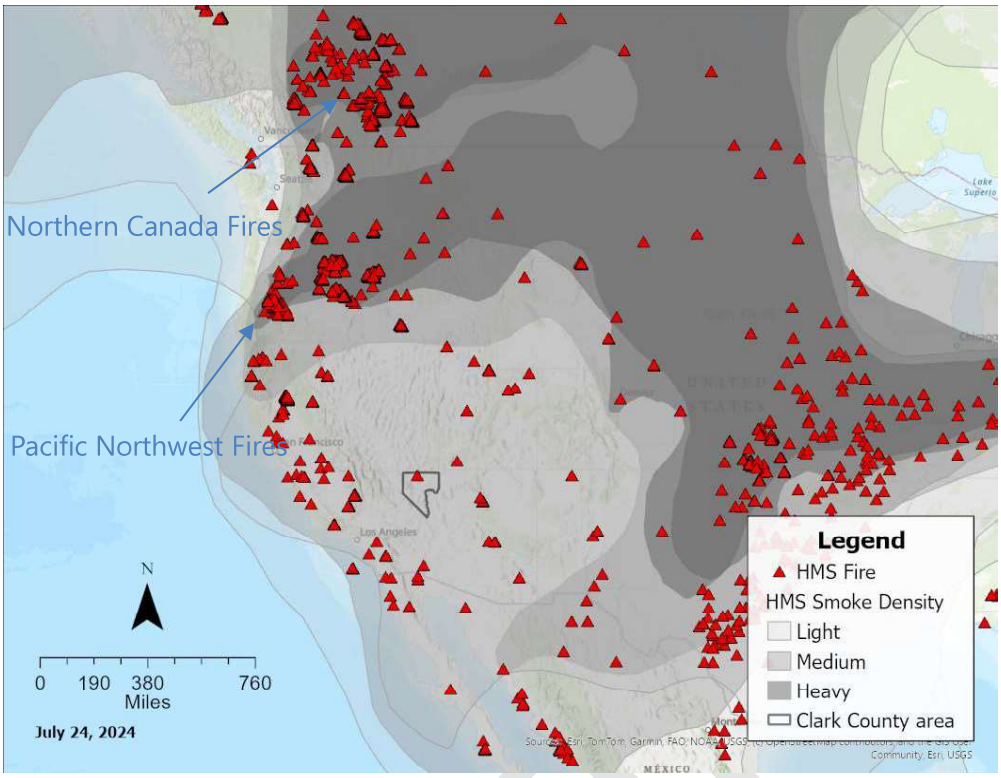

Figure 318. Continental view of HMS fire detections and smoke density on July 24, 2024. Clark County is outlined in grey.

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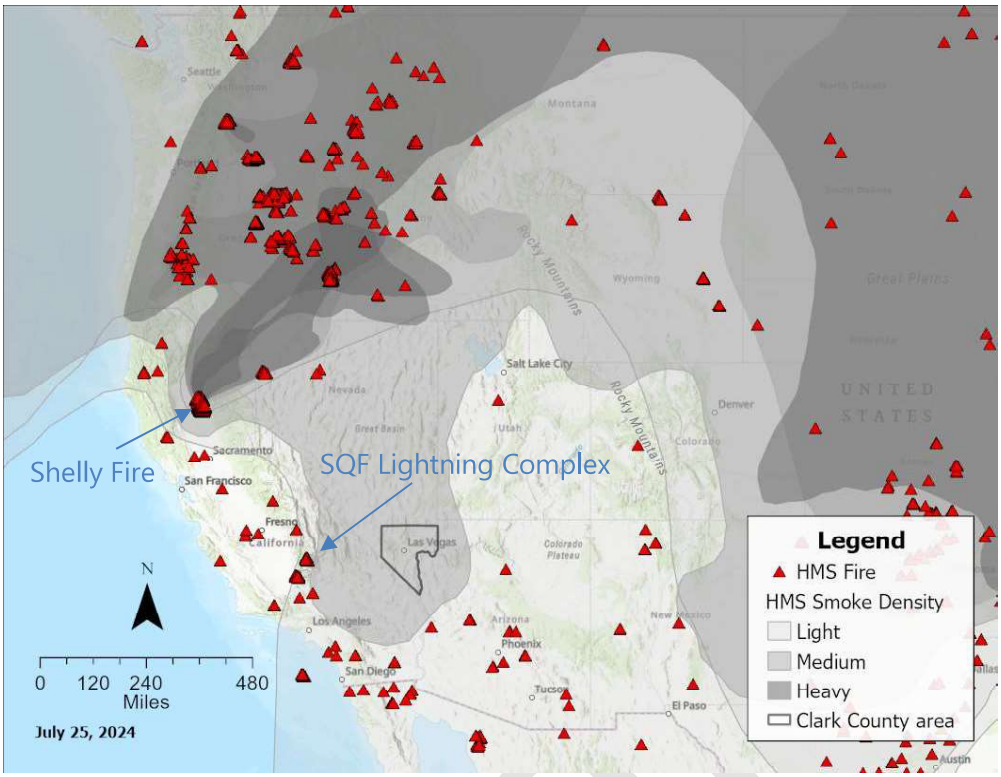

Figure 319. Western U.S. view of HMS fire detections (red triangles) and smoke density (grey contours) on July 25, 2024. Clark County is outlined in grey.

7.5.3 Meteorological Analysis

HRRR Smoke Model Output

The High-Resolution Rapid Refresh Smoke (HRRR-Smoke) model is a three-dimensional coupled weather-smoke model developed for real-time smoke prediction over flat and complex terrain. The model is run on a 3-km horizontal grid spacing at 50 vertical levels. It assimilates surface and upper-air meteorological and smoke data every hour, including fire radiative power data from VIIRS and MODIS satellites. Taking all these parameters into consideration, it produces hourly operational surface and aloft smoke forecasts that are widely used by air quality forecasters in the United States.

Archived hourly HRRR-Smoke forecast products for July 24 and 25, 2024, are shown in **Figure 320 and Figure 321.** These show the initial HRRR-Smoke forecasts of near-surface smoke for 16:00 PST each day. On the afternoon of July 24, 2-4 µg/m^3 of smoke was forecast at the surface in the Clark County area.

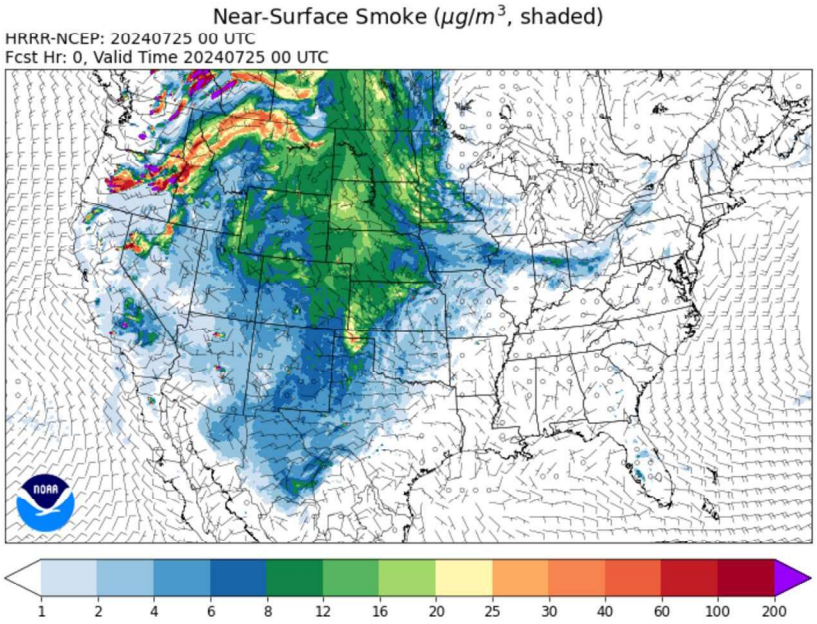

Figure 320. Model initialization of near-surface smoke (µg/m^3) at 16:00 PST on July 24, 2024, showing 2-4 µg/m^3 of near-surface smoke over southern Nevada. Source: NOAA Global Systems Laboratory.

The model predicted increasing near-surface smoke over the Las Vegas region on July 25, 2024, with a forecast of approximately 6-12 µg/m^3 near the surface at 16:00 PST.

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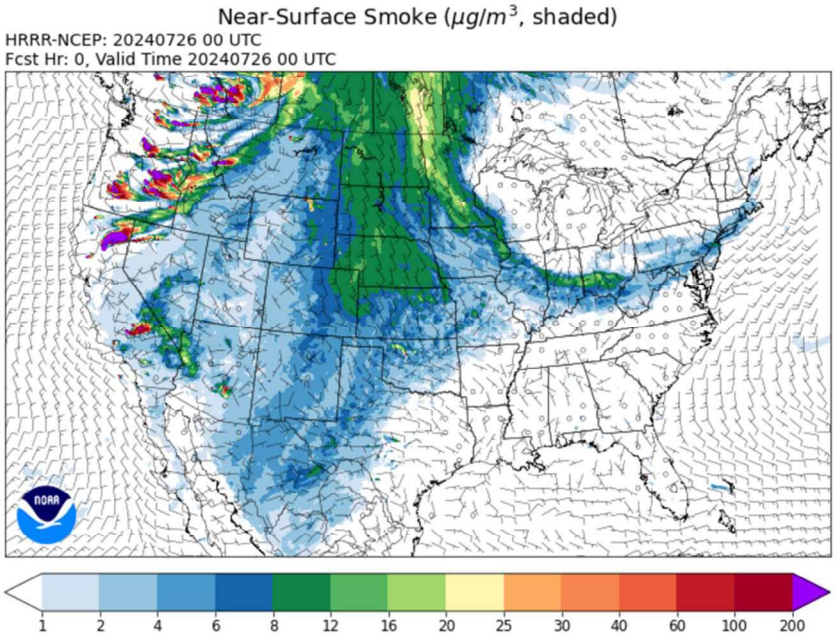

Figure 321. Model initialization of near-surface smoke (µg/m^3) at 16:00 PST on July 25, 2024, showing near-surface smoke increasing over southern Nevada. Source: NOAA Global Systems Laboratory.

Upper-Level Analysis

The height of the 500 millibar (mb) pressure level above ground level as well as the curvature of the 500 mb height field can be useful in discerning the potential for ozone production on the synoptic (large) scale. High pressure aloft is normally indicative of a warm and dry air mass in the mid-levels of the atmosphere. Those warm and dry mid-level conditions often promote sunny skies, increasing the potential for ozone development. The contour plots of geopotential height at 500 mb (approximately 18,000 feet) from July 24 and 25, 2024, shown in Figure 322 and Figure 323, indicate a large ridge of high pressure over southern Nevada. The high pressure aloft led to partly to mostly sunny skies in the Las Vegas region on each of these days, providing the ultraviolet radiation needed for the photochemical reactions that produce ozone.

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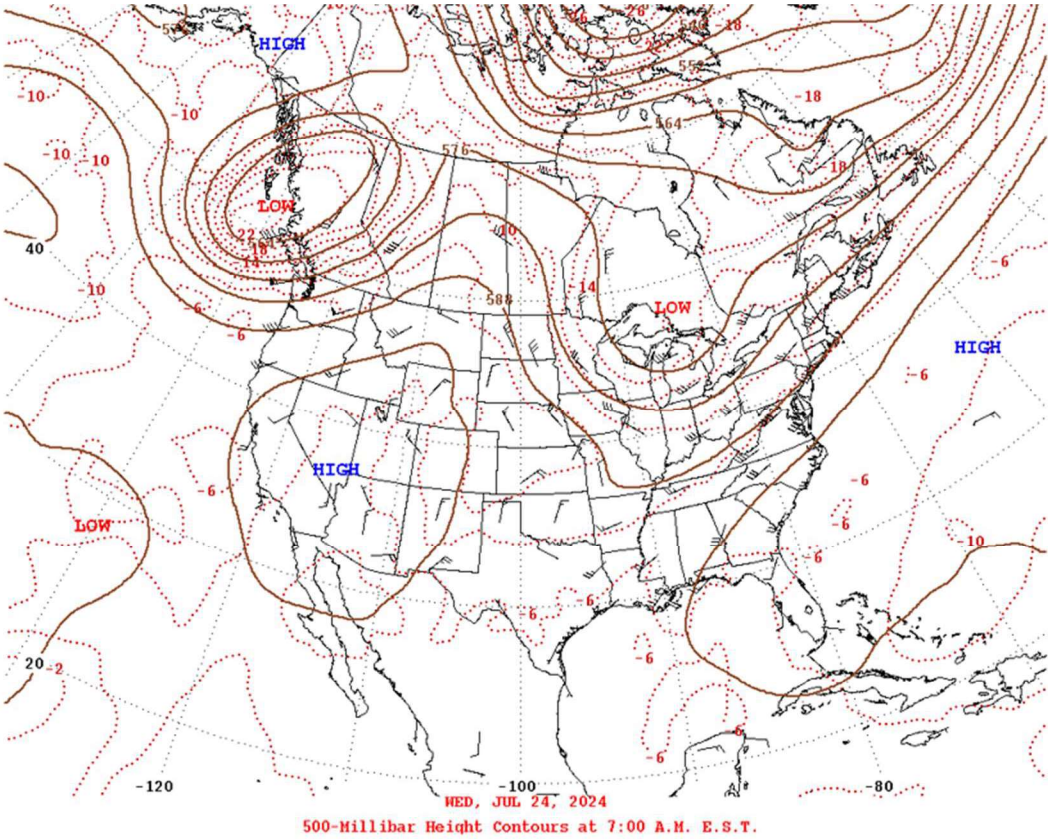

Figure 322. 500-mb heights, winds, and temperatures at 04:00 PST on July 24, 2024. Source: NOAA Weather Prediction Center.

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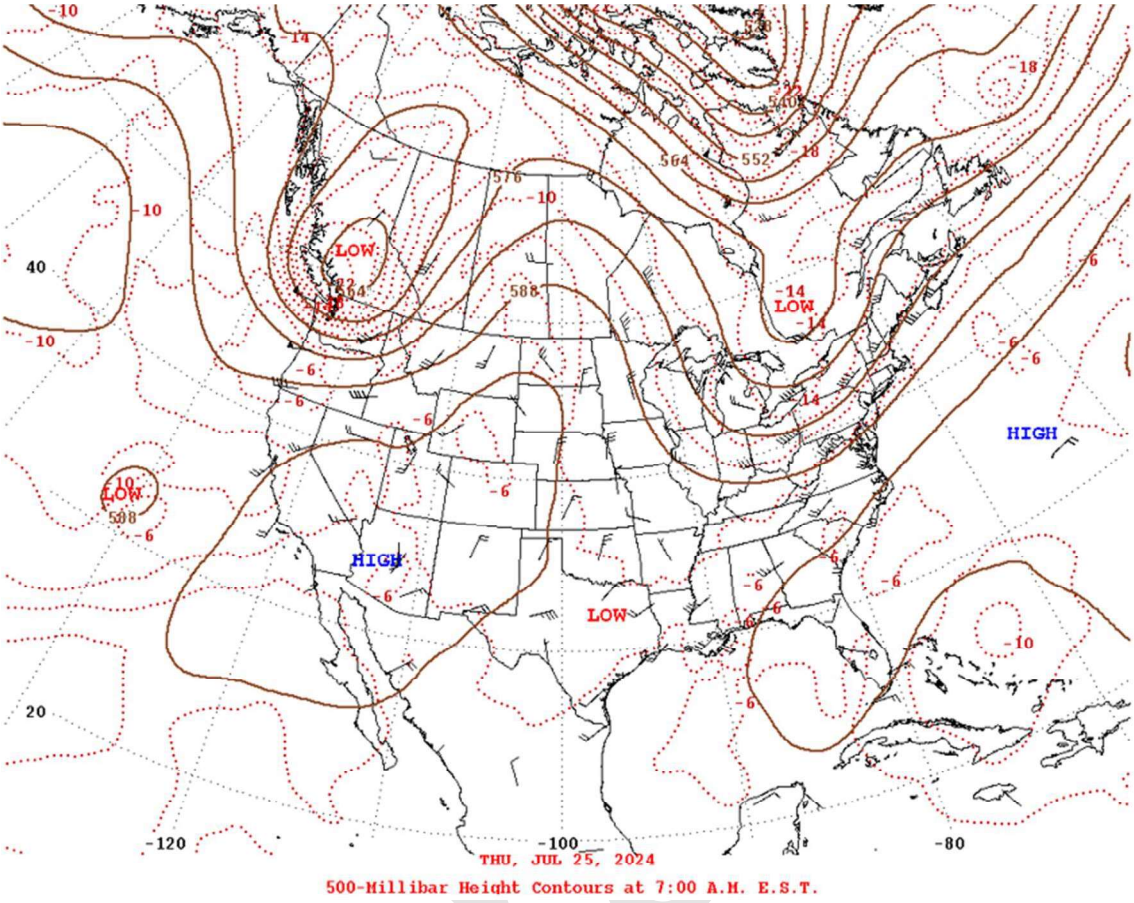

Figure 323. 500-mb heights, winds, and temperatures at 04:00 PST on July 25, 2024. Image courtesy of NOAA's Weather Prediction Center.

Surface Analysis

Surface pressure patterns can also be helpful in determining whether conditions at ground level are conducive to ozone formation. Surface high pressure generally indicates sinking air and increased stability, which can limit atmospheric mixing and increase ozone production. Conversely, surface low pressure can indicate rising air and increased atmospheric mixing, which can help reduce ozone formation. However, in the desert in the summer, surface low-pressure can also be indicative of rising air due to very warm surface temperatures. The increase in ozone production from hot temperatures can sometimes balance out the potential for air quality to improve due to enhanced atmospheric mixing in the vicinity of a weak surface low. Additionally, enhanced mixing can lead to subsidence of smoke aloft to the surface, aiding ozone development.

In addition to clues about atmospheric mixing, surface pressure patterns also indicate the potential for wind. When lines of constant pressure (isobars) are packed closely together (strong pressure gradient), there is increased potential for wind and dispersion. Alternatively, when isobars are further apart (weak pressure gradient), periods of light winds and reduced dispersion are more likely. The

direction of the pressure gradient determines the direction of the surface winds, with winds blowing from areas of high pressure to areas of low pressure.

Figure 324 and Figure 325 show a surface low-pressure system centered near Needles, CA, on the afternoons of both July 24 and 25, 2024, due to hot temperatures and rising thermals over the Desert Southwest. Meanwhile, higher surface pressures are shown over the cool waters of the eastern Pacific. As this weak west-to-east pressure gradient interacted with the terrain surrounding Clark County, it resulted in light southwesterly to northwesterly winds in Clark County each day, as shown in Table 73.

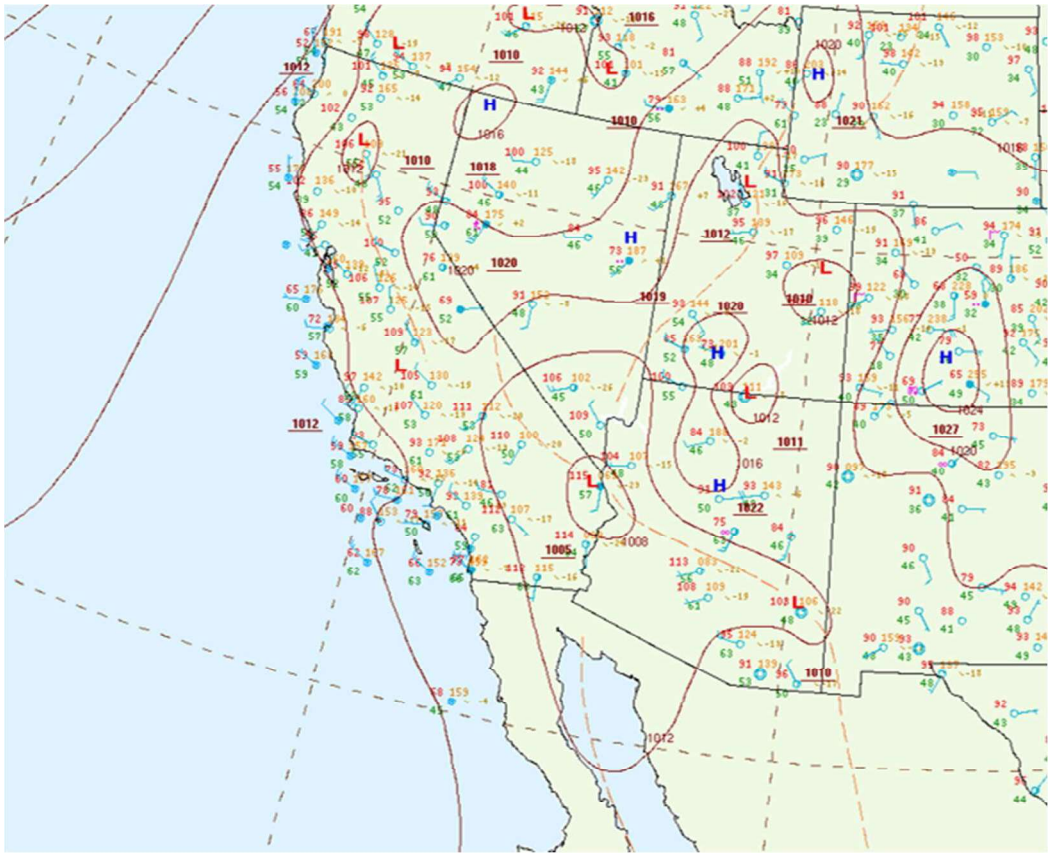

Figure 324. Surface weather conditions at 16:00 PST on July 24, 2024. Surface pressure (mb) indicated by dark red contours and underlined numbers. High and low pressures identified by blue "H" and red "L", respectively. Source: NOAA Weather Prediction Center.

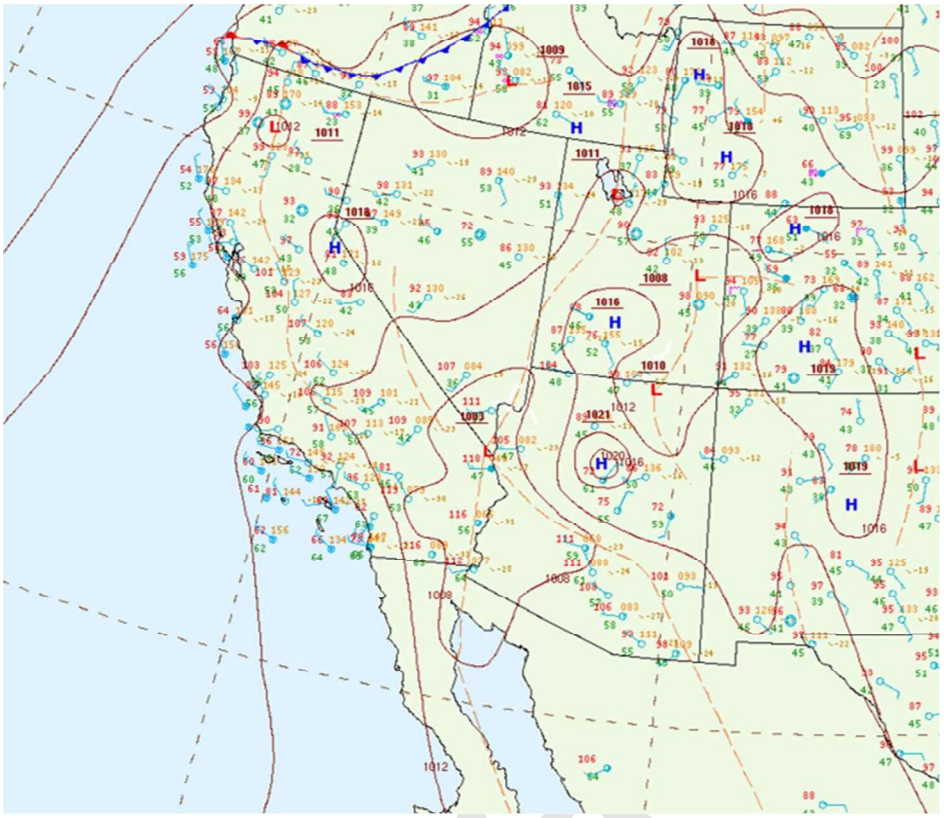

Figure 325. Surface weather conditions at 16:00 PST on July 25, 2024. Surface pressure (mb) indicated by dark red contours and underlined numbers. High and low pressures identified by blue "H" and red "L", respectively. Source: NOAA Weather Prediction Center.

The sunny skies, high pressure aloft, and light southwesterly to northwesterly winds resulted in hot surface temperatures in the Clark County area each day, with maximum high temperatures of 112°F on July 24, and 114°F on July 25 (Table 73), supporting ozone production.

Table 73. Maximum surface temperatures, average wind speeds, and wind directions from Clark County area airports on July 24 and 25, 2024.

Station Name (ID)	Day	Max Temperature (°F)	Average Wind Speed (mph)	Average Wind Direction (deg)
Las Vegas – Harry Reid Intl. (LAS)	07-24-24	112	6.7	311
Henderson (HND)	07-24-24	110	6.4	249
NORTH LAS VEGAS (VGT)	07-24-24	112	8.6	338
Las Vegas – Harry Reid Intl. (LAS)	07-25-24	114	8.7	276
Henderson (HND)	07-25-24	111	8.2	219
NORTH LAS VEGAS (VGT)	07-25-24	114	8.7	261

Satellite Smoke and Fire Detections

Beyond the sunny and hot conditions, as previously mentioned, ozone production can be further enhanced by the presence of smoke near the surface. VOCs in areas of smoke are ozone precursors and can therefore increase ozone formation. Satellite observations of smoke can be helpful in determining the potential for increased ozone precursors over a region.

Figure 326 and Figure 327 depict fires and smoke observed by NOAA's HMS. Light-to-moderate density smoke was observed over the Clark County region on both July 24 and 25, 2024, increasing the potential that smoke contributed to increased ozone precursors.

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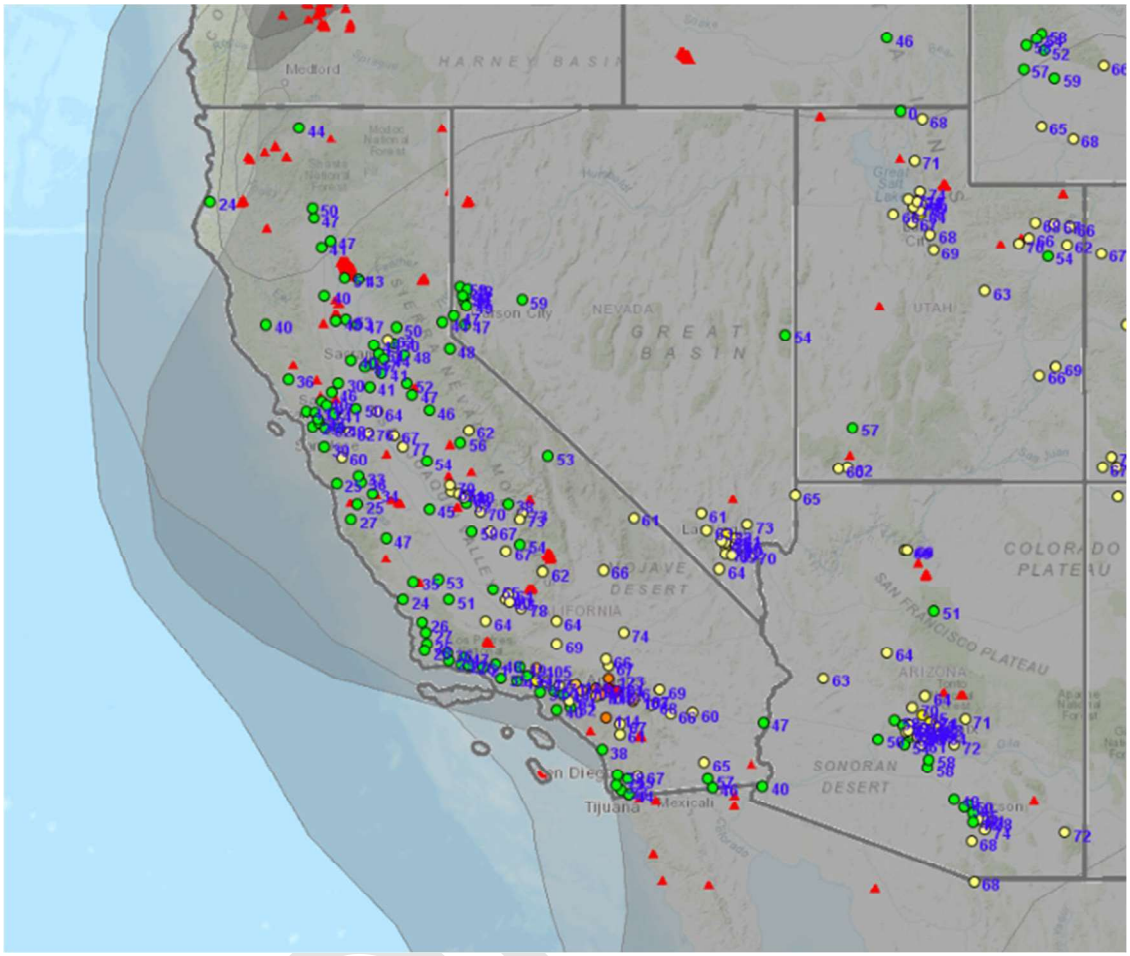

Figure 326. HMS smoke (gray contours), fire detections (red triangles), and hourly ozone concentrations (ppb) at 13:00 PST on July 24, 2024. Source: EPA AirNow-Tech.

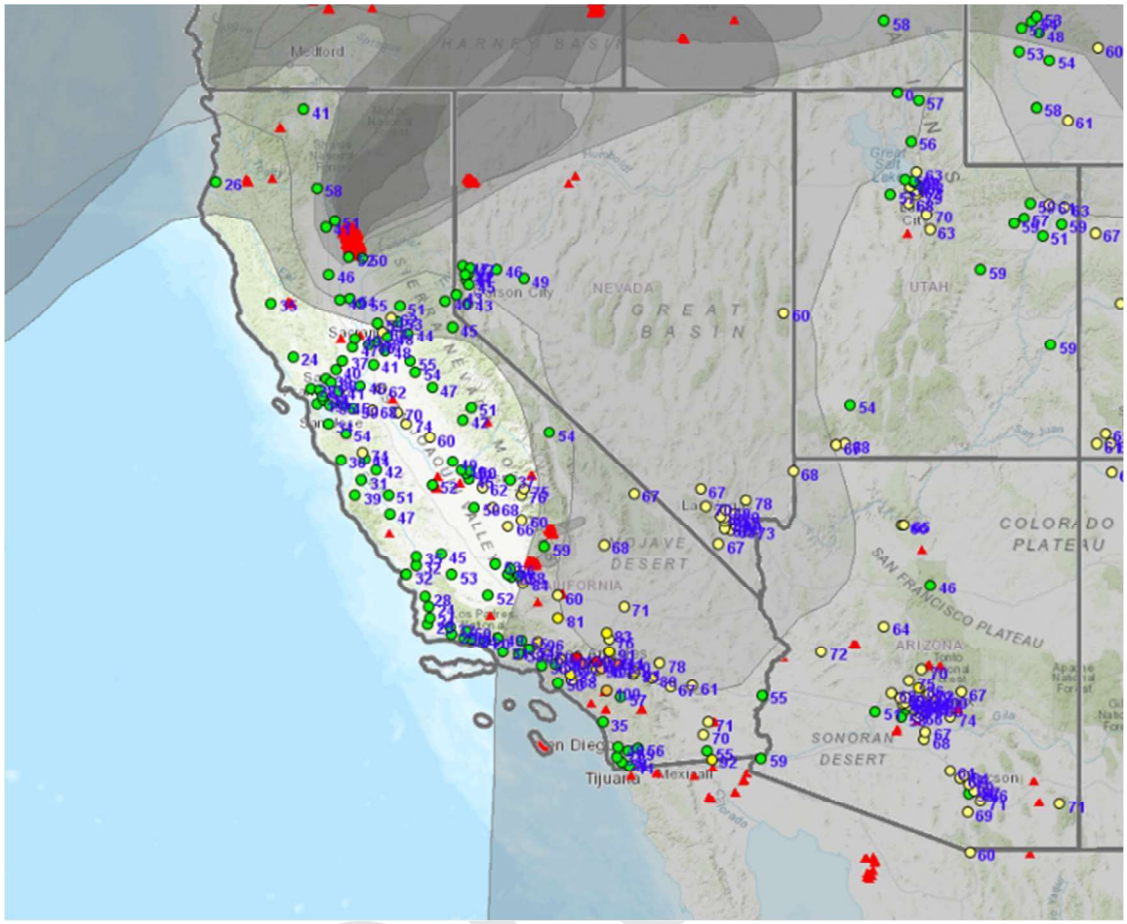

Figure 327. HMS smoke (gray contours), fire detections (red triangles), and hourly ozone concentrations (ppb) at 13:00 PST on July 25, 2024. Source: EPA AirNow-Tech.

These large areas of smoke were also noted in NOAA's satellite smoke discussions on July 24 and 25, 2024, as highlighted in Figure 328 and Figure 329.

Wednesday, July 24, 2024

DESCRIPTIVE TEXT NARRATIVE FOR SMOKE/DUST OBSERVED IN SATELLITE IMAGERY THROUGH 1200Z July 24, 2024

SMOKE:
Canada/United States/Mexico/Gulf of Mexico/Atlantic Ocean...
Mixed density smoke attributed to numerous wildfires in northern Canada and the Pacific Northwest region, as well as seasonal fire activity throughout the United States continues to be observed today. Light density smoke was seen over Alaska, most of Canada, and the U.S., while moderate to thick density smoke was expanding from fires in northwestern Canada to the east over Hudson Bay and Quebec. Smoke from Canadian fires mixed with more thick to moderate smoke from fires in the Pacific Northwest region and expanded to the south as far as Mexico and the Gulf of Mexico, and was partially obscured by clouds as it moved east offshore into the Atlantic.

Figure 328. NOAA's HMS Smoke/Dust text product through 04:00 PST on July 24, 2024.

Thursday, July 25, 2024

DESCRIPTIVE TEXT NARRATIVE FOR SMOKE/DUST OBSERVED IN SATELLITE IMAGERY
THROUGH 1725Z July 25, 2024

SMOKE:
Canada/United States/Northern Mexico/Pacific Ocean/Atlantic Ocean...
A significant amount of mixed density smoke attributed to a combination of seasonal fire activity throughout the United States and numerous wildfires in northern Canada, Alaska and the Pacific Northwest region continues to be observed today. Light density smoke was seen throughout the majority of the United States, extending east-southeast from Alaska and the Bering Sea into the northern Pacific Ocean off the coasts of Washington State and Oregon. The light density smoke continued moving east across northern Canada and the United States, extending south along the West Coast, reaching northern Mexico, before extending east through the Gulf States and eventually dispersing into the northern Atlantic Ocean. Areas of moderate density smoke were seen throughout Alaska, Canada and the central United States, while areas with the thickest density smoke were were concentrated in the Pacific Northwest, Alberta, Saskatchewan, Manitoba, Ontario and the Midwest region of the United States. The large mass of thick density smoke concentrated throughout these areas was seen stretching east-southeast from the Alaska to central Ontario, becoming more moderate to light in density as it moved into the Midwest region and Northeastern regions of the United States, however, two bands of moderate smoke continued extending east through Quebec and the Northeast United States before dispersing into the northern Atlantic Ocean past the southern tip of Greenland.

Figure 329. NOAA's HMS Smoke/Dust text product through 09:25 PST on July 25, 2024.

Soundings

Smoke can sometimes remain aloft if low-level mixing is insufficient to transport the smoke at higher altitudes to the surface. Soundings are one of the most useful tools to determine how deeply the atmosphere mixes each afternoon, and whether mixing could be deep enough to reach into the smoke above the ground. When determining the height of mixing from soundings, meteorologists compare the observed change of temperature with height (lapse rate) with the background grid of dry adiabats. If the observed temperature trace parallels the dry adiabats from the surface upward, it indicates that vertical mixing occurred between the surface to the height where the observed lapse rate is no longer parallel to the dry adiabats. While deep mixing normally helps ozone concentrations plateau during the afternoon, that mixing can transport aloft smoke to the surface and enhance ozone formation.

The units of the x-axes on the soundings in Figure 330 are temperature in degrees Celsius, and the units of the primary y-axes are pressure in millibars, with height (in meters) also annotated along that axis. The left black vertical trace on each graph represents observed dewpoint temperature, and the right black vertical trace represents observed air temperature. The green, slightly curved diagonal lines that slope downward from left to right are the dry adiabats. As long as the right black line

originating from the surface parallels the green lines as it moves upward, vertical mixing is inferred through that layer, and that layer is called the boundary layer. The boundary layer is the layer of air that can freely mix with air near the surface. The height of the top of the boundary layer is called the mixing height. The two right-most panels of Figure 330 show that afternoon mixing heights ranged from approximately 4,000 meters on July 24, to 4,500 meters on July 25.

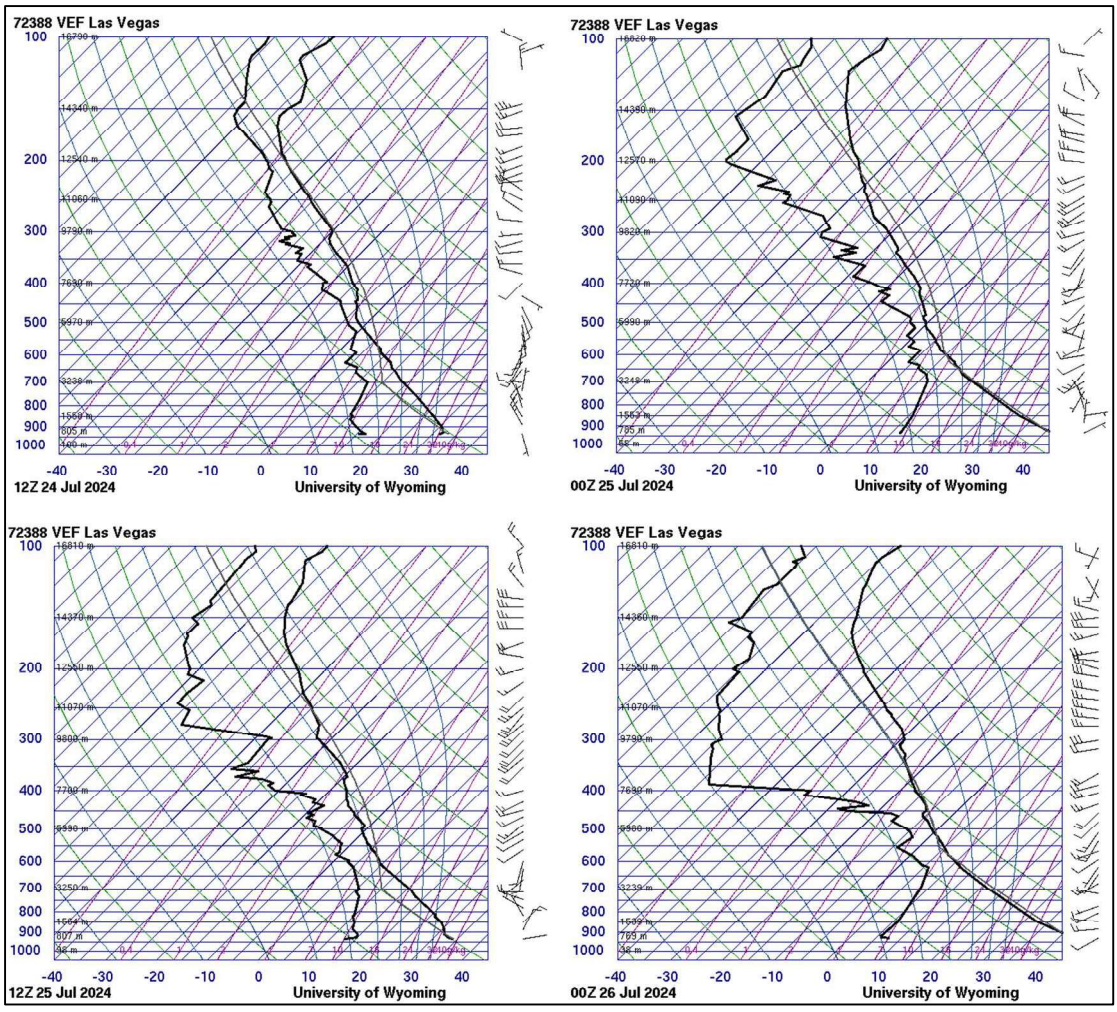

Figure 330. Observed soundings from 04:00 PST (left panels) and 16:00 PST (right panels) from July 24, 2024 (top) and July 25, 2024 (bottom). Source: University of Wyoming.

Upon reviewing the numerical output from each of the afternoon soundings, the mixing height in Las Vegas was determined to be approximately 4,110 meters (13,484 feet) on July 24, and 4,471 meters (14,669 feet) on July 25. While not uncommon in desert regions during the summer, these mixing heights are considered to be very deep and further support the evidence that the smoke aloft shown in Figure 322 and Figure 323 had the potential to mix to the surface.

Smoke Transport

Mixing heights can also be used to compute the origin of an air mass that arrives in the boundary layer at a specified time using the HYSPLIT model. To coincide with the observed mixing heights and near the time of maximum ozone concentrations, back trajectories were computed from 16:00 PST each day. The trajectories were run for 24 hours to determine where the boundary layer air originated from the prior day, and they were overlaid with satellite smoke and fire detections from the prior day to evaluate the potential for smoke transport.

Back trajectories ending in Clark County at 16:00 PST on July 24, 2024, at 10 m (near surface), 2,055 meters (middle of the boundary layer) and 4,110 meters (top of the boundary layer) all originated from an area of moderate density smoke over California (Figure 331). In addition, the near-surface trajectory originated near the SQF Lightning Complex Fires in the Sequoia National Forest west of the city of Ridgecrest, CA. This provides evidence of direct smoke transport into the Las Vegas region on July 24.

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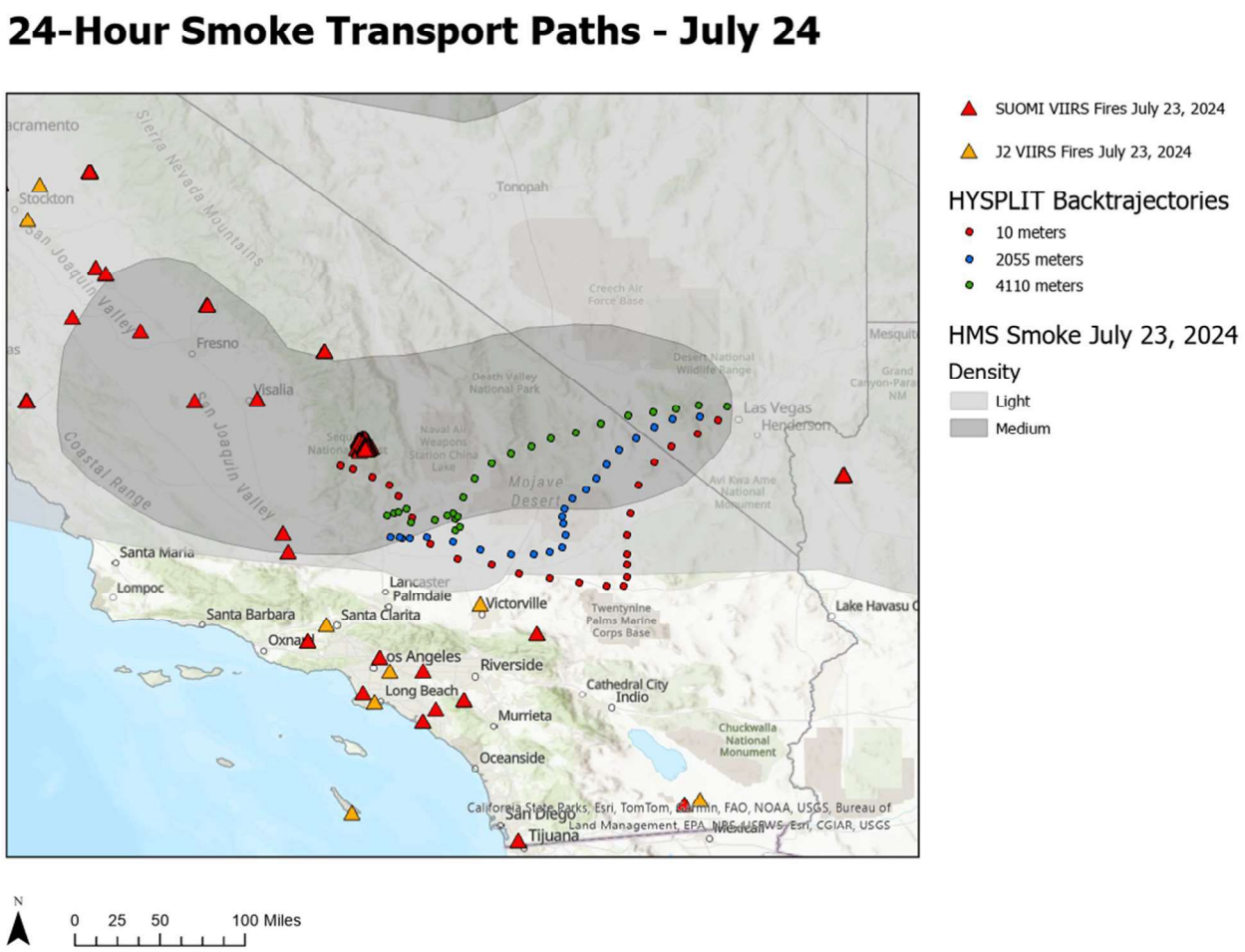

Figure 331. 24-hour boundary-layer backward trajectories from the HRRR model ending at 16:00 PST July 24, 2024, at 10 meters (red dots), 2,055 meters (blue dots) and 4,110 meters (green dots). HMS fires (triangles) and smoke (gray contours) are also displayed.

Similarly, Figure 332 shows that back trajectories ending in Clark County at 16:00 PST on July 25, 2024, at 10 m (near surface), 2,236 meters (middle of the boundary layer) and 4,471 meters (top of the boundary layer) also originated from a broad area of moderate density smoke over California. In route to Clark County, these trajectories also crossed several smaller active fires.

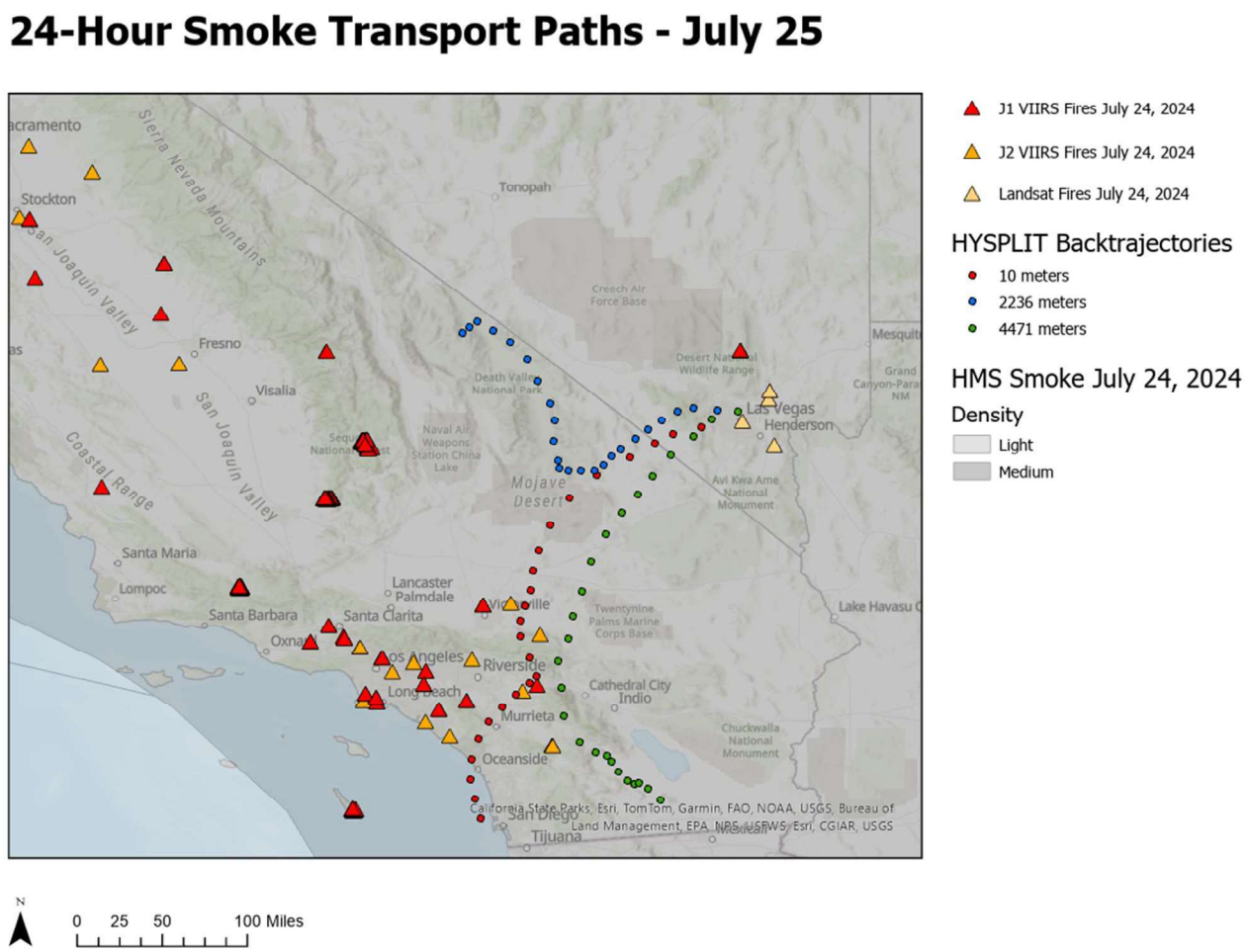

Figure 332. 24-hour boundary-layer backward trajectories from the HRRR model ending at 16:00 PST July 25, 2024, at 10 meters (red dots), 2,236 meters (blue dots) and 4,471 meters (green dots). HMS fires (triangles) and smoke (gray contours) are also displayed.

Summary

For July 24-25, 2024, meteorological, fire, and smoke conditions provide strong evidence that ozone formation was enhanced by ozone precursors from smoke in the Clark County area. Specifically,

- A ridge of high pressure aloft, hot surface temperatures, and light surface winds promoted ozone development.
- Smoke plumes were visible in satellite data over Clark County on each day.
- Deep mixing heights increased the potential for smoke to mix to the surface and 24-hour boundary-layer back trajectories from Clark County originated in regions with active fires and smoke.
- Near-surface smoke was modeled over southern Nevada on each day.

7.5.4 Surface Impacts

Smoke from fires in Canada, Alaska, and the Pacific Northwest, as well as the 2024 SQF Lightning Complex Fire in Sequoia National Forest spread over Clark County in the days leading up to the exclusion dates and was visible in Clark County on July 24 and July 25, 2024. Smoke is visible throughout the day on both days in photos taken from the M Resort Hotel looking to the north, northeast, south, and northwest (Figure 333 and Figure 334).

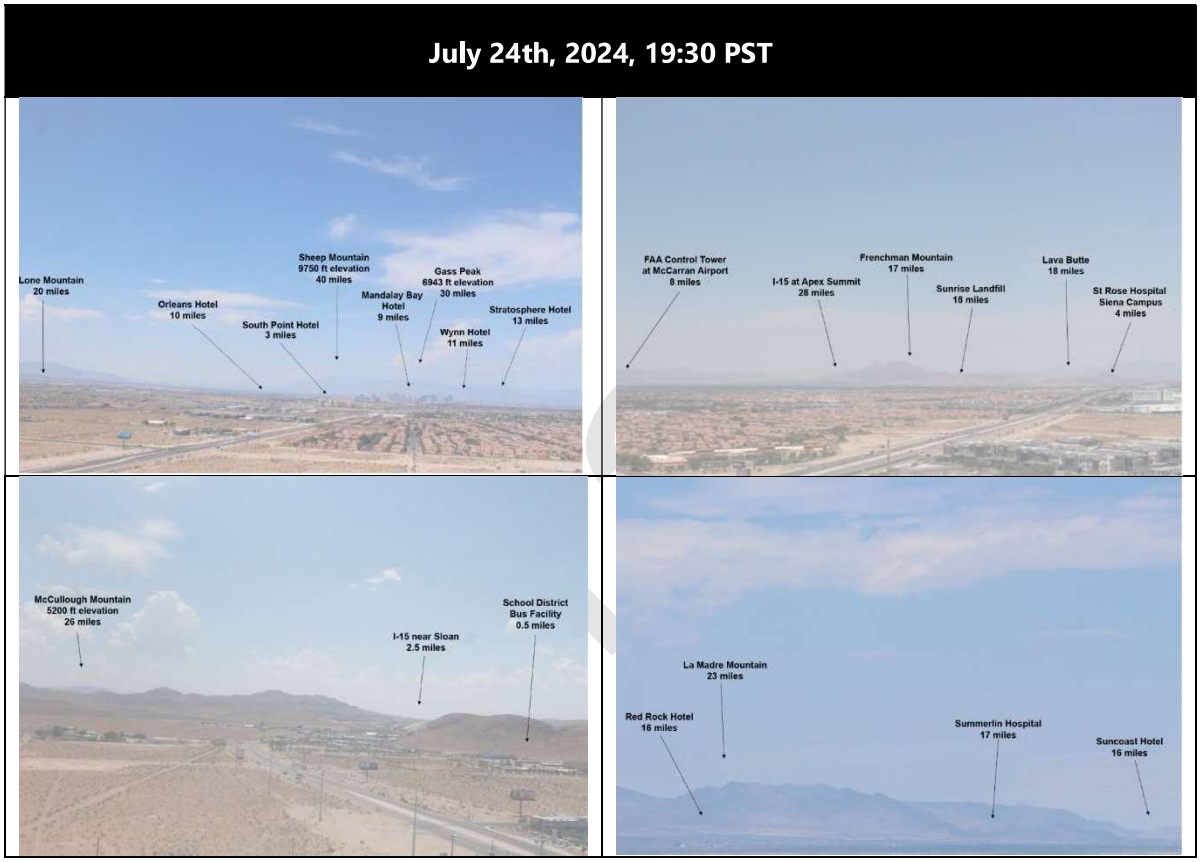

Figure 333. Webcam images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) views from the M Resort Hotel in Clark County, NV, on July 24, 2024, at 19:30 PST.

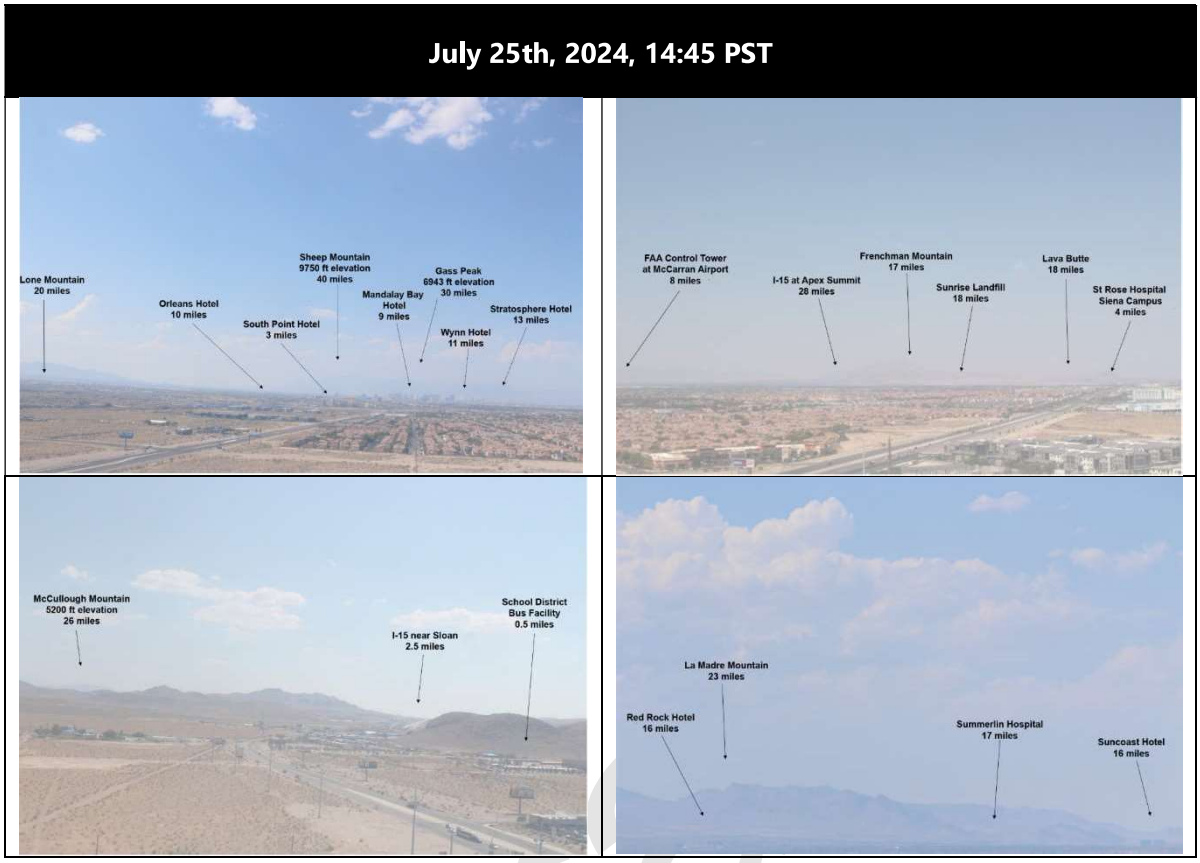

Figure 334. Webcam images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) views from the M Resort Hotel in Clark County, NV, on July 25, 2024, at 14:45 PST.

$PM_{2.5}$ concentrations were enhanced in Clark County on July 24 and 25, 2024, as smoke from the SQF Lightning Complex in California and wildfires in Canada, Alaska, and the Pacific Northwest entered the region and mixed towards the surface; this is further evidence that wildfire smoke was present as an atypical influence on ozone concentrations during the exclusion period.

Figure 335 shows hourly $PM_{2.5}$ concentrations at seven of the affected sites (Garrett Jr. High*, Green Valley, Joe Neal, Mountain's Edge*, Palo Verde, Paul Meyer, and Walnut Community Center*) overlaid on the 10th to 90th percentile hourly concentrations during ozone season (April to September) calculated using data from 2019-2024, where available. As smoke moved into the area, $PM_{2.5}$ concentrations steadily rose throughout the afternoon of July 24, peaking at 20:00 PST on July 24, and began to rise again at 05:00 PST on July 25 until peaking at 23:00 PST on July 25. At midday on both days, $PM_{2.5}$ concentrations were above the 6-year median concentration at most sites and reached peak concentrations that far exceeded the 90th percentile concentration (particularly during the late evening of July 25).

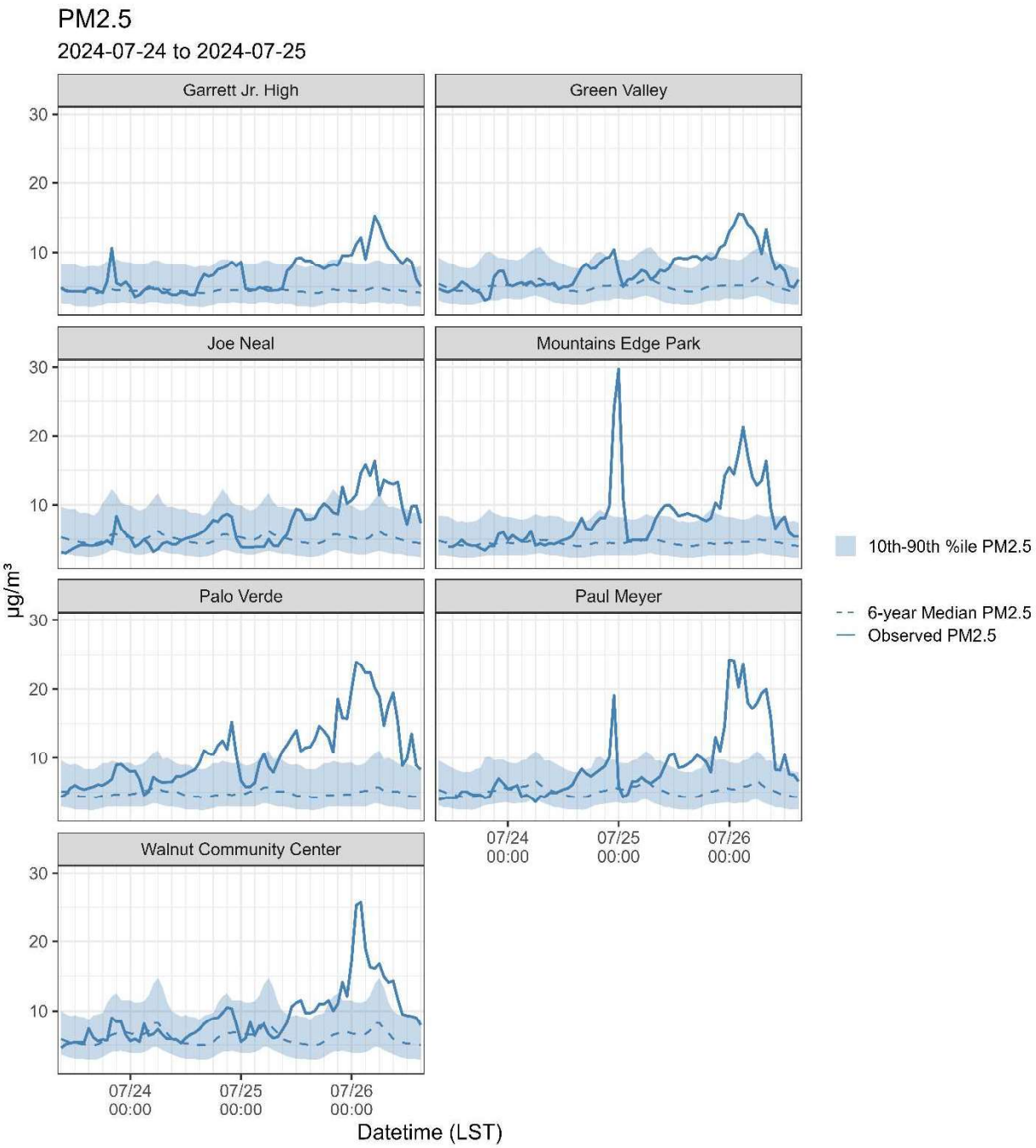

Figure 335. Hourly $PM_{2.5}$ concentrations overlaid on the 10th-to-90th percentile diurnal concentration at the Garrett Jr. High (AQS site code 320030602), Green Valley (AQS site code 320030298), Joe Neal (AQS site code 320030075), Mountain's Edge (AQS site code 320030044), Palo Verde (AQS site code 320030073), Paul Meyer (AQS site code 320030043), and Walnut Community Center (AQS site code 320032003) monitoring sites. The 10th-to-90th percentile concentration is calculated across the ozone production season (April-September) of 2019-2024. Note: the Garrett Jr. High site only includes data from April 1, 2021, and onwards; the Mountain's Edge site only includes data from October 1, 2020, and onwards; and the Walnut Community Center site only includes data from June 1, 2021, and onwards.

During wildfire events, the ratio of $PM_{2.5}$-to-PM_{10} concentrations increases, so this ratio was examined to determine if wildfire smoke entered Clark County on or before the exclusion dates. Figure 336 shows a time series of the ratio of $PM_{2.5}$-to-PM_{10} concentrations from July 23-26, 2024, with the multiyear average ratio and 10th to 90th percentile shown for the following sites: Garrett Jr. High*, Green Valley, Joe Neal, Mountain's Edge*, Palo Verde, Paul Meyer, and Walnut Community Center*. While $PM_{2.5}$-to-PM_{10} ratio fluctuated throughout this period, it increased following the same pattern as $PM_{2.5}$ concentrations noted above. During this period, the ratio exceeded the multiyear median concentration and 90th percentile concentration, especially during the afternoon and evening of July 25. Across the sites, the highest $PM_{2.5}$-to-PM_{10} ratios on July 24 and 25 were between 0.4-0.5. This is indicative of wildfire smoke entering the area. These observations provide evidence that wildfire smoke was present in Clark County on July 24 and 25 during the atypical ozone event.

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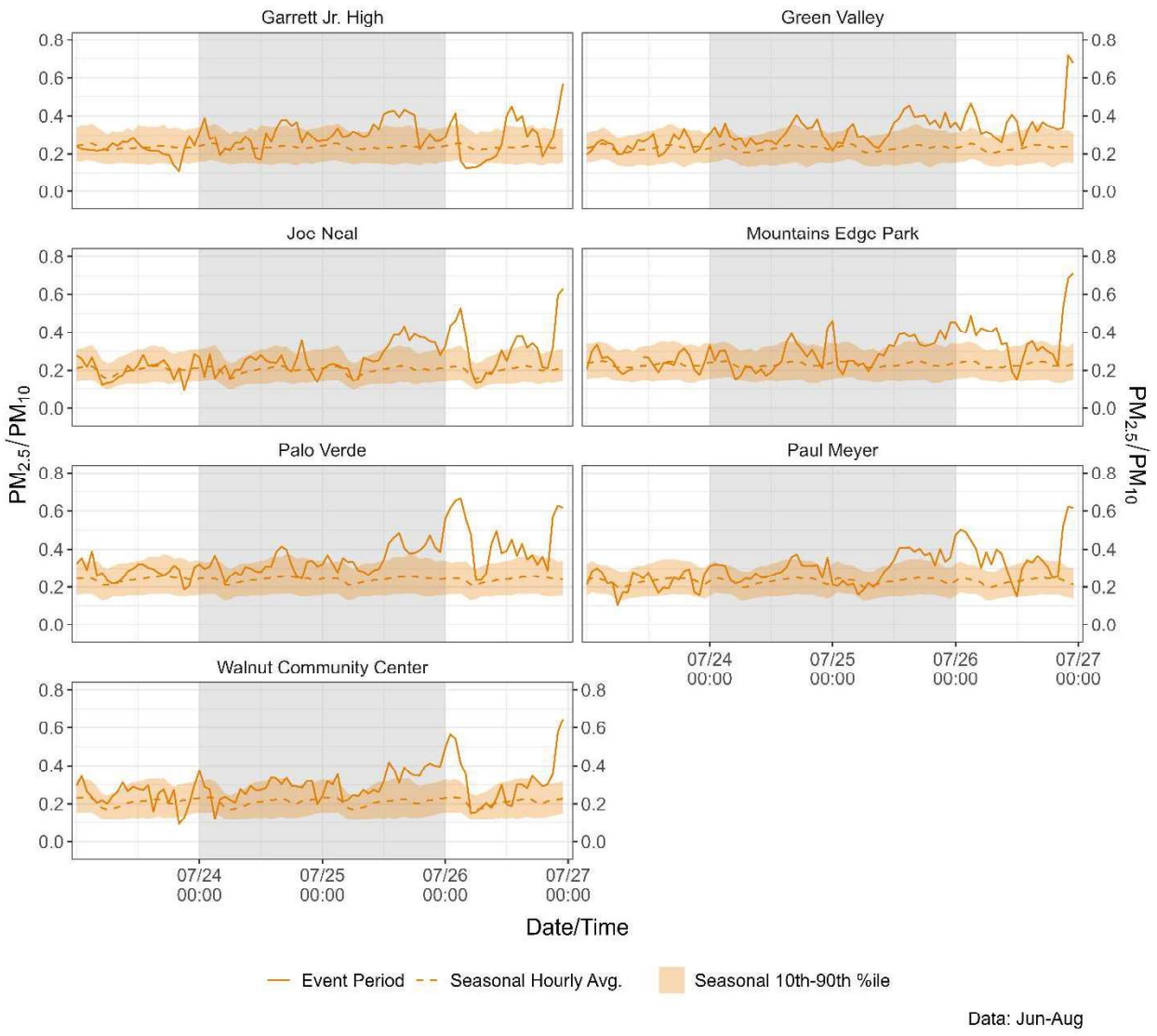

Figure 336. Ratio of $PM_{2.5}$-to-PM_{10} concentrations during the event period, overlaid on the 10th-to-90th percentile diurnal concentrations at the Garrett Jr. High* (AQS site code 320030602), Green Valley (AQS site code 320030298), Joe Neal (AQS site code 320030075), Mountain's Edge* (AQS site code 320030044), Palo Verde (AQS site code 320030073), Paul Meyer (AQS site code 320030043), and Walnut Community Center* (AQS site code 320032003) sites. The 10th-to-90th percentile concentration is calculated across the ozone production season (April-September) of 2019-2024. Note: the Apex site only includes data from June 1, 2023, and onwards; the Garrett Jr. High site only includes data from April 1, 2021, and onwards; the Mountain's Edge site only includes data from October 1, 2020, and onwards; and the Walnut Community Center site only includes data from June 1, 2021, and onwards.

The concurrence of enhanced $PM_{2.5}$ concentrations and higher $PM_{2.5}$-to-PM_{10} ratios in Clark County on July 24 and 25, 2024, in addition to analysis of meteorological conditions and smoke imagery, provides strong evidence that surface-level smoke was present in Clark County during the exclusion period. This combined evidence suggests that the SQF Lightning Complex in California and numerous wildfires in Canada, Alaska, and the Pacific Northwest region provided an atypical source of ozone and ozone precursors that caused enhanced ozone concentrations on July 24 and 25.

7.5.5 Event Statistics

Table 74 summarizes concentrations of ozone and $PM_{2.5}$ on the exclusion days, as well as the percentile rank of the observations compared to the previous 6-yrs of data (2019-2024). Ozone MDA8 concentrations ranged from the 96th to 99th percentile on July 24-25.

Across the sites, 24-hour $PM_{2.5}$ concentrations were high, ranging from the 58th to 96th percentile. As shown in Figure 335, $PM_{2.5}$ concentrations exceeded the seasonal median and peaked well above the seasonal 90th percentile for the majority of July 24-25.

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Table 74. Percentile of pollutant concentration on exclusion day compared with most recent 6-yrs* (2019-2024). The percentile rank is calculated across the ozone production season (April 1 – September 30) of 2019-2024. Sites that have less than six years of data available for a given parameter are indicated with an asterisk.

Date	Site Name	Site Code	Ozone		$PM_{2.5}$	
			Ozone MDA8 (ppb)	Percent Rank	$PM_{2.5}$ 24-hr average ($\mu g/m^3$)	Percent Rank
7/24/2024	Green Valley	320030298	70	95.90%	6.4	71.90%
7/24/2024	Joe Neal	320030075	77	98.80%	5.5	58.40%
7/24/2024	Mountain's Edge	320030044	71	96.4%*	6.6	86.5%*
7/24/2024	Palo Verde	320030073	73	98.40%	8.6	91.8%*
7/24/2024	Paul Meyer	320030043	71	95.50%	6.6	74.50%
7/24/2024	Walnut Community Center	320032003	72	96.2%*	7.3	59.4%*
7/25/2024	Apex	320030025	70	99.7%*		
7/25/2024	Garrett Jr. High	320030602	71	99.2%*	7	89.3%*
7/25/2024	Green Valley	320030298	70	95.90%	8.1	86.80%
7/25/2024	Joe Neal	320030075	73	97.00%	7	78.90%
7/25/2024	Palo Verde	320030073	71	97.20%	11.2	95.7%*
7/25/2024	SM Youth Camp	320037771	72	97.20%		
7/25/2024	Walnut Community Center	320032003	73	97.1%*	9.2	77.9%*

7.6 September 6, 2024

7.6.1 Event Summary

The unrepresentative ozone event took place on September 6, 2024, and affected ozone concentrations at the Palo Verde site in Clark County, NV. Figure 337 shows a time series of hourly ozone concentrations exceeding seasonal medians (calculated using April 1 – September 30, 2019-2024) and 10th to 90th percentiles at the site.

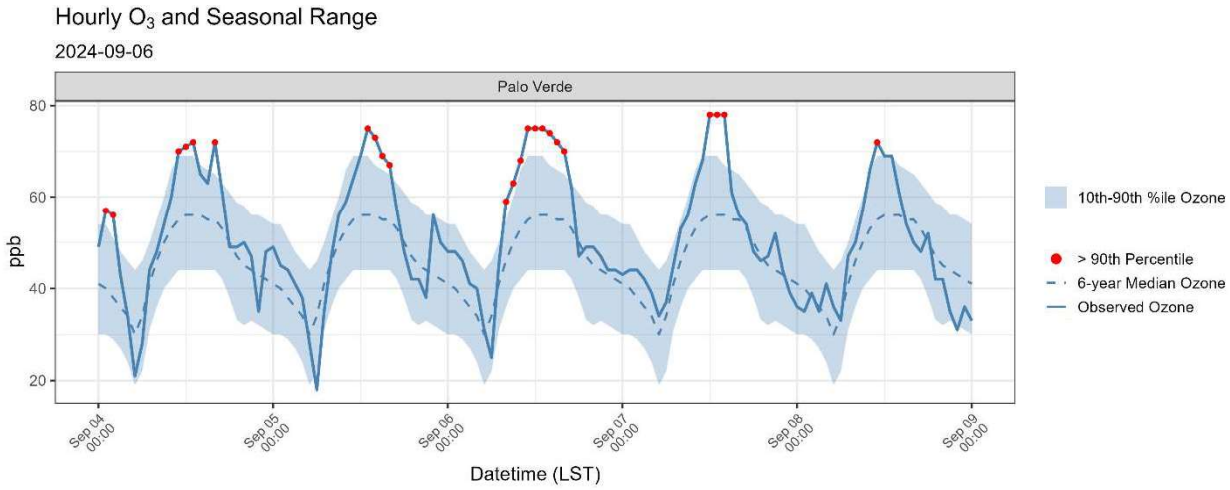

Figure 337. Hourly ozone concentrations (ppb) for September 6, 2024, and surrounding days compared to 6-year ozone season (April 1 – September 30) hourly medians and 10th-to-90th percentiles.

On September 6, ozone concentrations at the Palo Verde site were above the 6-year ozone season median and 90th percentile from 08:00 to 16:00 PST. The maximum daily 8-hour average (MDA8) concentration at the Palo Verde site on September 6 was 71 ppb. Ozone concentrations increased in the early morning hours of September 6, after smoke entered the Clark County area during the evening hours of September 5 and was trapped by a temperature inversion. While there were hourly observations that exceeded the 90th percentile on the two days prior to and following the event, the MDA8 concentrations did not exceed the standard on these days.

Numerous large wildfires, including several "megafires," burning in Oregon and Idaho, as well as the Broom Canyon wildfire burning in eastern Nevada and the Bear Fire in Sierra County, CA, were identified as contributors to this event. Evidence includes (1) HYSPLIT back trajectories and meteorological analysis indicating transport and accumulation of smoke in Clark County, (2) visible smoke in camera images, and (3) synchronous enhancement of $PM_{2.5}$ concentrations as well as increased $PM_{2.5}$-to-PM_{10} ratios aligned with wildfire-driven ozone enhancement. This combination of

evidence strongly indicates that this is an unrepresentative event for base and future design value ozone assessments.

7.6.2 Identification of Wildfire(s)

Many large fires in Oregon and Idaho (**Figure 338**) were active on the days leading up to and during September 6, 2024, the exclusion day. As of September 6, international support personnel from Australia and New Zealand were assisting with management of large fires in the Pacific Northwest, and soldiers were deployed to support wildland fire operations in the Boise National Forest.[78] The largest fire at the time was the Wapiti Fire, which was ignited by lightning two miles southwest of Grandjean, ID, and experienced increased fire activity in late August.[79] It eventually burned 125,965 acres and was not fully contained until late October. As of September 4, the Durkee, Monkey Creek, Falls, and Lone Rock megafires (i.e., greater than 100,000 acres) had been burning for approximately 50 days in Oregon.[80] Additionally, the Broom Canyon Fire (Figure 283) in eastern Nevada, 35 miles southwest of Ely, NV, had been burning since July 29 and reached a size of 8345 acres by September 6. Finally, the 3,233-acre Bear Fire started in Sierra County, CA, on September 2, and was contained on September 17, 2024.[81]

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[78] https://goldrushcam.com/sierrasuntimes/index.php/news/local-news/60072-national-fire-news-for-friday-september-6-2024-the-national-preparedness-level-has-now-increased-to-5-pl-5-the-highest-level
[79] https://inciweb-prod-media-bucket.s3.us-gov-west-1.amazonaws.com/s3fs-public/2024-10/Wapiti%20Fire%20Burned%20Area%20Report%20-%20BAER.pdf?VersionId=uaaKFi0m8M2t9uZ.ohhKWdSwaOEiYmbb
[80] https://www.koin.com/news/wildfires/oregon-megafire-burn-50-days-falls-lone-rock-durkee-monkey-creek/
[81] https://www.fire.ca.gov/incidents/2024/9/2/bear-fire

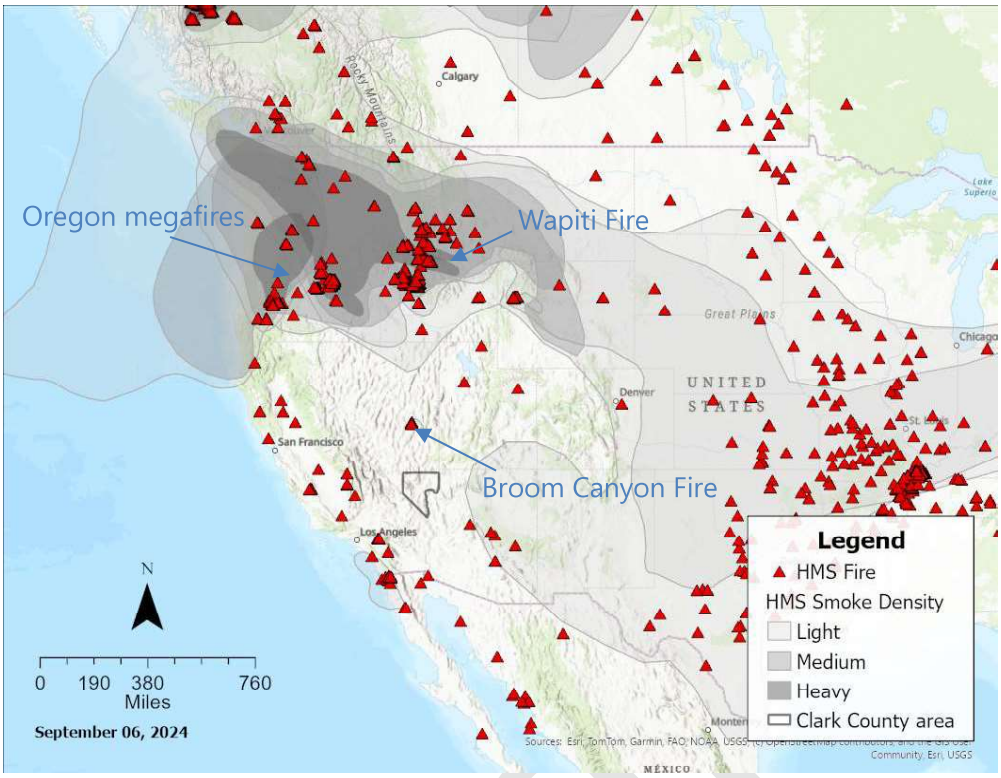

Figure 338. Continental view of HMS fire detections (red triangles) and smoke density (grey contours) from September 6, 2024. Clark County is outlined in grey.

7.6.3 Meteorological Analysis

Upper-Level Weather Patterns

To determine the meteorological conditions on September 6, 2024, an analysis was conducted using observed upper-level weather maps, observed PBL meteorological data, NOAA HMS satellite fire data, and HYSPLIT paths.

Mean winds at 500 mb (18,000 feet above ground level [AGL]) from September 4-6, 2024, are shown in **Figure 339**. Based on a clockwise wind pattern across California, Nevada, and Arizona, upper-level high pressure was analyzed over the California/Nevada border. Over Clark County, aloft winds during the three-day period were light north-northeasterly. The upper-level high pressure system over the region also produced subsidence (sinking air) and compressional heating. This upper-level configuration limits cloud development and yields hot surface temperatures.

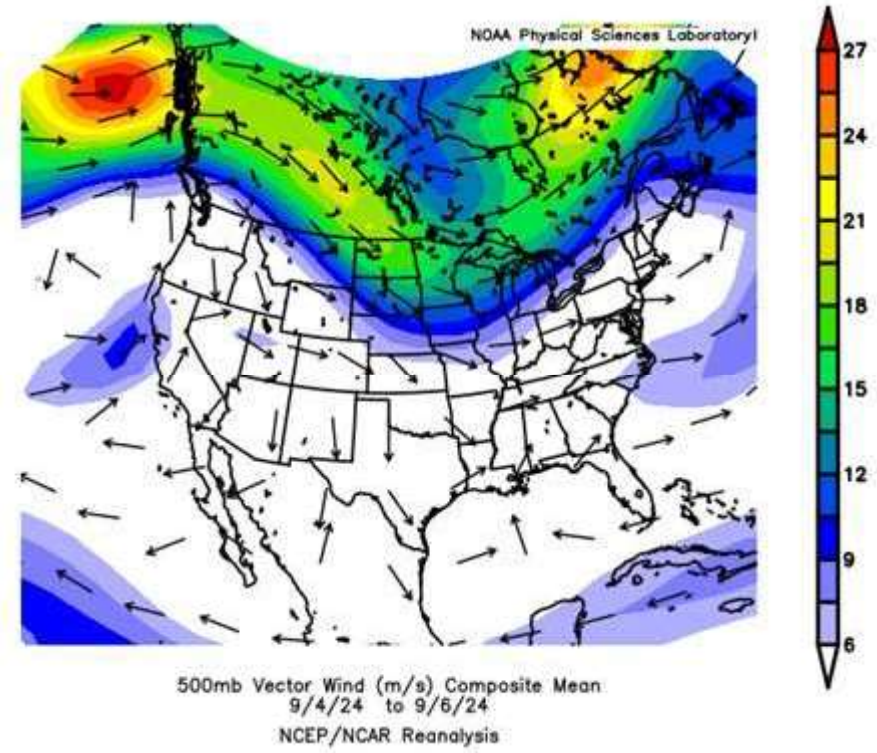

Figure 339. Mean 500-mb winds between September 4-6, 2024. Upper-level high pressure over southern Nevada and the Colorado River Valley produced light north-northeasterly winds aloft in the Clark County area. Source: NOAA.

Surface Weather Patterns

Table 75 contains the pertinent daily meteorological data for September 6, 2024, at the Harry Reid International Airport (KLAS). On the afternoon of September 6, KLAS reached a high temperature of 104°F, with hazy sunshine appearing in the webcam image from the M Resort Hotel in Henderson, NV, shown in Figure 340. While haze was not reported by the KLAS weather station, meteorologists at the National Weather Service (NWS) Las Vegas office observed haze and wildfire smoke on this day, which was mentioned in several area forecast discussions throughout the day. The 06:30 PST NWS forecast discussion is displayed in Figure 341.

Table 75. Daily maximum temperatures, average daily wind speed, and average daily wind direction at KLAS for September 6, 2024.

Date	Maximum temperature (°F)	Average wind speed (mph)	Average wind direction (deg)
9/6	104	4.2	86

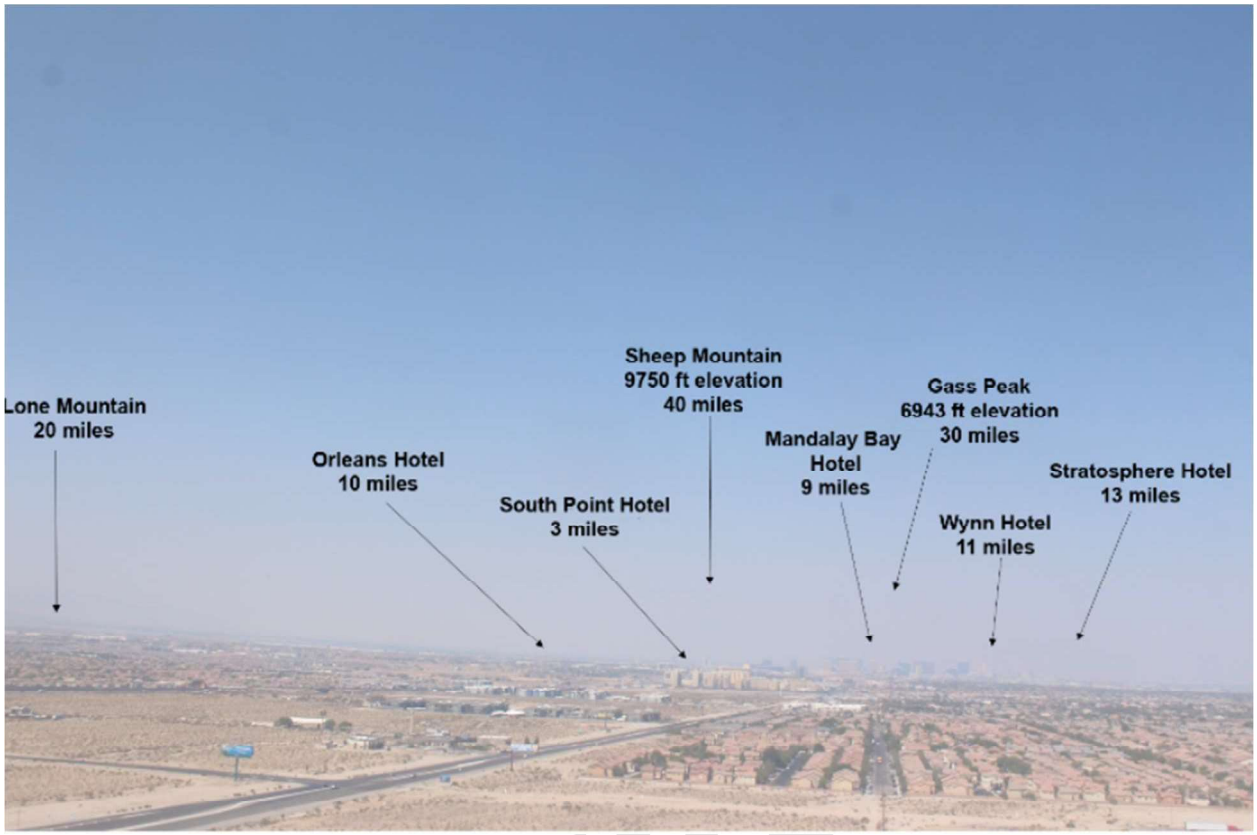

Figure 340. Webcam image from M Resort Hotel in Henderson, NV, looking north at 1:30 p.m. PDT on September 6, 2024. Hazy skies were present across the Las Vegas Valley. Source: Clark County Air Quality.

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```
Area Forecast Discussion
National Weather Service Las Vegas NV
731 AM PDT Fri Sep 6 2024

.SYNOPSIS...Excessive heat, hazy skies and dry conditions continue
through today. Temperatures lower this weekend as moisture and storm
chances return to the area. Drier weather resumes next week while
temperatures hold steady at several degrees above normal. Cooler
temperatures along with breezy conditions expected next Wednesday
and Thursday.

&&

.UPDATE...Wildfire smoke trapped under the high made for a unique
sunrise this morning. This anomalous high remains mostly overhead
today, keeping temperatures at dangerous levels across the lower
deserts (though the smoke may limit heating slightly). Tomorrow, the
high shifts east and south-southeasterly flow brings mid-level
moisture and precipitation chances back to the area. Isolated to
scattered showers and storms are expected this weekend, with the
main concern being strong outflow winds. Rain chances begin to
dwindle early next week as southwesterly flow and troughing develop,
bring temperatures down to more seasonal values.

&&

.SHORT TERM...Through tonight.

Satellite shows skies clear across the region this morning, however
air quality sensors continue to detect moderate levels of PM2.5
particulate matter from the wildfire smoke lingering in the area.
```

Figure 341. Area forecast discussion valid at 06:00 PST on September 6, 2024. Meteorologists at the National Weather Service Las Vegas observed haze and wildfire smoke in the region.

Surface winds on September 6, 2024, varied throughout the day, as shown in the wind rose diagram in Figure 342. At KLAS, calm-to-light and variable winds were present throughout much of the morning. After a brief period of light to moderate northeasterly winds between 09:00-11:00 PST, winds became light and variable during the remainder of the afternoon and early evening. Light winds inhibited dispersion of pollutants and ozone precursors, while sunny and hot conditions were conducive for ground-level ozone formation in Clark County.

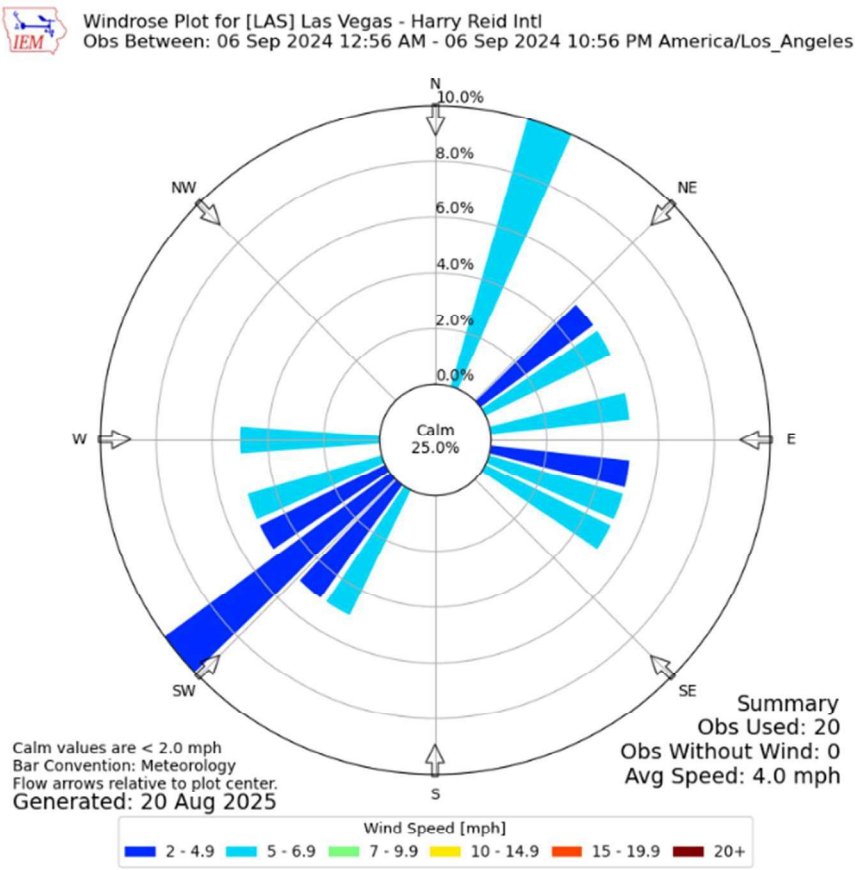

Figure 342. 24-hour wind rose for KLAS on September 6, 2024. Wind directions varied throughout the day, while wind speeds were generally less than 7 mph. Source: Iowa State Mesonet.

Vertical Temperature Profiles and Mixing Heights

Upper-level skew-T diagrams can provide information on the depth of vertical mixing from the surface to the top of the boundary layer and can also aid in assessing potential transport paths within the boundary layer. Higher PBL heights often result in deep mixing vertically, allowing upper-level air to be transported to the surface. The Las Vegas upper-air weather station (KVEF) data for 04:00 PST on September 6 is shown in skew-T diagram format in Figure 343, which indicated a shallow temperature inversion from the surface to approximately 110 m AGL, with aloft temperatures at 110 m that were 5°C warmer than ground level. This inversion trapped pollutants and ozone precursors near the surface, contributing to the hazy conditions mentioned by the NWS in Figure 341.

Twelve hours later, at 16:00 PST, the KVEF upper-air temperature profile on the skew-T diagram showed a well-mixed PBL (Figure 343). The estimated PBL height from the KVEF upper-air data was approximately 4,000 m AGL, which is sufficient for the vertical transport of aloft air (and any lofted pollutants) down to the surface.

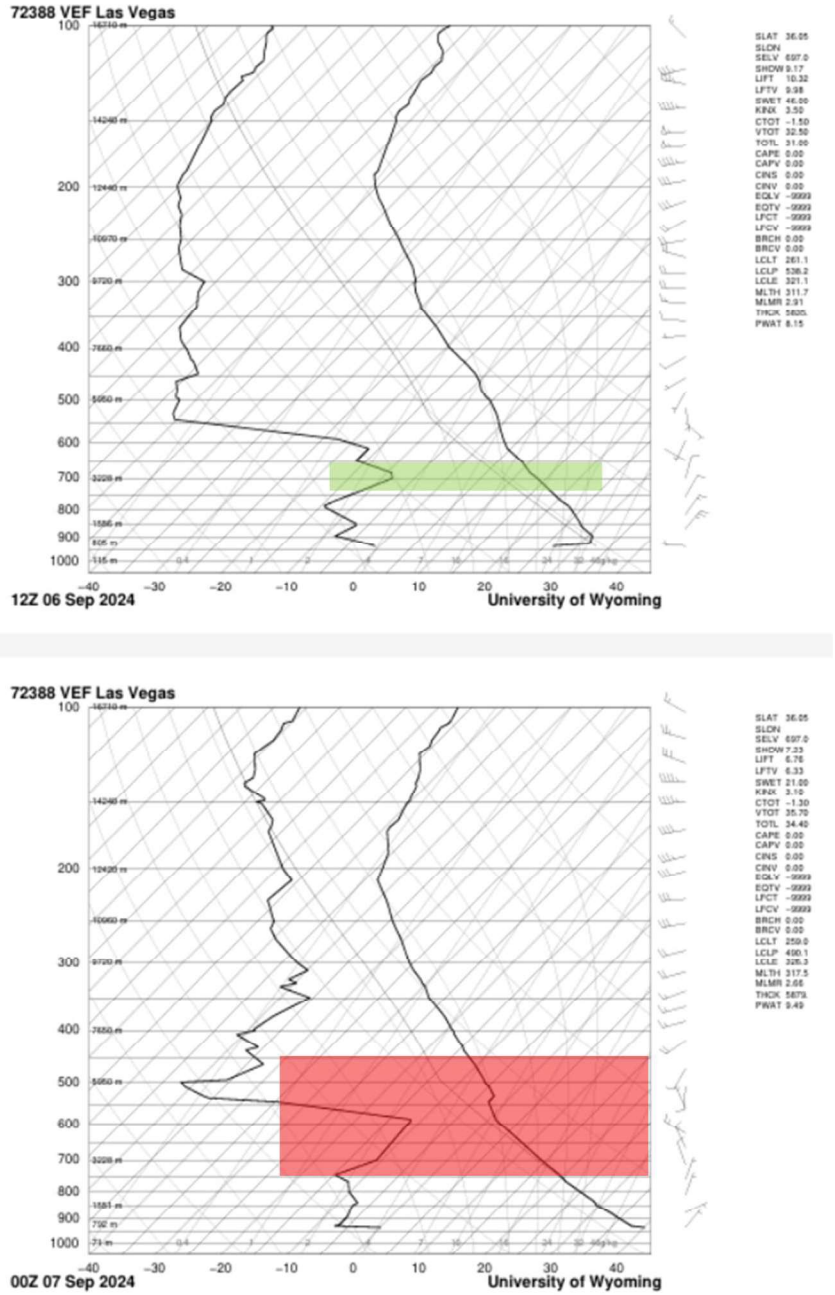

Figure 343. KVEF upper-air skew-T diagrams for September 6, 2024, at 04:00 PST (top) and 16:00 PST (bottom). The green shading indicates the location of a shallow temperature inversion present during the morning, while the red shading shows the depth of the PBL in the late afternoon. Source: University of Wyoming.

Smoke Transport

While haze and smoke were observed via webcam and by NWS meteorologists over the Las Vegas Valley on September 6, 2024, the NOAA HMS did not analyze smoke or detect fires over southern Nevada. However, smoke and several fires were detected by NOAA HMS north and west of Clark County between September 3-5, 2024. NOAA's HYSPLIT tool was used to determine if this smoke impacted air quality in Las Vegas on September 6.

Figure 344 shows the 54-hour back-trajectory analysis starting at 21:00 PST on September 3 and ending at 03:00 PST on September 6. Inputs for each transport path were based within the 4,000 m PBL. In addition, the NOAA HMS satellite fire detections from September 3-5 were overlaid on the back trajectory paths. The back trajectory analysis showed a clockwise transport path and north-northeasterly flow into Clark County within the PBL, which coincides with the 500 mb upper-level pattern shown in Figure 339. Additionally, each path within the PBL was near or crossed over fires detected by satellites during the September 3-5 period.

At the 4,000 m AGL level, the start of the back trajectory around 00:00 PST on September 4 was close to the Bear Fire in Sierra County, CA. The 2,000 m AGL back trajectory intersected numerous fires burning in eastern Oregon around 23:00 PST on September 3. In the lower levels of the PBL, the 10 m AGL path intersected the Broom Canyon Fire in eastern Nevada around 04:00 PST on September 5. These back trajectories indicate transport of smoke, and associated ozone precursors, into Clark County by the early morning hours of September 6.

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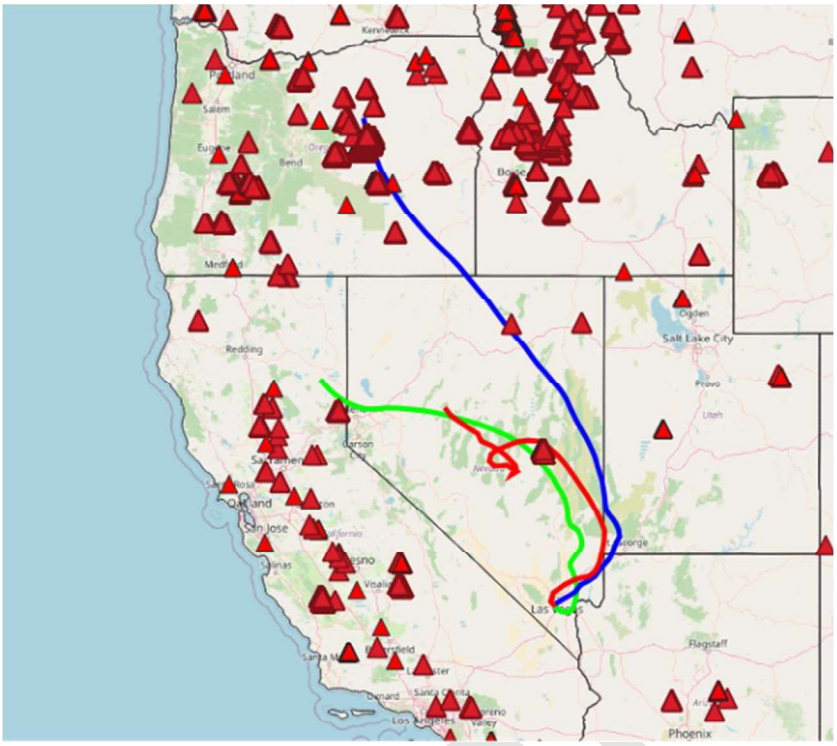

Figure 344. 54-hour back trajectory analysis ending 03:00 PST on September 6, 2024. The 10 m (red line), 2,000 m (blue line), and 4,000 m AGL paths (green line) intersect several fires detected by satellites (red triangles) between September 3-5. Source: NOAA.

Summary

As a result of the prevailing weather conditions and back trajectory analysis, there is evidence that supports smoke enhancing ozone development in Clark County on September 6. Specifically:

- Upper-level high pressure over the California/Nevada border between September 4-6, 2024, which produced north-northeasterly aloft winds into Clark County.
- Subsidence associated with the upper-level high pressure generated sunny and hot conditions in Clark County on September 6, which promoted ozone production.
- A shallow temperature inversion during the morning of September 6 trapped ozone precursors and yielded hazy skies, which NWS meteorologists observed as smoke in numerous forecast discussions during the morning and afternoon.
- A deep PBL of 4,000 m AGL the late afternoon of September 6, which promoted the vertical transfer of aloft air to the surface. Furthermore, back trajectory analysis through the PBL, combined with NOAA HMS satellite fire detections, indicated smoke transport into Clark County. Potential sources for the smoke include the Bear Fire in Sierra County, CA, the Broom Canyon Fire in eastern Nevada, and numerous wildfires in Oregon and Idaho.

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7.6.4 Surface Impacts

Beginning on September 5, 2024, smoke from wildfires in the Pacific Northwest and northern Nevada was present in Clark County and remained throughout the day of September 6. Figure 345 through Figure 347 feature webcam images of the north, northeast, south, and northwest views from the M Resort Hotel. Smoke is visible beginning on the morning of September 5 (Figure 345) and remains in the region through September 6, as evidenced by the north facing webcams (Figure 346 and Figure 347). The smoke was a news-worthy occurrence. The local Fox news channel discussed the conditions in their September 6 article,[82] "Nearby wildfires continue to bring hazy skies into Las Vegas Valley," and reported that several wildfires burning to the north, including the Broom Canyon Fire in eastern Nevada, contributed to moderate air quality conditions on the U.S. EPA's Air Quality Index (AQI) scale across southern Nevada.

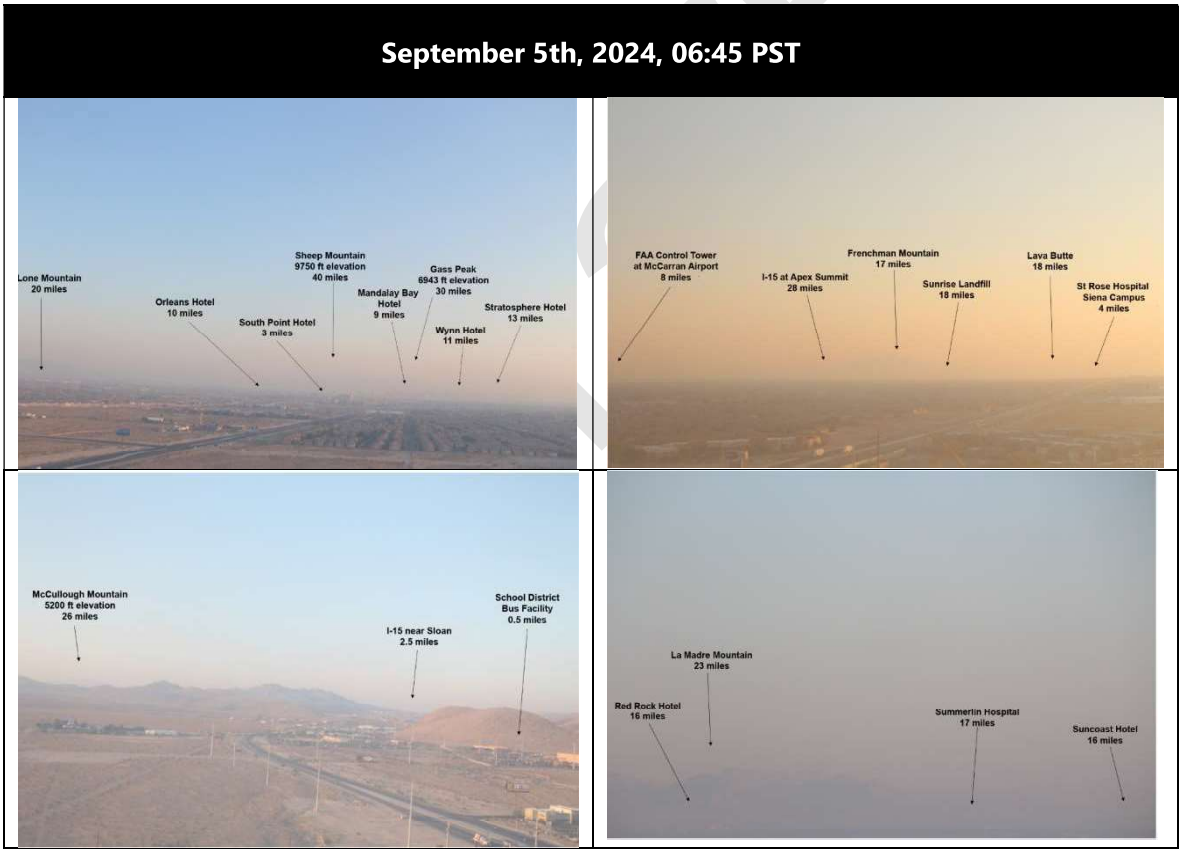

Figure 345. Webcam images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) views from the M Resort Hotel in Clark County, NV, on September 5, 2024, at 06:45 PST.

[82] https://www.fox5vegas.com/2024/09/06/nearby-wildfires-continue-bring-hazy-skies-into-las-vegas-valley/

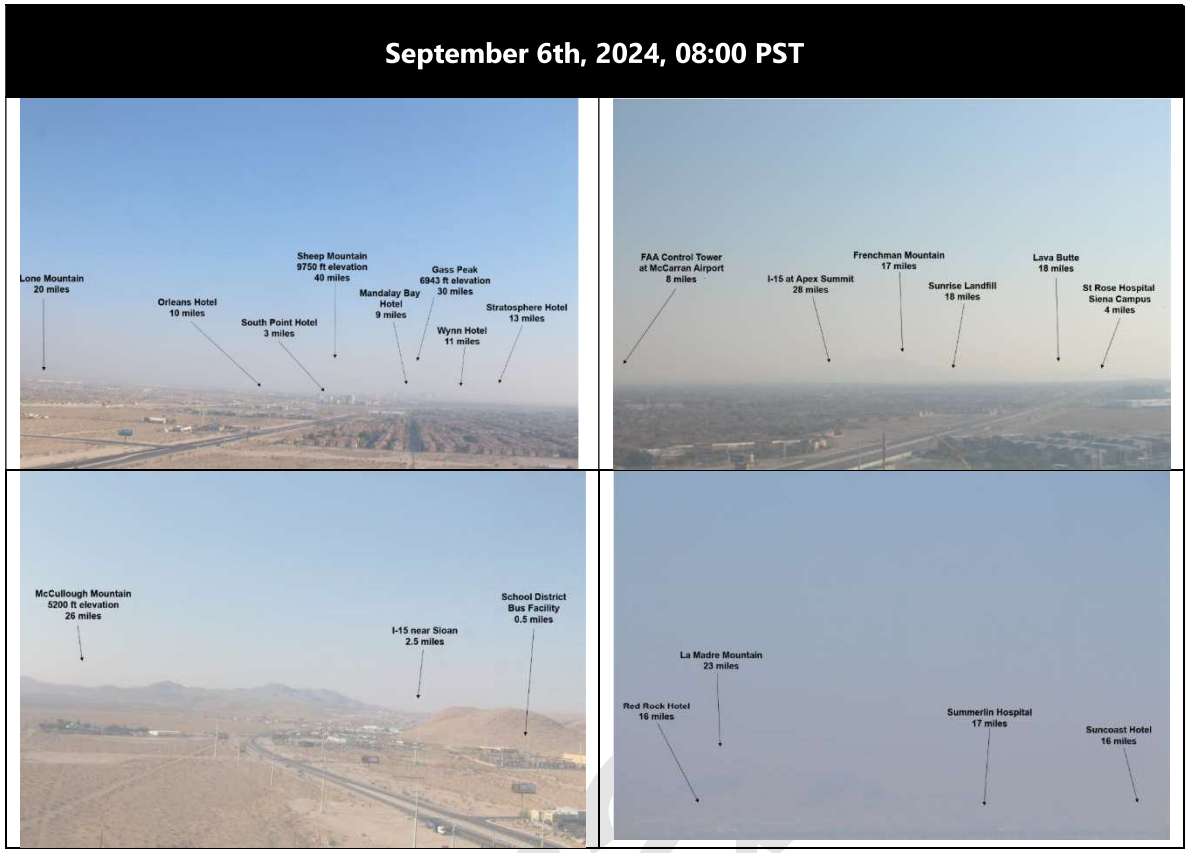

Figure 346. Webcam images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) views from the M Resort Hotel in Clark County, NV, on September 6, 2024, at 08:00 PST.

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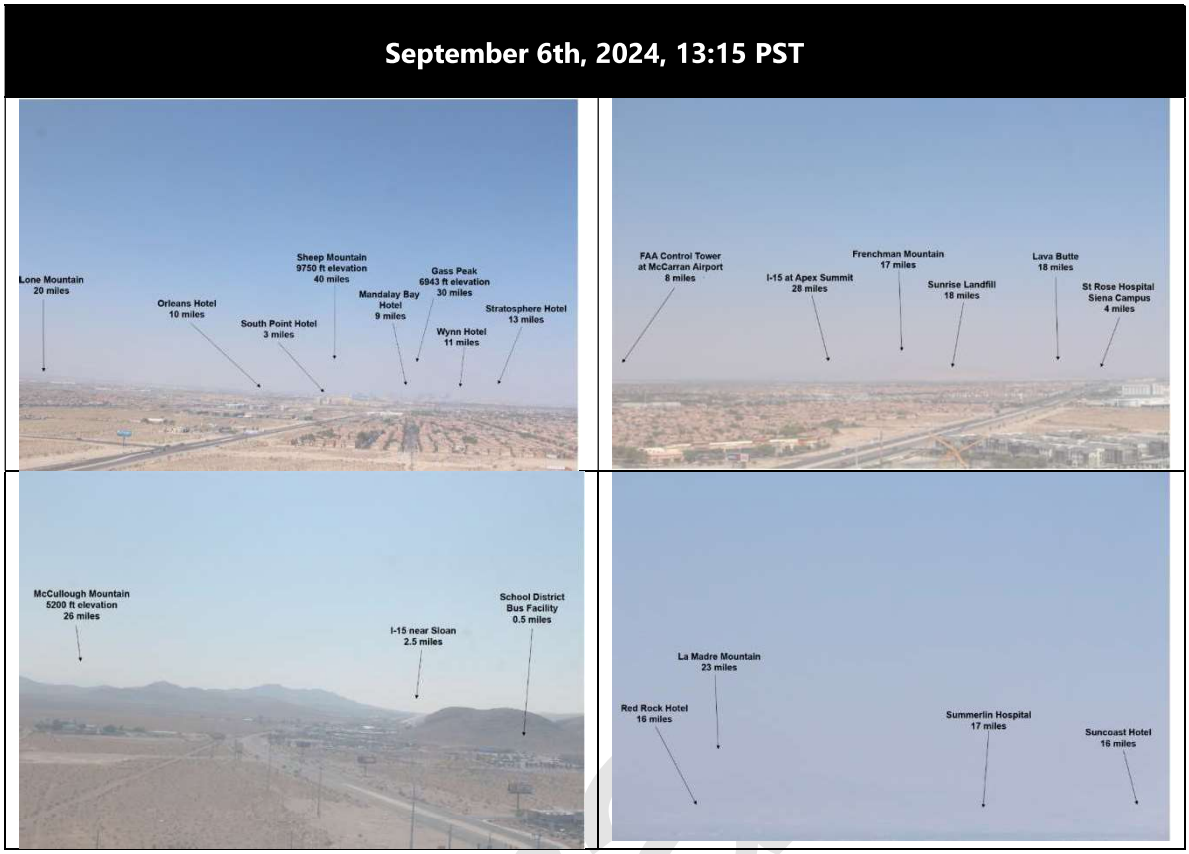

Figure 347. Webcam images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) views from the M Resort Hotel in Clark County, NV, on September 6, 2024, at 13:15 PST.

$PM_{2.5}$ concentrations were enhanced in Clark County on September 6, 2024, due to smoke from fires in northern Nevada, northern California, and the Pacific Northwest which entered the region and mixed towards the surface; this is further evidence that wildfire smoke was present as an atypical influence on ozone concentrations during the exclusion period.

Figure 348 shows hourly $PM_{2.5}$ concentrations at the Palo Verde site from September 5-8, 2024, overlaid with the 10th to 90th percentile hourly $PM_{2.5}$ concentrations during ozone season (April to September), calculated using data from 2019-2024. Concentrations of $PM_{2.5}$ rose sharply between 03:00 and 09:00 PST on September 5 as smoke moved into the area and proceeded to steadily decline through September 7 before returning to typical seasonal levels on September 8. On September 6, $PM_{2.5}$ concentrations were elevated far above the 6-year median and 90th percentile concentrations for the entire day.

The ratio of $PM_{2.5}$-to-PM_{10} concentrations was also examined to determine if wildfire smoke entered Clark County on or before the exclusion dates, which would increase this ratio. Figure 349 shows a time series of the ratio of $PM_{2.5}$-to-PM_{10} concentrations on September 5 through 7 at the Palo Verde site, with the 6-year average ratio and 10th to 90th percentile range shown. The ratio exceeded the

six-year hourly average and 90th percentile for the entire day at the Palo Verde site by a substantial amount. On September 6, the $PM_{2.5}$-to-PM_{10} ratio ranged between 0.5-0.6. These observations provide evidence that wildfire smoke entered Clark County on September 5, which increased the $PM_{2.5}$-to-PM_{10} ratios immediately prior to and throughout the atypical ozone event on September 6.

The concurrence of enhanced $PM_{2.5}$ concentrations and $PM_{2.5}$-to-PM_{10} ratios in Clark County on September 6, 2024, in addition to analysis of meteorological conditions and active fires, provides strong evidence that surface-level smoke was present in Clark County during the exclusion period. This combined evidence suggests that fires in the Pacific Northwest, northern Nevada, and northern California provided an atypical source of ozone and ozone precursors that caused enhanced ozone concentrations on September 6.

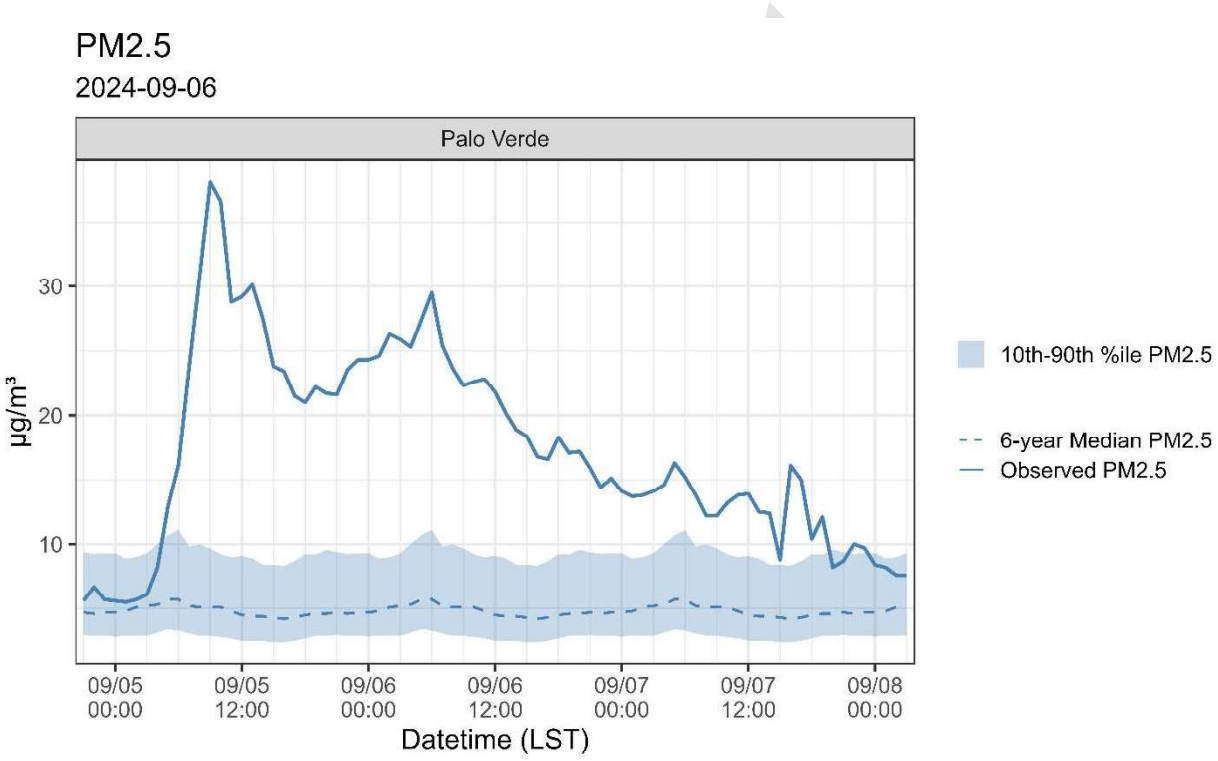

Figure 348. Hourly $PM_{2.5}$ measurements from September 5-8, 2024, overlaid on the 10th-to-90th percentile diurnal concentrations at the Palo Verde site (AQS site code 320030073). The 10th-to-90th percentile concentration is calculated across the ozone production season (April-September) of 2019-2024.

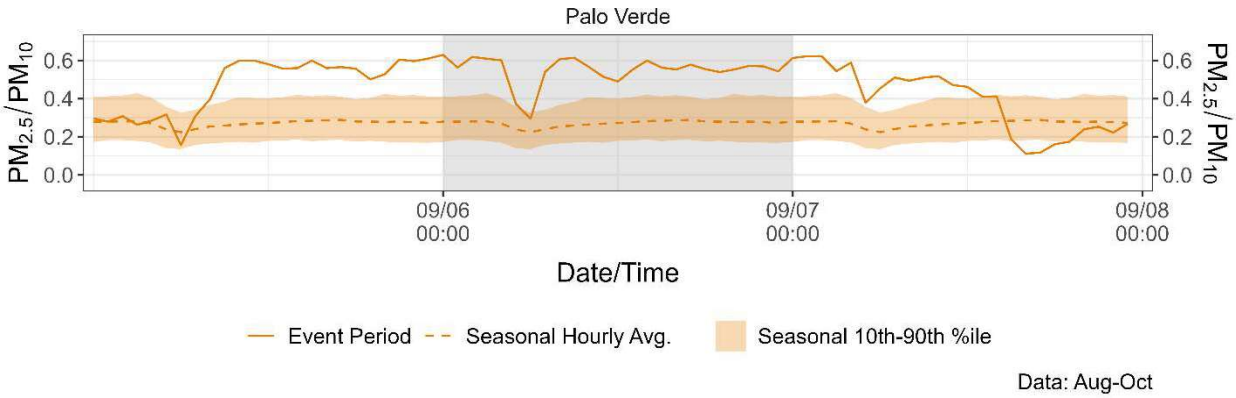

Figure 349. Ratio of $PM_{2.5}$-to-PM_{10} concentrations during the event period overlaid on the 10th-to-90th percentile diurnal concentrations at the Palo Verde site (AQS site code 320030073). The 10th-to-90th percentile concentration is calculated across the ozone production season (April-September) of 2019-2024. The date of September 6, 2024, is shaded in grey.

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7.6.5 VOC Analysis

VOC samples were collected on September 5 and 6, 2024. VOC ratios shown in Table 76 were calculated at all sites. These ratios were compared with the fire and no fire regimes calculated in Section 7.1.2 and found to all fall within the fire regime for all sites and all ratios. All sites saw particularly high ratios for each species during this event, confirming the presence of a significant amount of smoke both upwind and within Clark County immediately before and during the September 6 event.

Table 76. VOC Ratios calculated for September 5 and 6, 2024 from the Jean, Jerome Mack, and Sunrise Acres monitoring sites. These ratios can be compared with the fire and no fire regimes calculated in Section 7.1.2. Ratio abbreviations are defined in Table 61.

Sample Date	Site	ACE_ ACN	ACN_ ACE	ACN_ ACR	ACN_ BZN	ACN_ PEN	ACN_ TOL
9/5/2024	Jerome Mack	82.0	0.072	5.9	5.9	2.0	0.2
	Jean	20.3	0.086	1.8	5.1	1.0	0.9
	Sunrise Acres	79.0	0.073	5.8	5.8	2.0	2.0
9/6/2024	Jerome Mack	25.9	0.089	2.3	5.1	2.0	0.5
	Jean	51.0	0.092	4.7	2.2	1.1	0.3
	Sunrise Acres	40.0	0.045	1.8	4.0	0.6	0.7

7.6.6 Event Statistics

Table 77 summarizes concentrations of ozone and $PM_{2.5}$ on the exclusion day at the Palo Verde site, as well as the percentile rank of the observations compared to the previous 6-years of data (2019-2024). Ozone MDA8 concentrations ranked at the 97th percentile on September 6. 24-hour $PM_{2.5}$ concentrations at the site were high and ranked at the 99th percentile. As shown in Figure 348, $PM_{2.5}$ concentrations were elevated for the entirety of September 6, exceeding both the seasonal median and 90th percentile.

Table 77. Percentile of pollution concentration on September 6, 2024, exclusion day, compared with most recent 6-years (2019-2024). The percentile rank is calculated across the ozone production season (April 1 – September 30) of 2019-2024.

Date	Site Name	Site Code	Ozone		$PM_{2.5}$	
			Ozone MDA8 (ppb)	Percentile Rank	$PM_{2.5}$ 24-hr average ($\mu g/m^3$)	Percentile Rank
9/6/2024	Palo Verde	320030073	71	97.2%	21.3	98.9%

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7.7 Request for Exclusion

The wildfire smoke events outlined in this report resulted in ozone measurements that are atypical, extreme, and nonrepresentative of past and future days for Clark County, NV. Appendix W to Part 51 states "control agencies have long expressed a need for consistency in the application of air quality models for regulatory purposes…the expanded requirements for models to cover even more complex problems have emphasized the need for period review and update of guidance on these techniques."[58] Wildfire smoke events are one such complex problem, as wildfire season has extended and encompasses the summer months, also considered to be ozone production season. Wildfire occurrence is widely considered to be a stochastic natural phenomenon and is therefore inconsistent year-to-year. Downstream smoke impacts, including ozone formation, are not typical nor representative of the ambient conditions of Clark County, NV. The five wildfire smoke events identified in this report are inconsistent with previous records and are determined to be extreme, as indicated by:

- All site exceedances are above the 94th percentile of all ozone measurements.
- Multiple sites were affected during each event, including those that did not exceed regulatory standards.
- Significant smoke was identified from local or regional wildfire incidents.

Table 78 summarizes the evidence and exclusion narratives for the five exclusion dates.

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Table 78. Exclusion dates and event summaries.

Exclusion Date(s)	Event Summary
June 16, 2024	An upper-level trough of low pressure enhanced atmospheric mixing and strengthened low-level southwesterly winds to allow for regional transport of smoke from wildfires in southern California on the exclusion day. Enhancements of $PM_{2.5}$ and CO concentrations, camera images, and back trajectory analysis confirm the presence of smoke from these fires at the surface in Clark County. Statistics show pollutant concentrations, including ozone, were atypical due to this event.
July 9-12, 2024	Regional transport of smoke from multiple large wildfires across the western U.S. coincided with an enhancement in $PM_{2.5}$ in Clark County during the exclusion days. A weak surface pressure gradient produced calm-to-light winds during much of the four-day period, which reduced dispersion and allowed smoke to be gradually transported into and linger in the region. Statistics show ozone and other pollutant concentrations were atypical, webcam images confirm the presence of smoke, and trajectory analysis substantiates transport.

Exclusion Date(s)	Event Summary
July 15-17, 2024	Regional transport of smoke from numerous large fires in western Canada and southern California was carried by a clockwise aloft wind pattern and aided by light surface winds during the exclusion days. Co-emitted pollutants and $PM_{2.5}$-to-PM_{10} ratios were enhanced, indicating smoke impacts. Camera images confirm the trajectory analyses indicating smoke reaching the surface. Statistics show pollutant concentrations, including ozone, were atypical due to this event.
July 24-25, 2024	Regional transport of smoke from wildfires in California and numerous wildfires in Canada, Alaska, and the Pacific Northwest led to enhancement in $PM_{2.5}$ concentrations during the exclusion days. Trajectory and meteorological analysis confirm transport and enhancement in surface pollutants, and camera images, satellite imagery, and surface smoke modeling all corroborate the transport of smoke in the Clark County area. Statistics show pollutant concentrations, including ozone, were atypical due to this event.
September 6, 2024	Regional transport of smoke from a wildfire in eastern Nevada and several "megafires" in Oregon and Idaho coincides with $PM_{2.5}$ and $PM_{2.5}$-to-PM_{10} ratios above the 90th percentile on the exclusion day. A shallow morning temperature inversion trapped ozone precursors and yielded hazy skies, which was confirmed by camera images and local NWS forecast discussions. Trajectory analysis confirms transport of smoke to the surface. Statistics show pollutant concentrations, including ozone, were atypical due to this event.

Based on the evidence provided, we formally request exclusion of the aforementioned dates in base and projected ozone design values.