ATTACHMENT I:

Wildfire Atypical Events Analyses

Wildfire Atypical Event Analysis for Ozone Attainment Demonstration State Implementation Plan (SIP)

Final Report Prepared for

U.S. EPA Region 9
San Francisco, CA

November 2023

STi | Sonoma Technology

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Wildfire Atypical Event Analysis for Ozone Attainment Demonstration State Implementation Plan (SIP)

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Cover graphic shows visibility images taken from the M Resort Hotel in Clark County, Nevada, during the exceptional event on August 7, 2021. Visibility images are available in real-time from Clark County DES here: https://bit.ly/408P7yD.

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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.

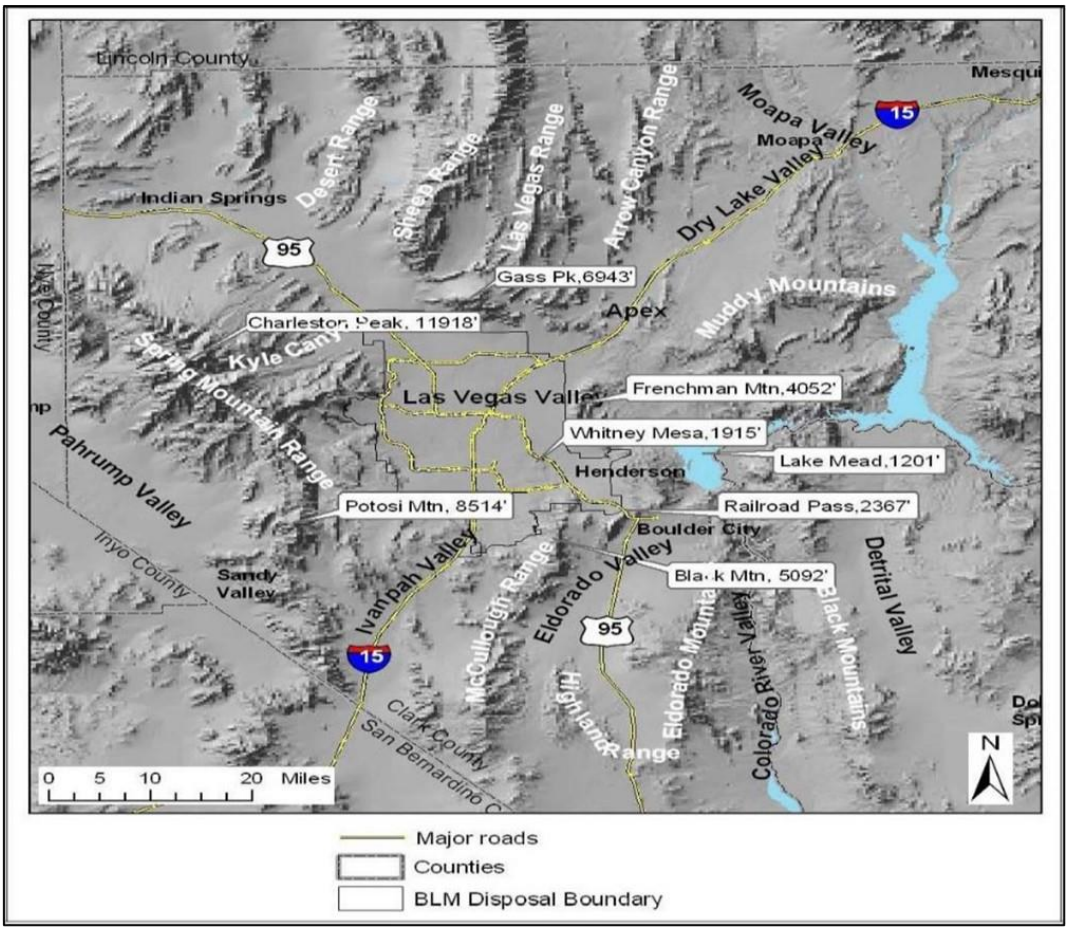

Figure 1. Mountain ranges and hydrographic areas surrounding the Las Vegas Valley.

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.

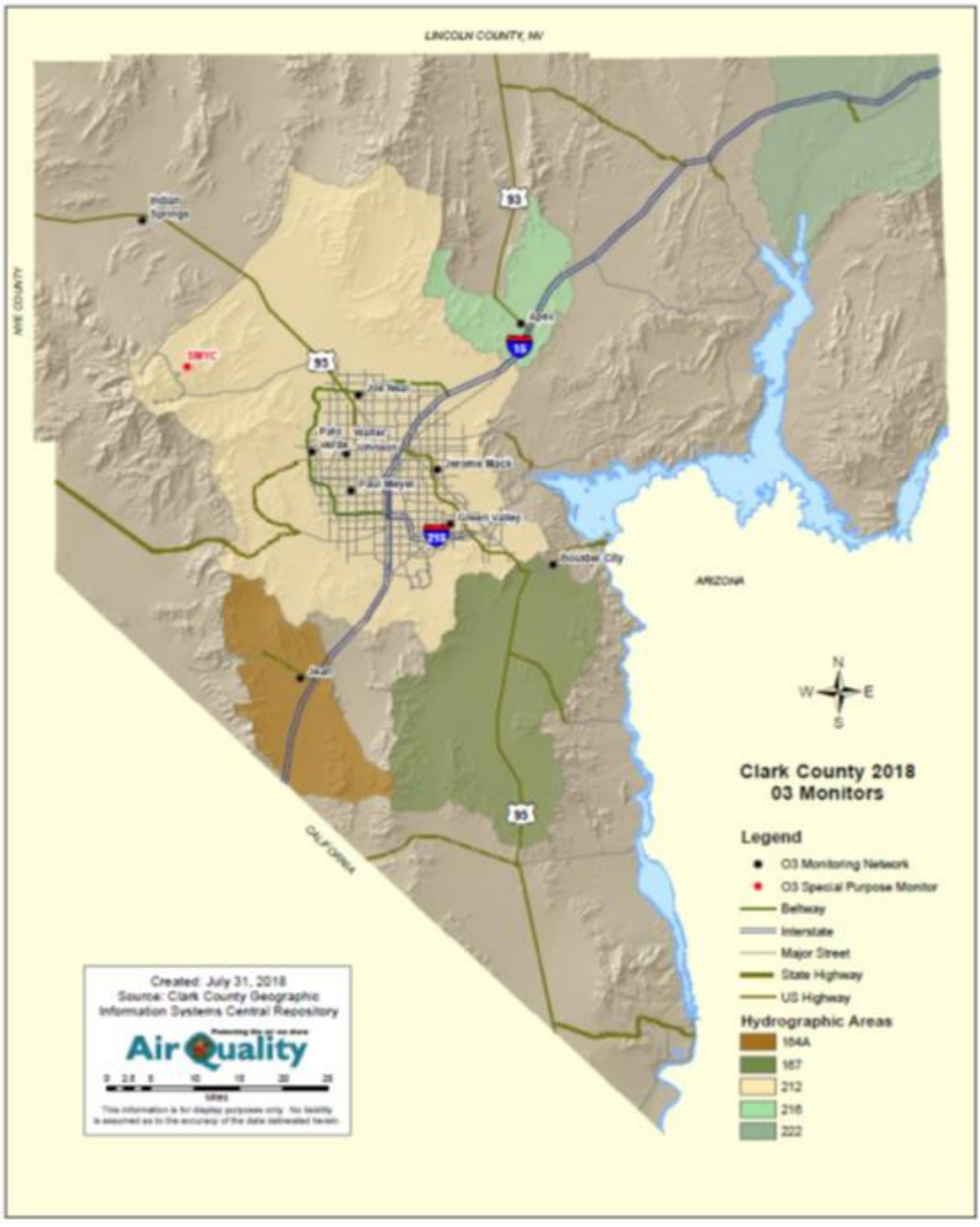

Figure 2. Map of Clark County showing the 2018 ozone monitoring network, hydrographic areas, and major roadways.

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.

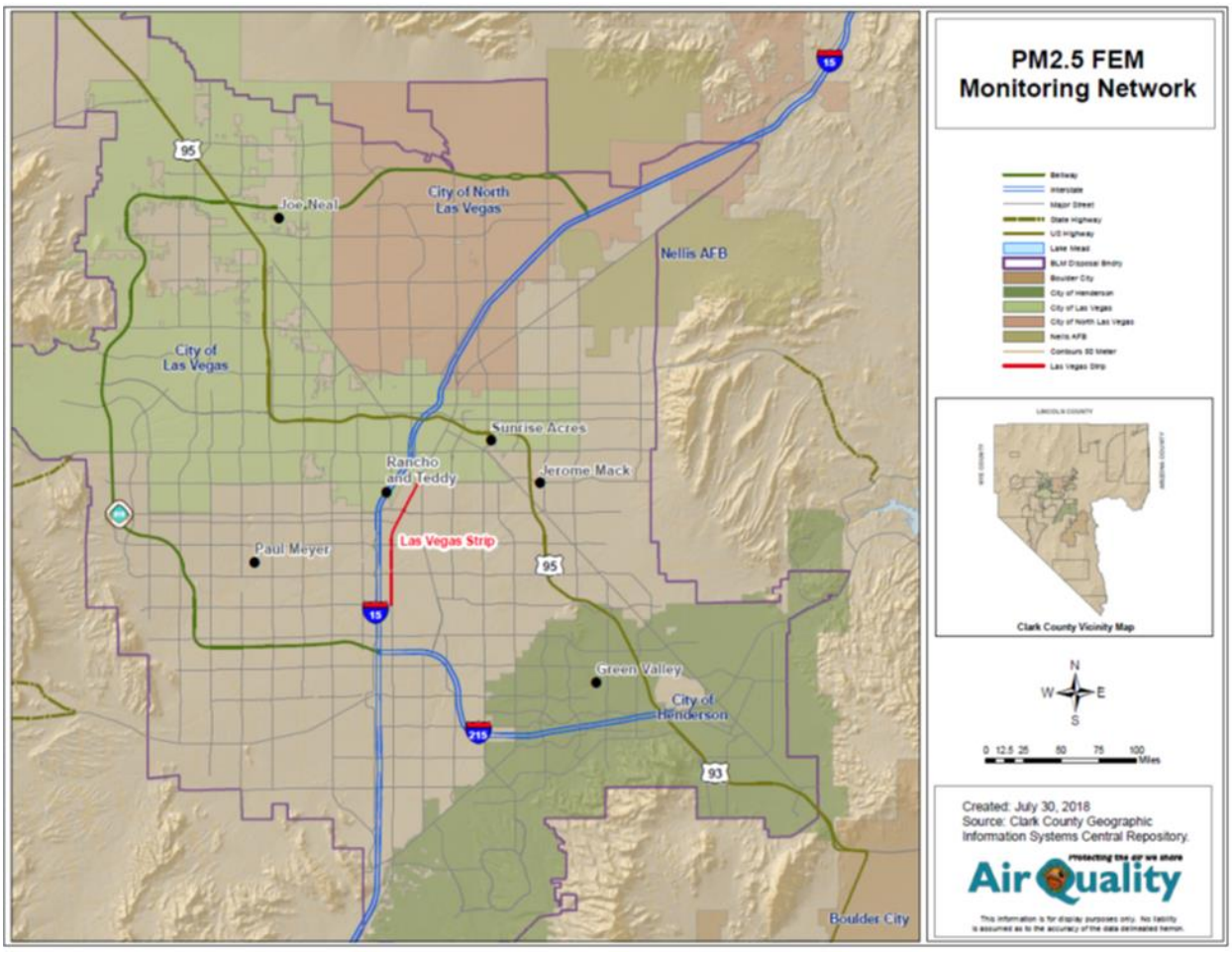

Figure 3. Locations of FEM $PM_{2.5}$ monitors within the LVV in 2018. The Jean FEM monitor (not shown) is located well south of the valley along I-15 (see Figure 2).

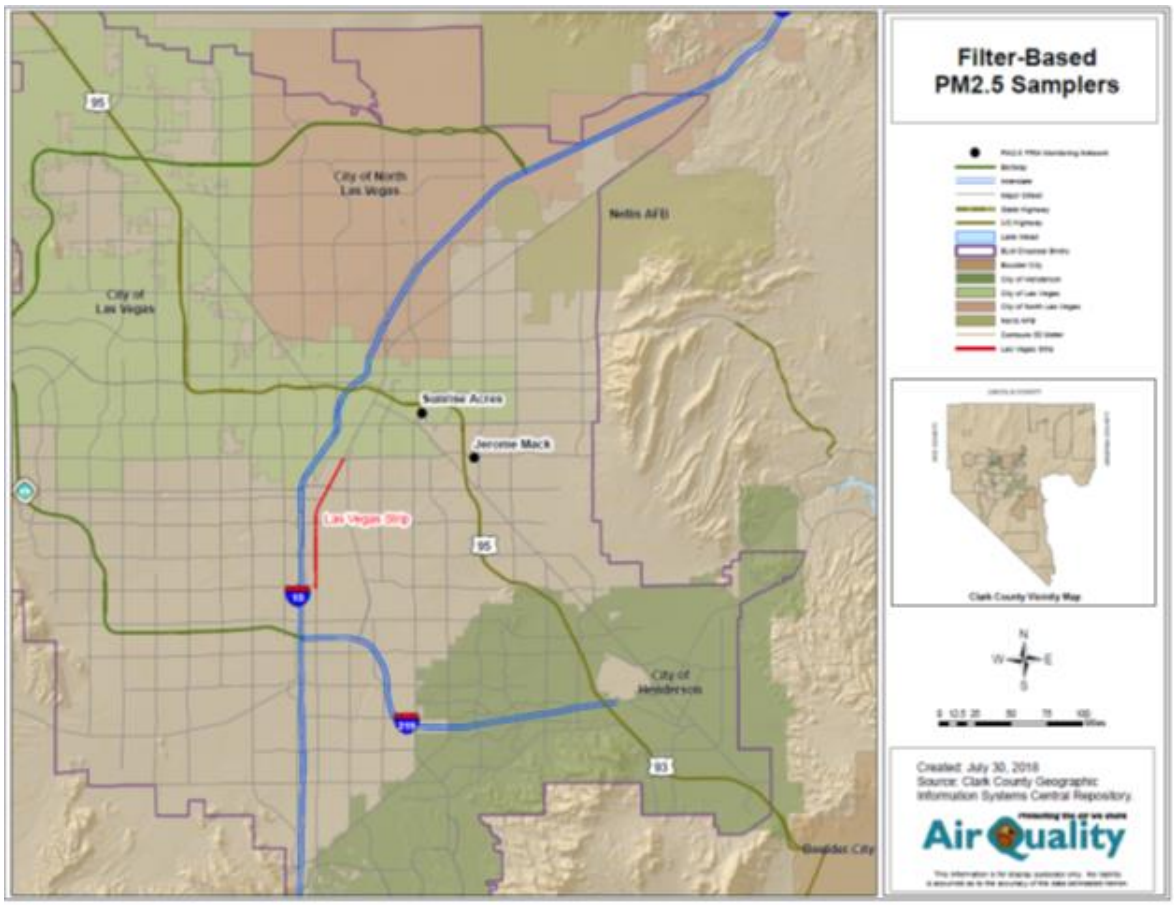

Figure 4. Locations of FRM $PM_{2.5}$ monitors within the LVV in 2018.

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.

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

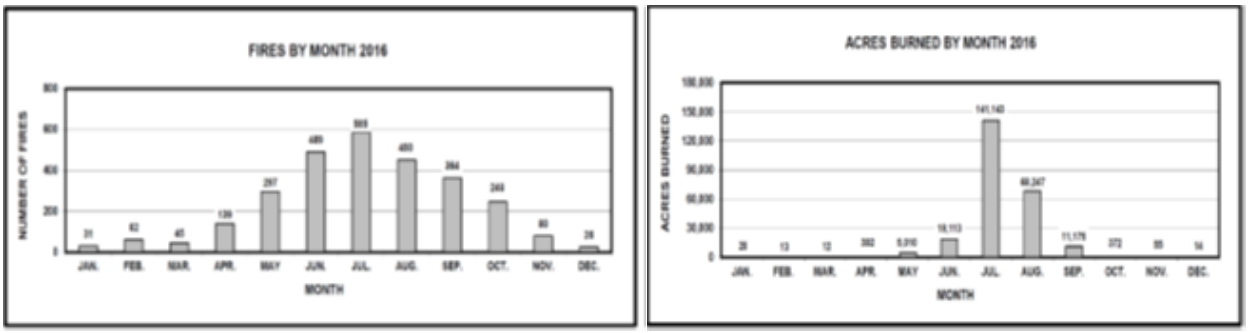

Figure 5. Number of fires and acres burned by month in 2016 (CAL FIRE, reference).

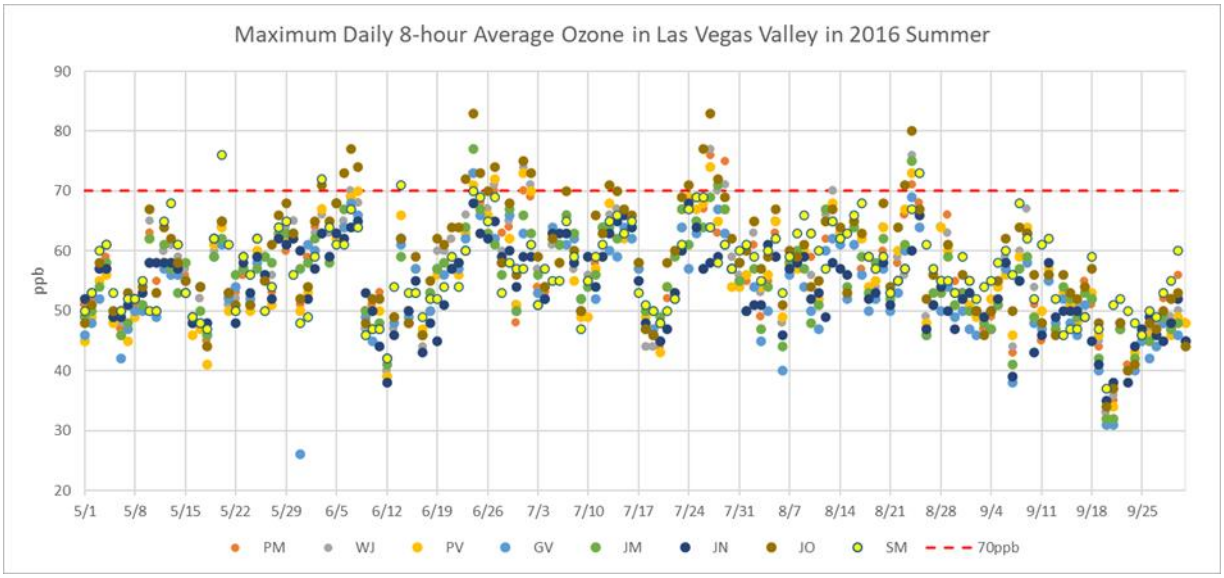

Figure 6. MDA8 ozone (ppb) at LVV monitors during the 2016 ozone season.

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.

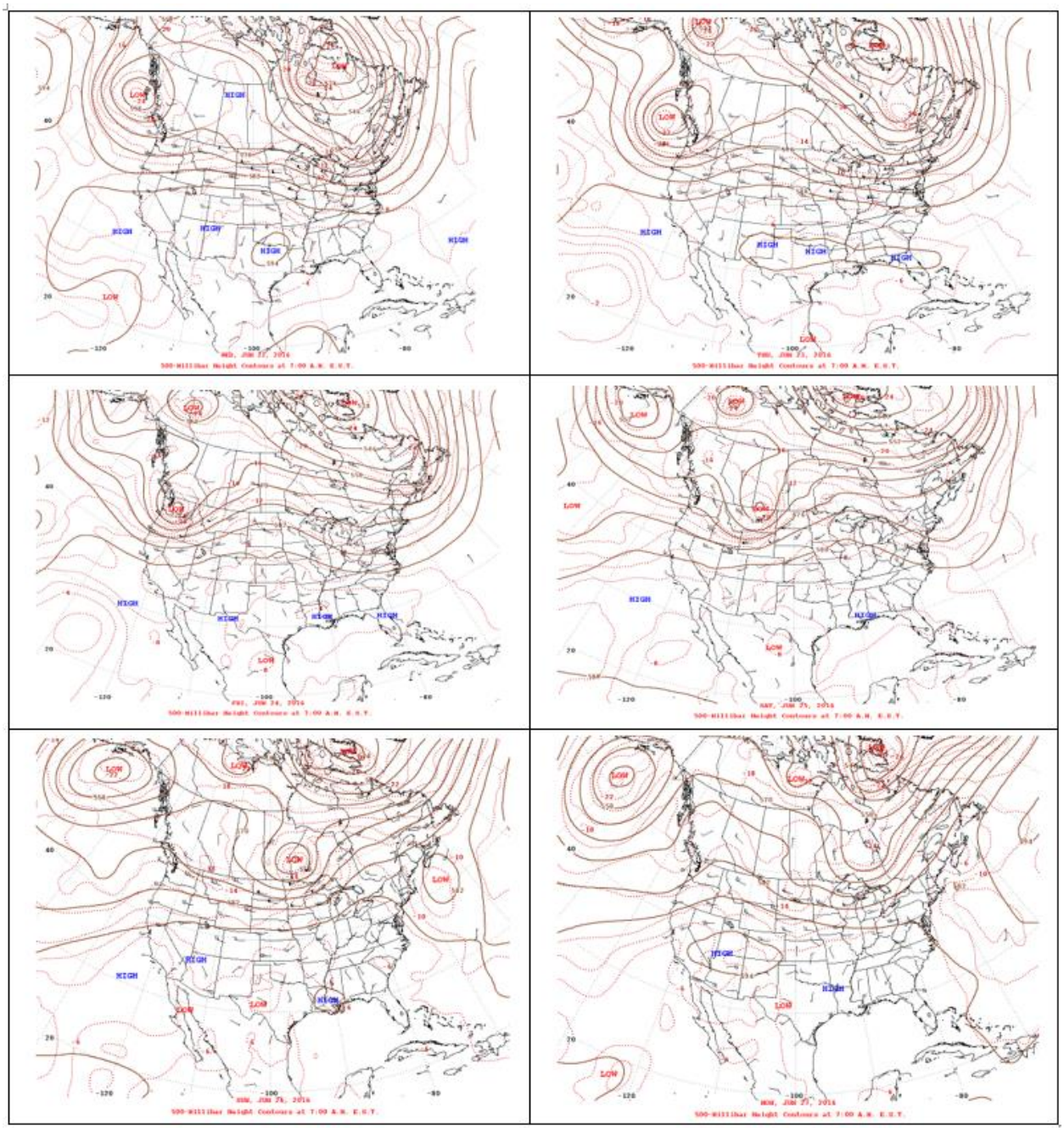

Figure 8. 500 hPa (approximately 5,500 m) weather patterns at 07:00 EST (04:00 PST) from June 22 to 27, 2016.

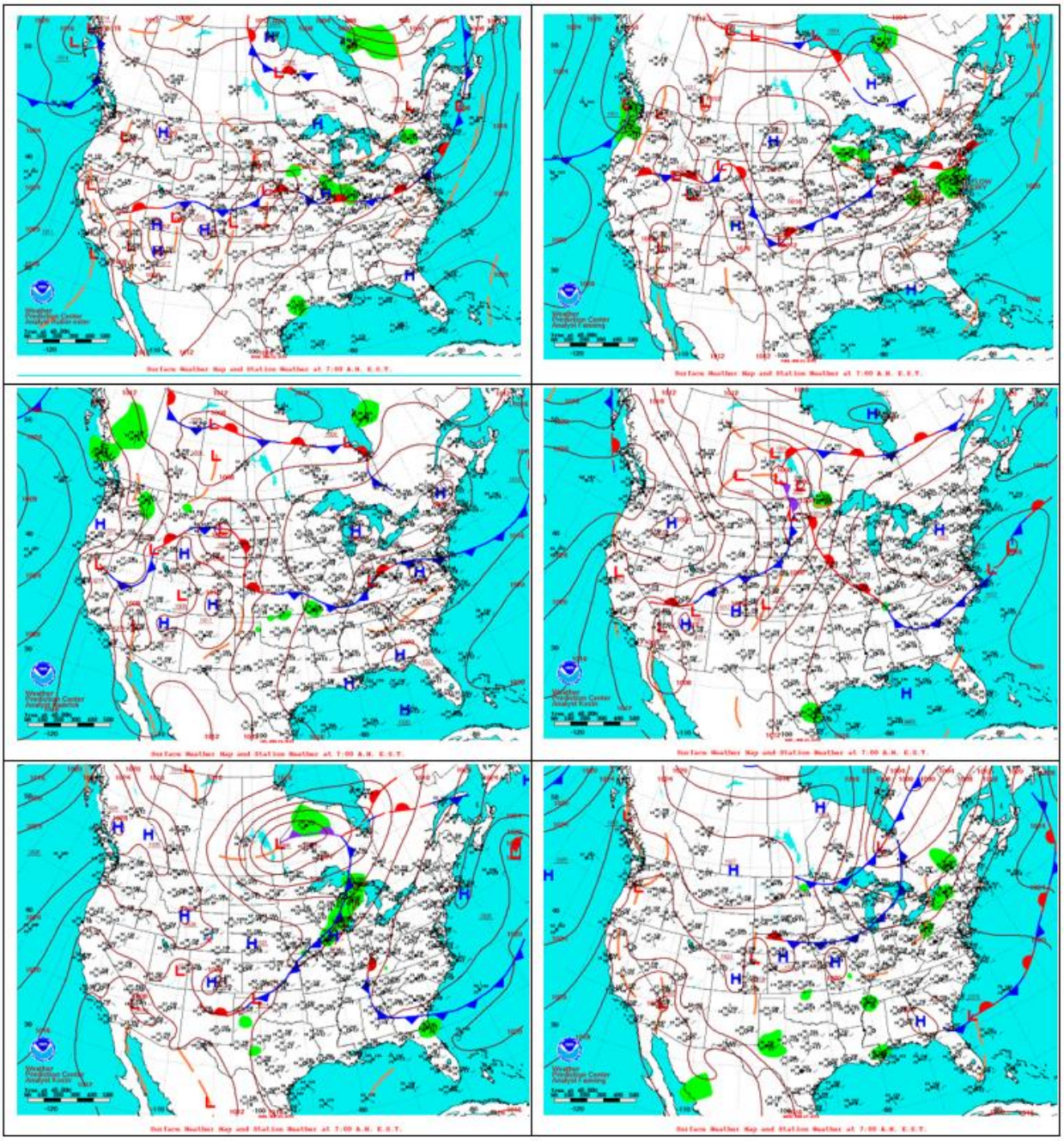

Figure 9. Surface weather patterns at 07:00 EST (04:00 PST) from June 22 to 27, 2016.

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 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.

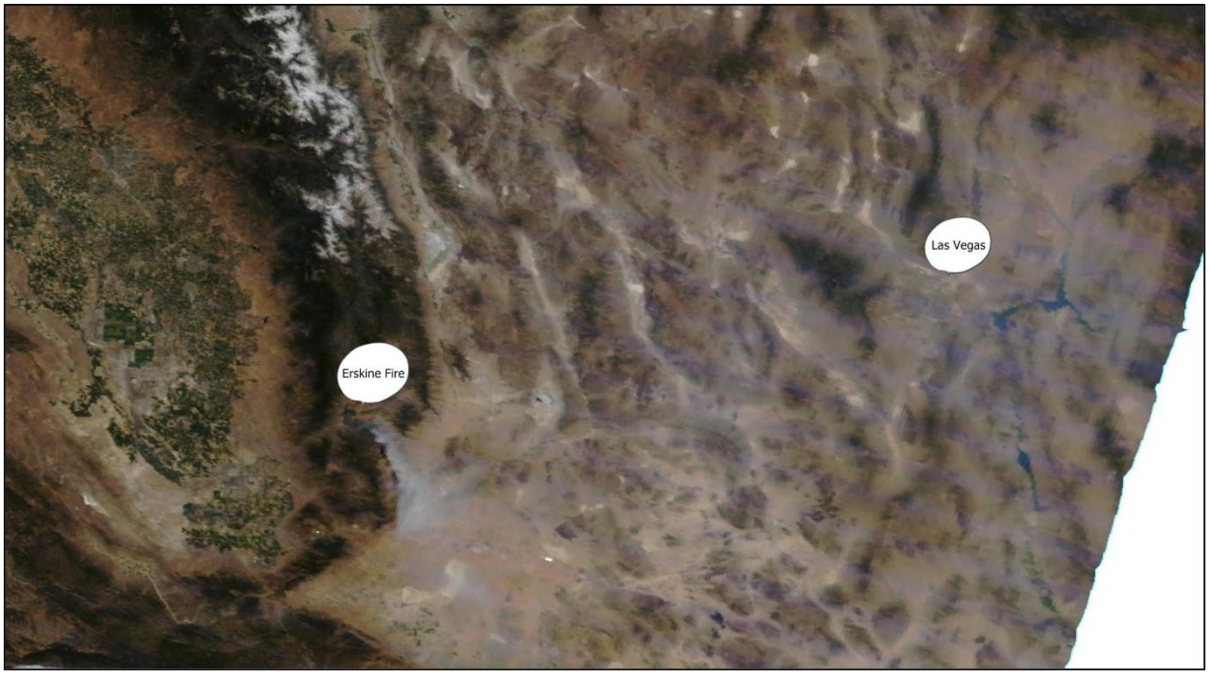

Figure 10. Visible satellite imagery of southern California and Nevada on June 24, 2016.

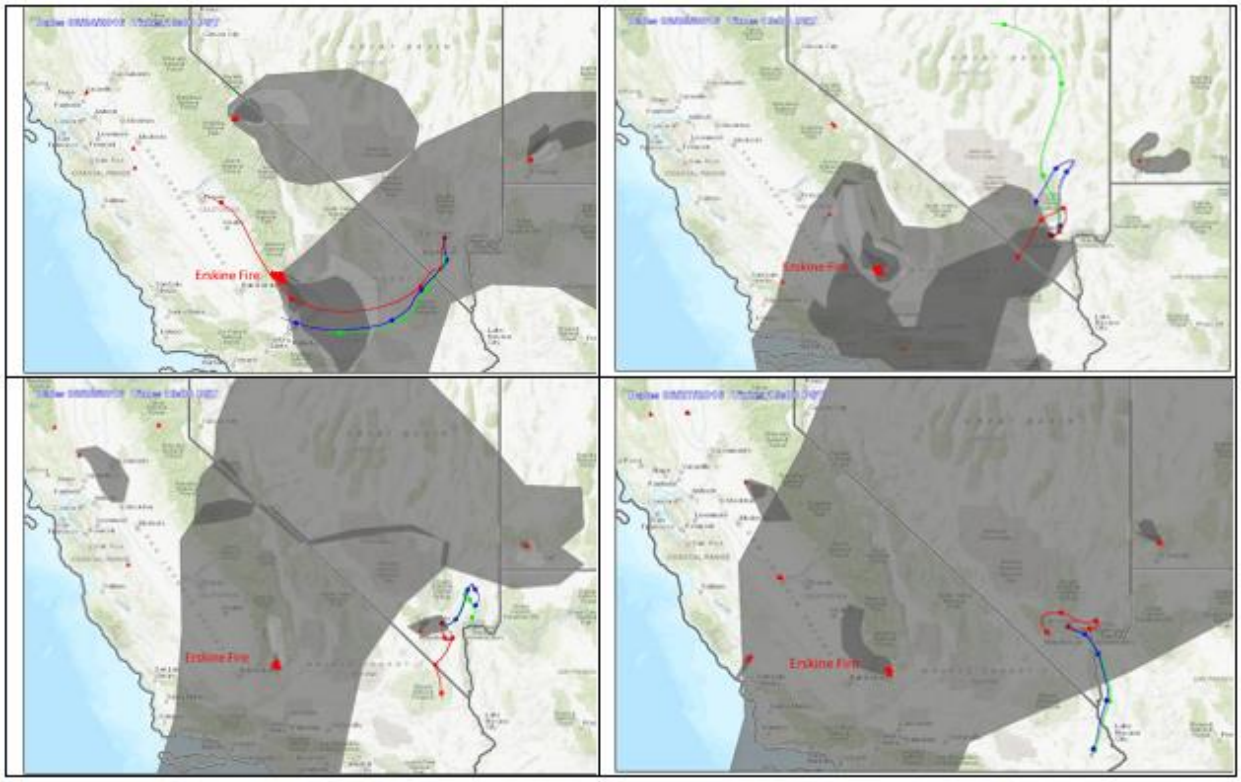

Figure 11. 24-hr backward trajectories arriving in Las Vegas at 13:00 PST on June 24-27, 2016, at altitudes of 20 m (green), 200 m (blue), and 2,000 m (red).

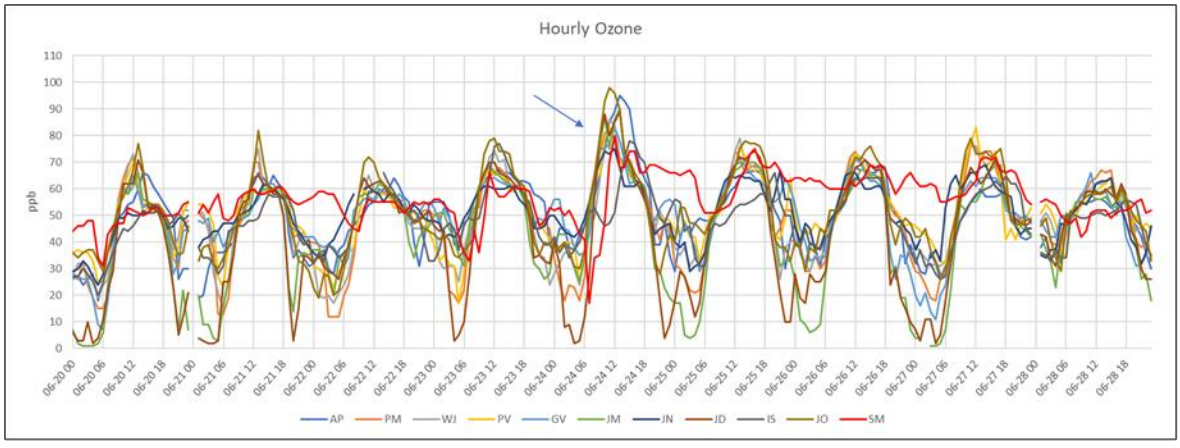

Figure 12. Time series of 1-hr ozone (ppb) at all LVV monitors during June 20-28, 2016.

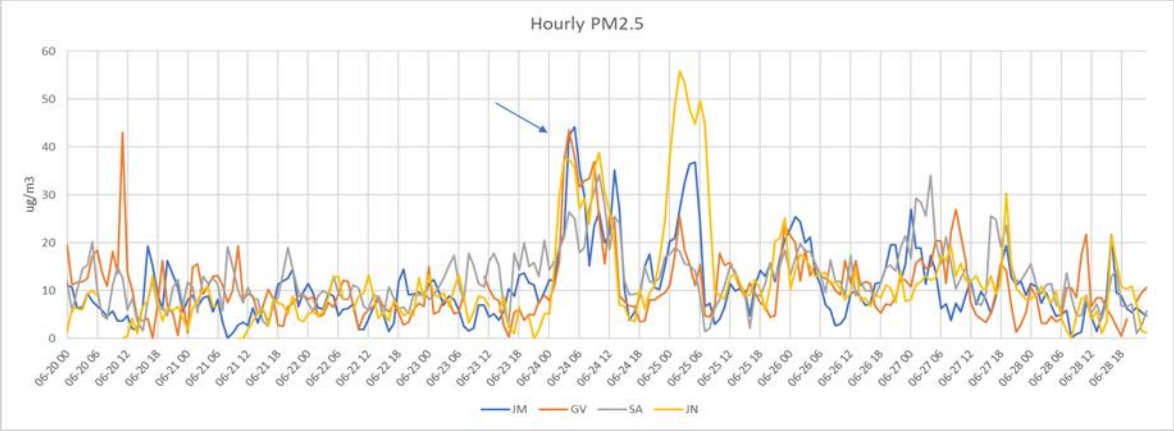

Figure 13. Time series of 1-hr $PM_{2.5}$ concentration (µg/m^3) at LVV FEM monitors during June 20-28, 2016.

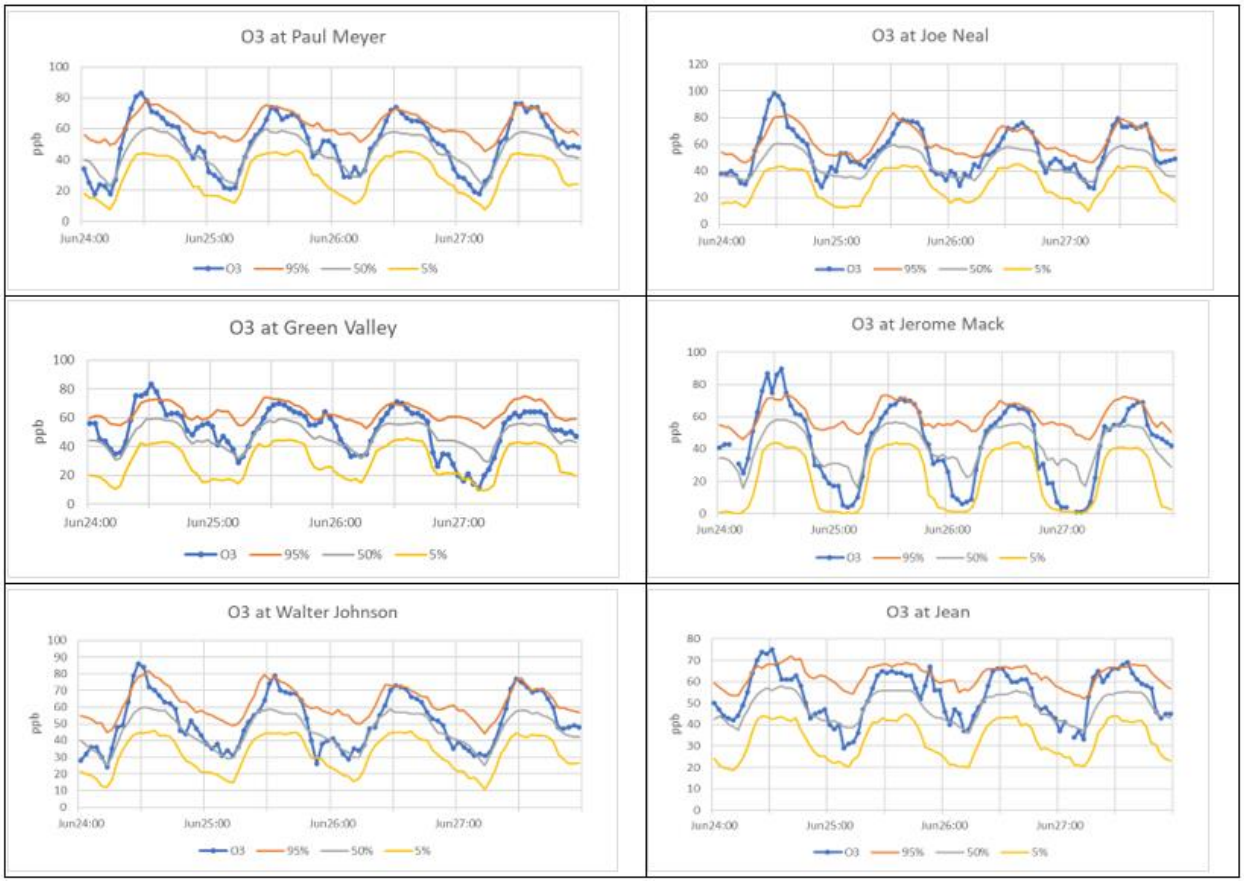

Figure 14. 6-yr hourly seasonal 95th, 50th, and 5th percentiles for ozone concentrations at the Paul Meyer, Joe Neal, Green Valley, Jerome Mack, Walter Johnson, and Jean monitoring sites during June 24-27, 2016.

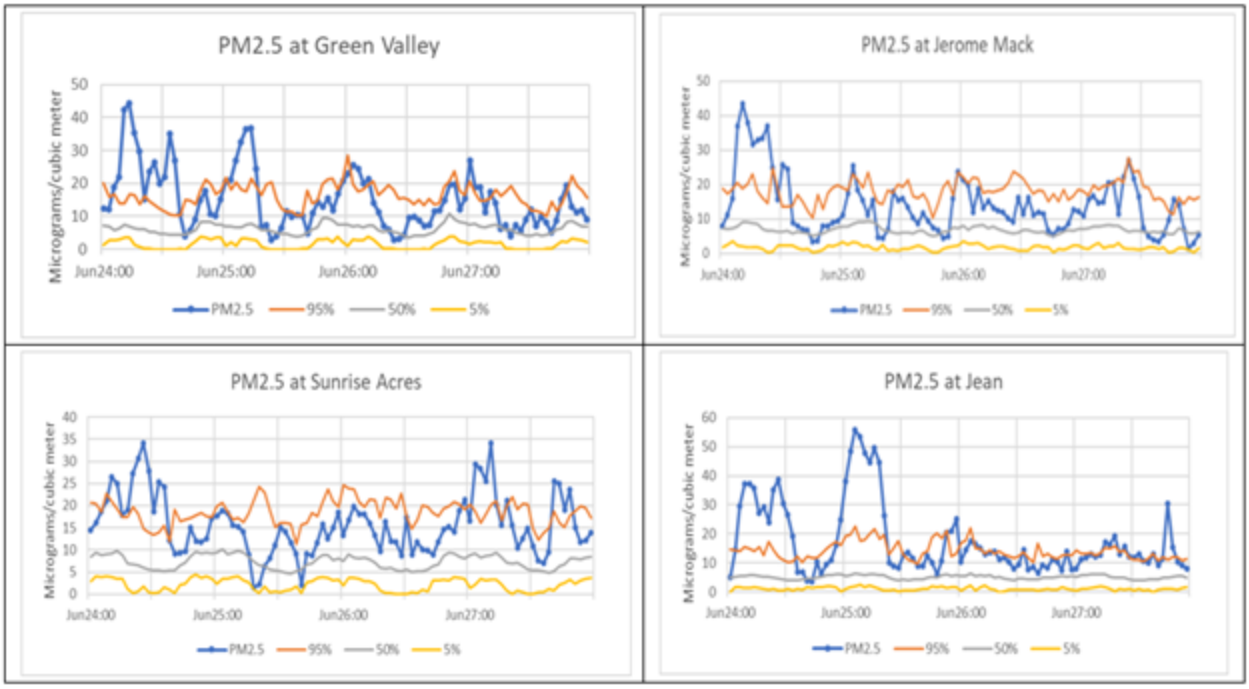

Figure 15. 6-yr hourly seasonal 95th, 50th, and 5th percentiles for $PM_{2.5}$ concentrations ($\mu g/m^3$) at LVV FEM monitors during June 24-27, 2016.

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.

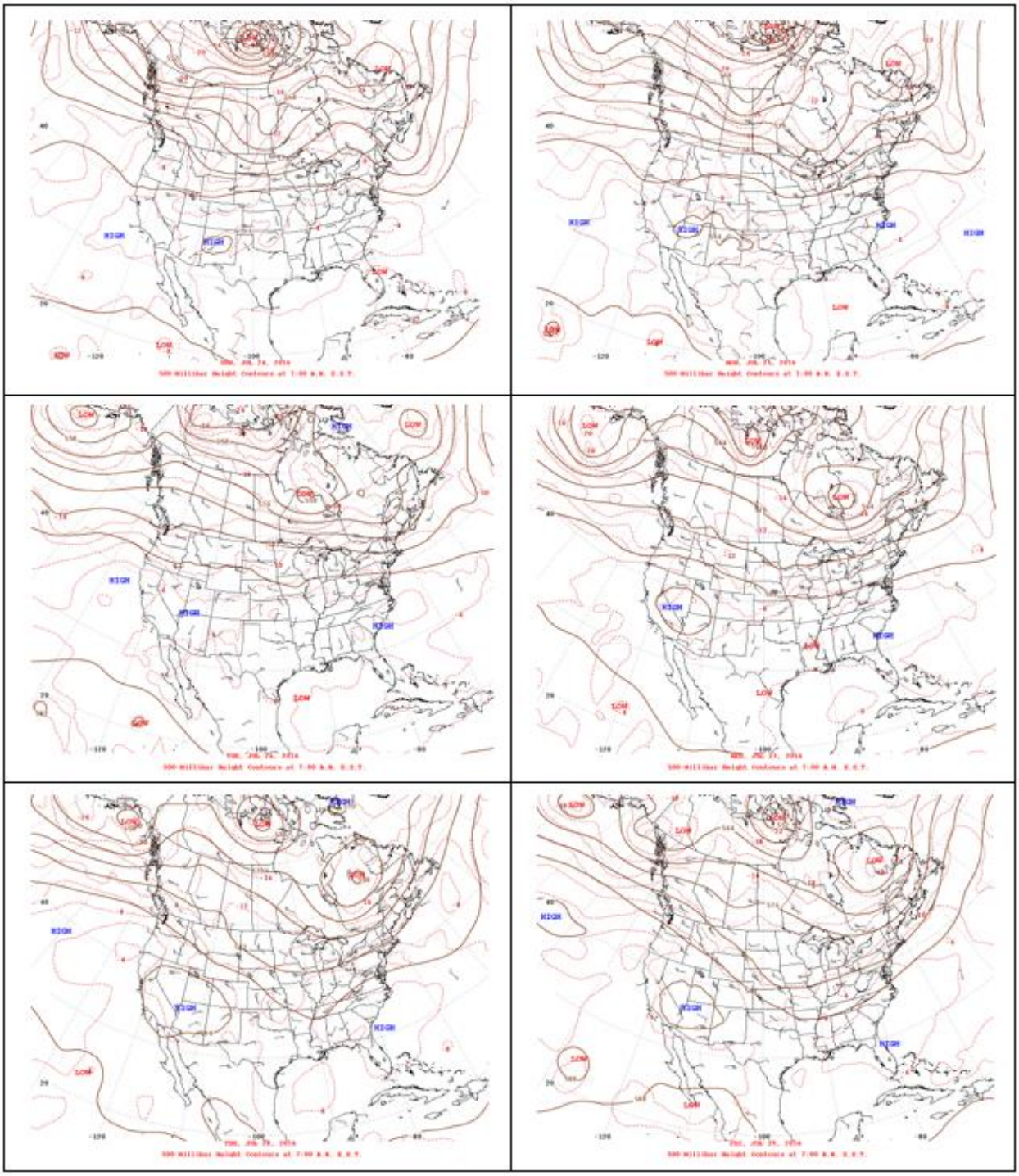

Figure 17. 500 hPa (approximately 5,500 m) weather patterns at 07:00 EST (04:00 PST) from July 24 to 29, 2016.

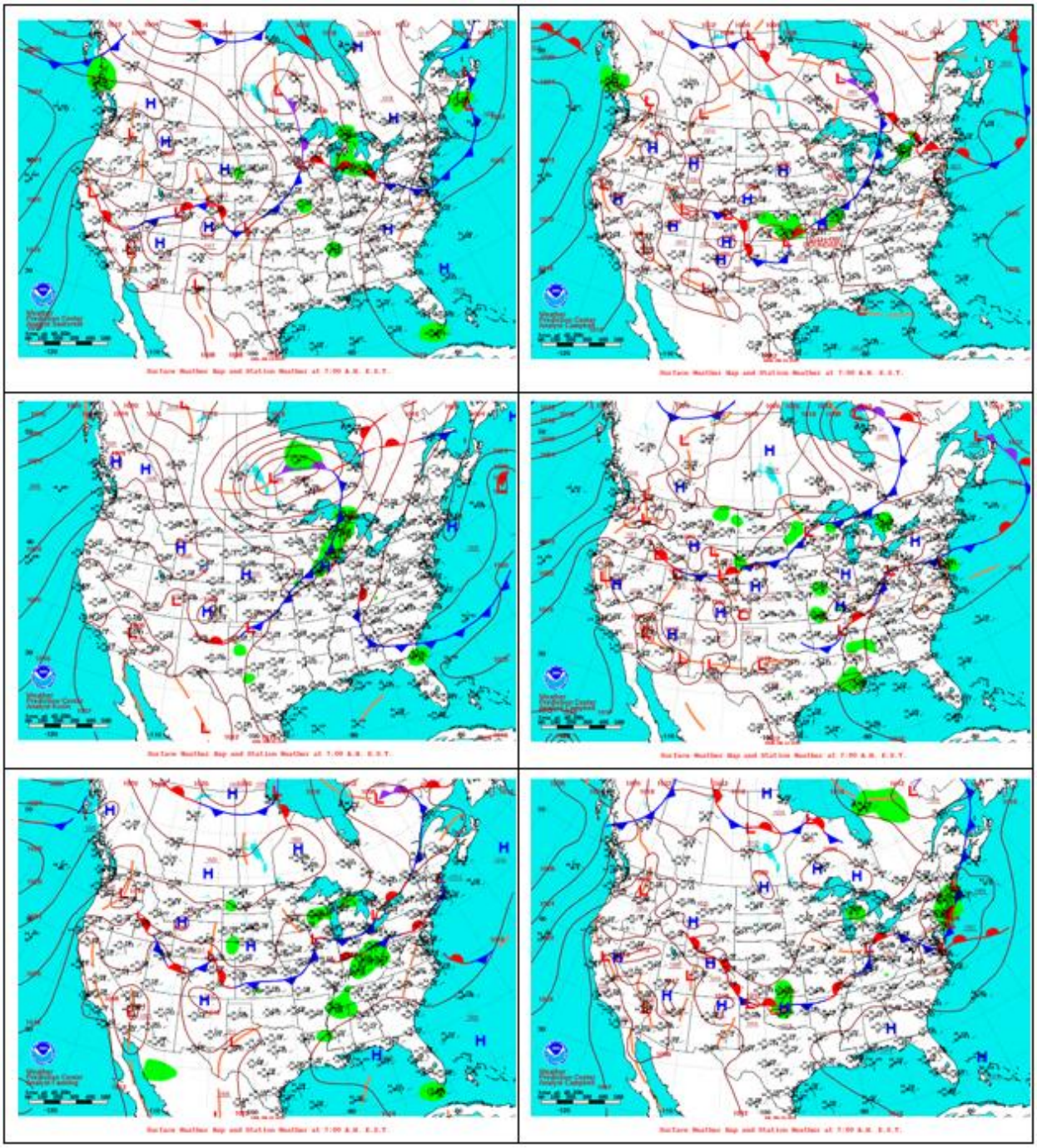

Figure 18. Surface weather patterns at 07:00 EST (04:00 PST) from July 24 to 29, 2016.

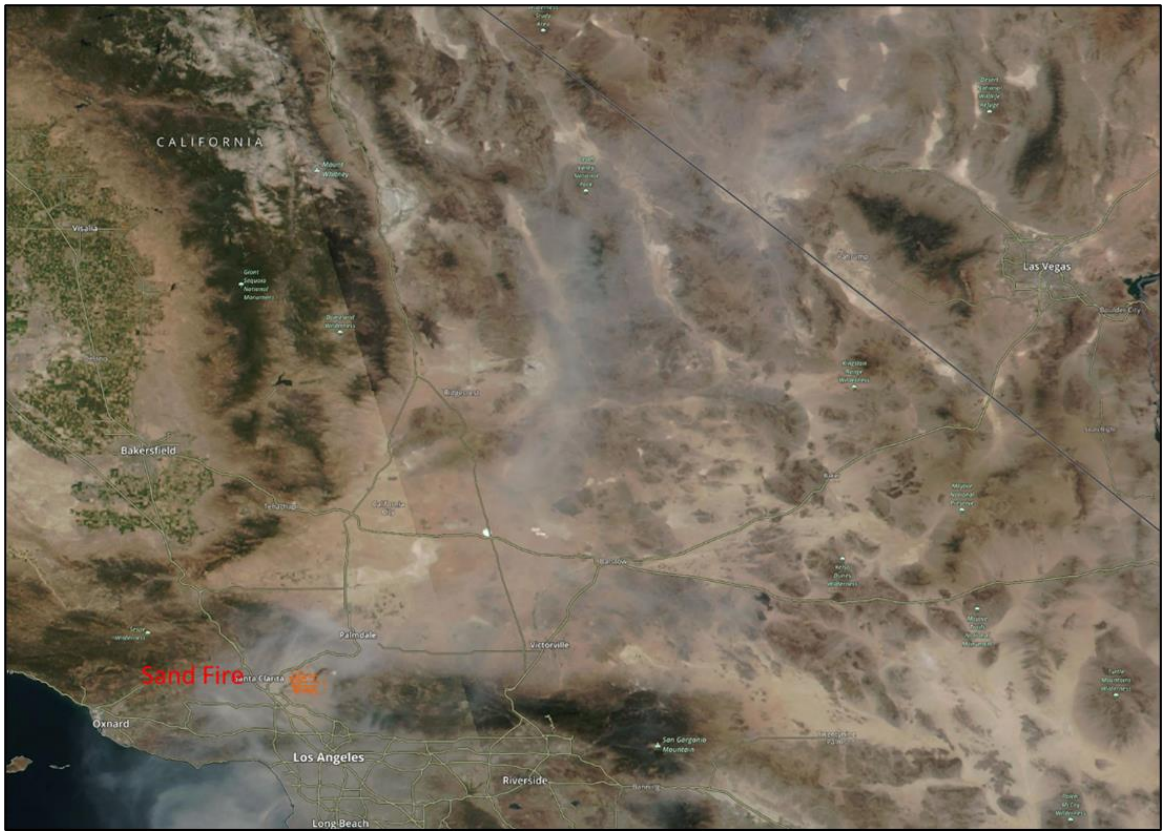

Figure 19. Visible satellite imagery of southern California and Nevada on July 23, 2016.

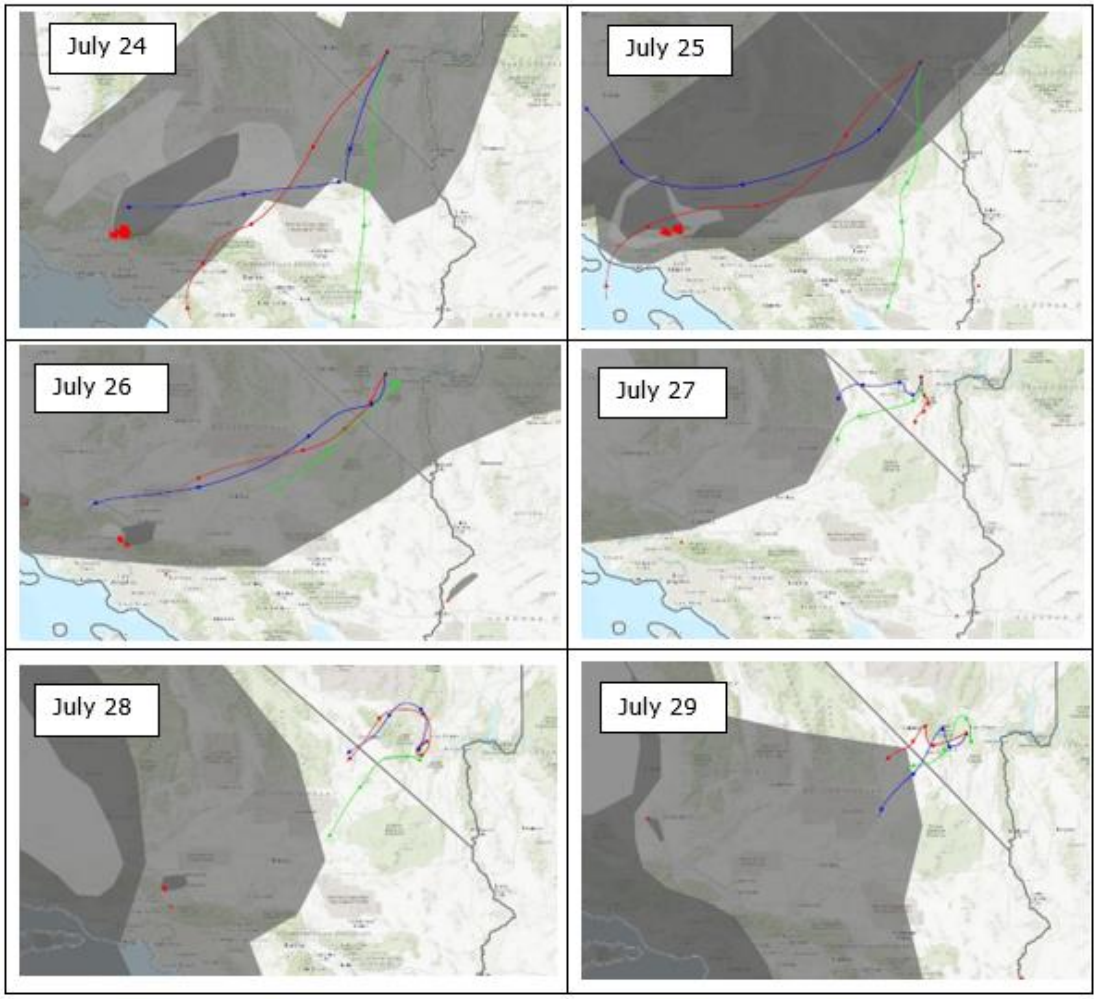

Figure 20. 24-hr backward trajectories arriving in Las Vegas at 13:00 PST on July 24-29, 2016, at altitudes of 100 m (green), 1,000 m (blue), and 2,000 m (red).

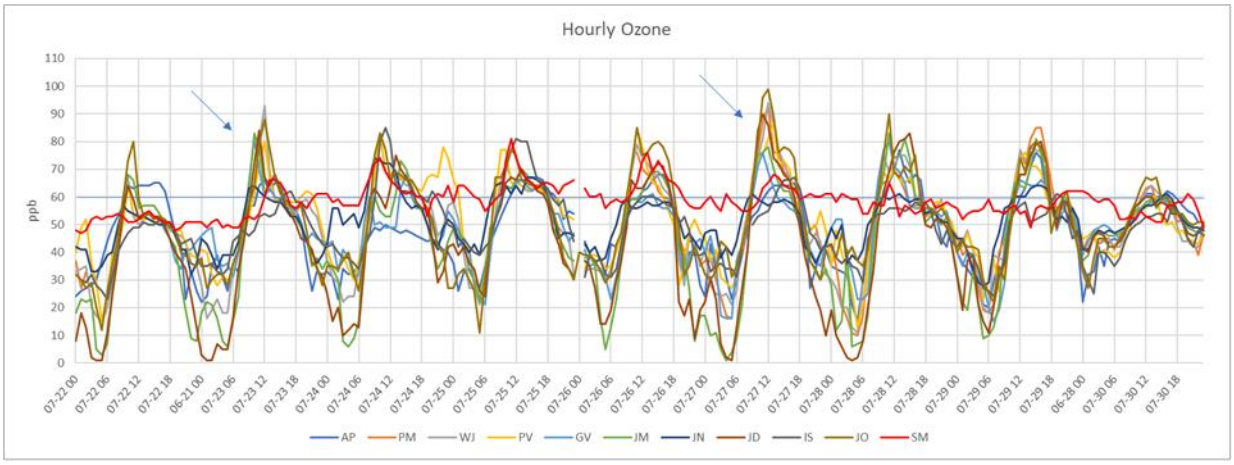

Figure 21. Time series of 1-hr ozone (ppb) at all Las Vegas Valley monitors during July 22-30, 2016.

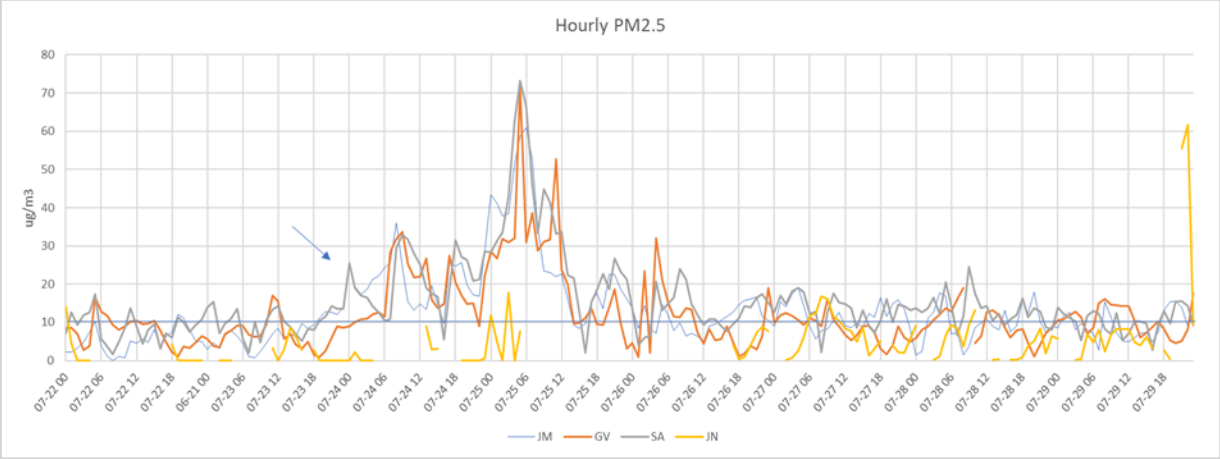

Figure 22. Time series of 1-hr $PM_{2.5}$ concentration (µg/m^3) at LVV FEM monitors during July 22-29, 2016.

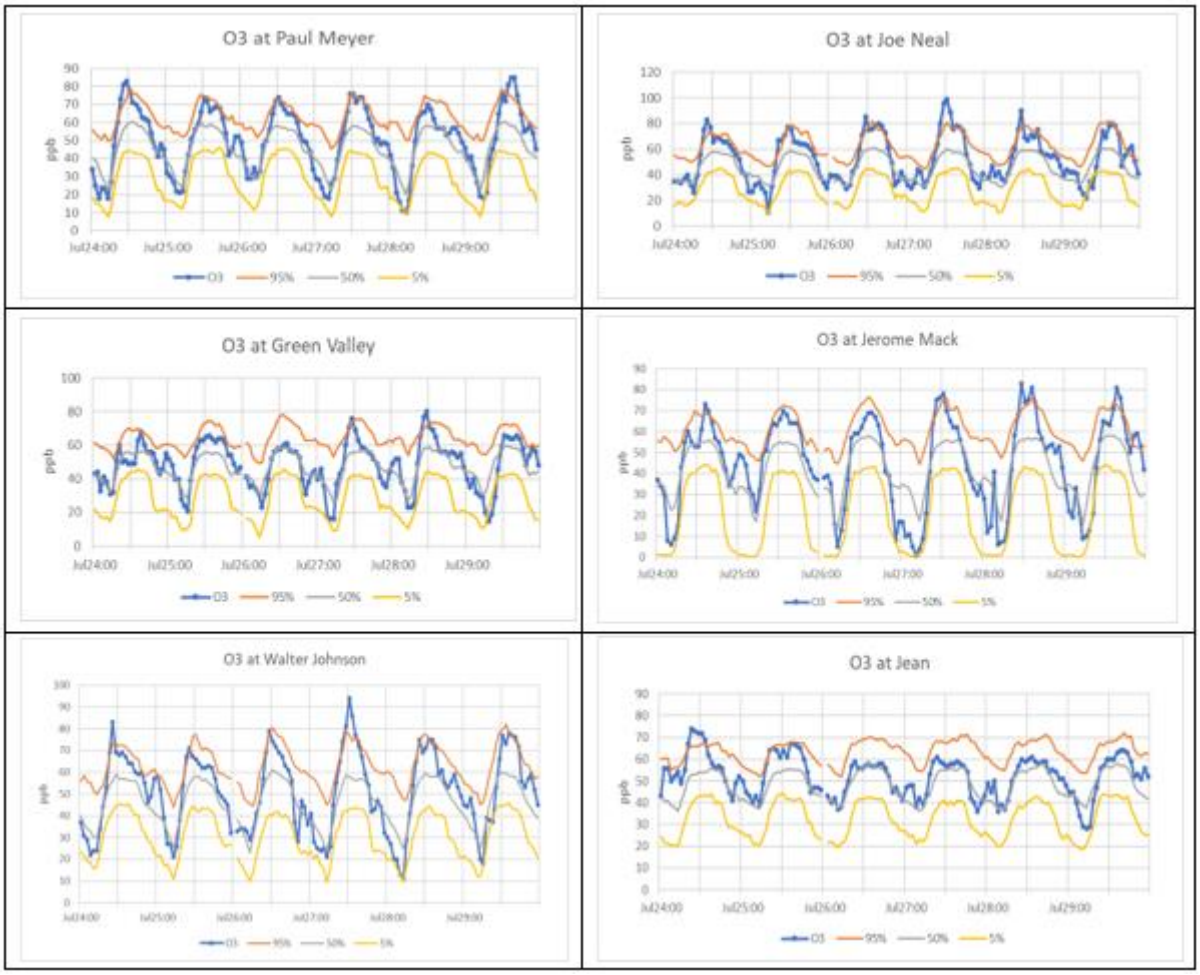

Figure 23. 6-yr hourly seasonal 95th, 50th, and 5th percentiles for ozone concentrations at the Paul Meyer, Joe Neal, Green Valley, Jerome Mack, Walter Johnson, and Jean monitoring sites during July 24-29, 2016.

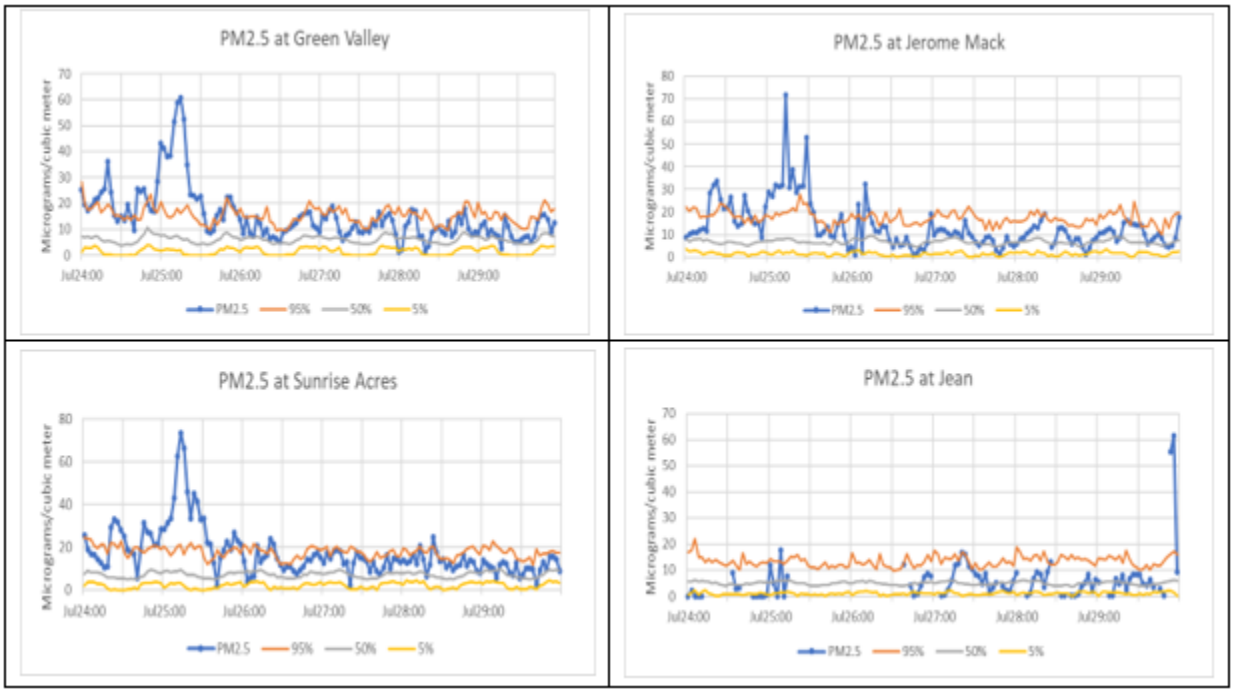

Figure 24. 6-yr hourly seasonal 95th, 50th, and 5th percentiles for $PM_{2.5}$ concentrations ($\mu g/m^3$) at LVV FEM monitors during July 24-29, 2016.

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.

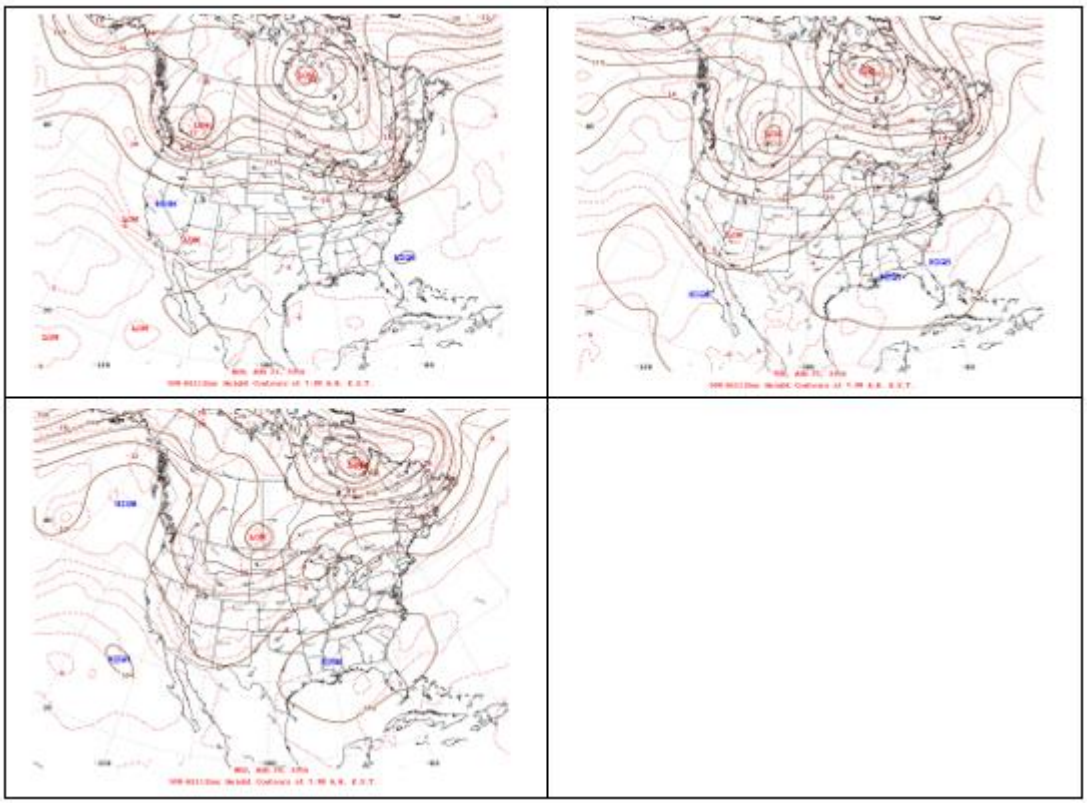

Figure 26. 500 hPa (approximately 5,500 m) weather patterns at 07:00 EST (04:00 PST) from August 22 to 24, 2016.

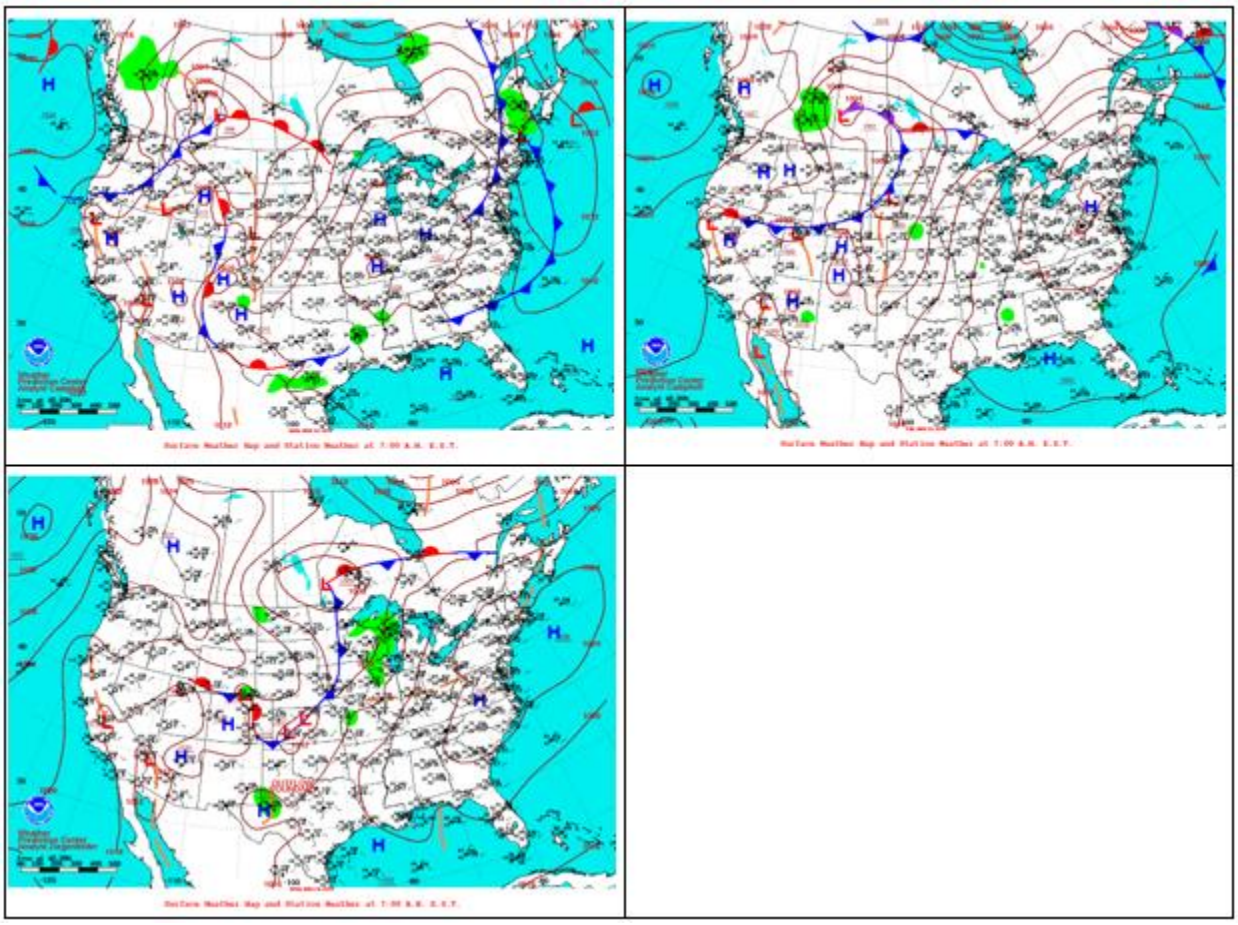

Figure 27. Surface weather patterns at 07:00 EST (04:00 PST) from August 22 to 24, 2016.

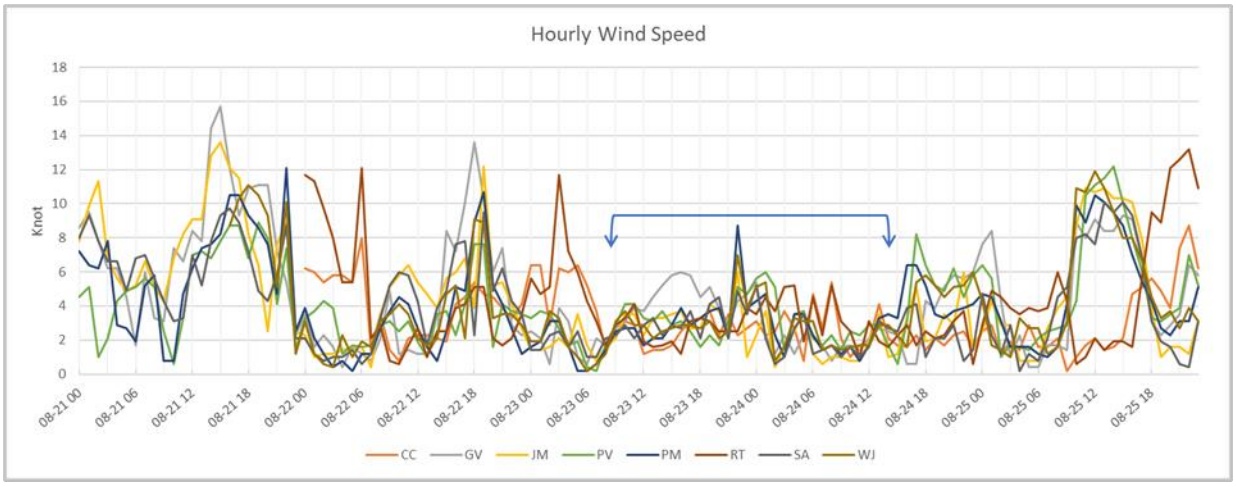

Figure 28. Time series of 1-hr wind speed (knots) at all monitors in the LVV from August 21 to 25, 2016.

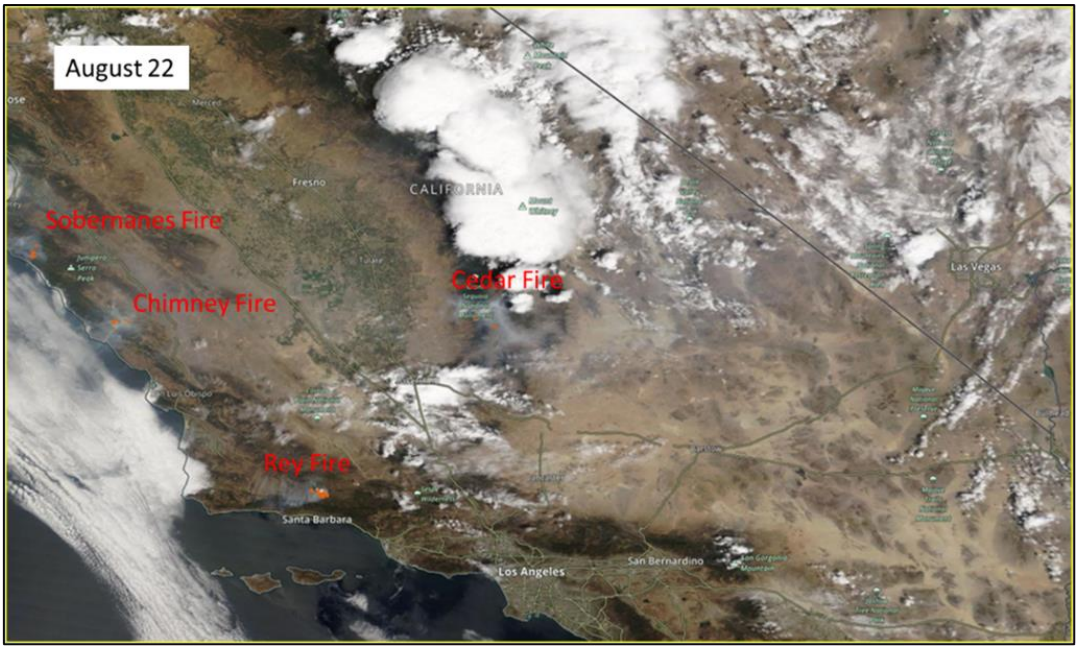

Figure 29. Visible satellite imagery of Central and Southern California and Nevada on August 22, 2016.

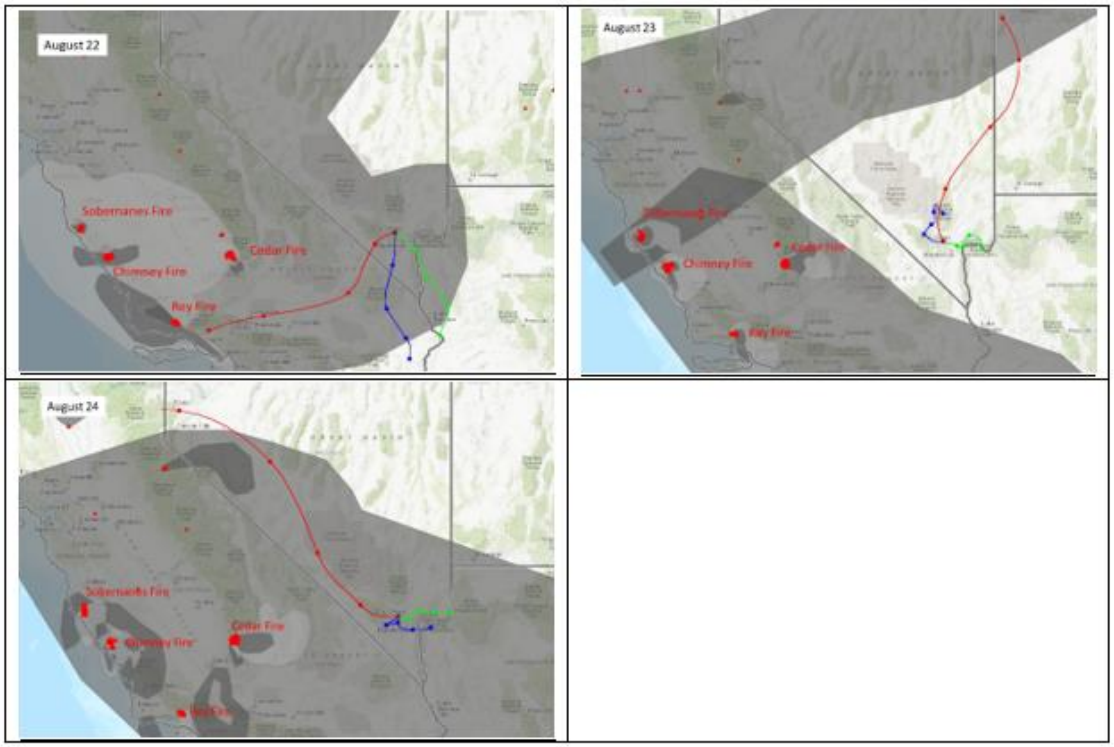

Figure 30. 24-hr backward trajectories arriving in Las Vegas at 13:00 PST on August 22-24, 2016, at altitudes of 100 m (green), 1,000 m (blue), and 2,000 m (red).

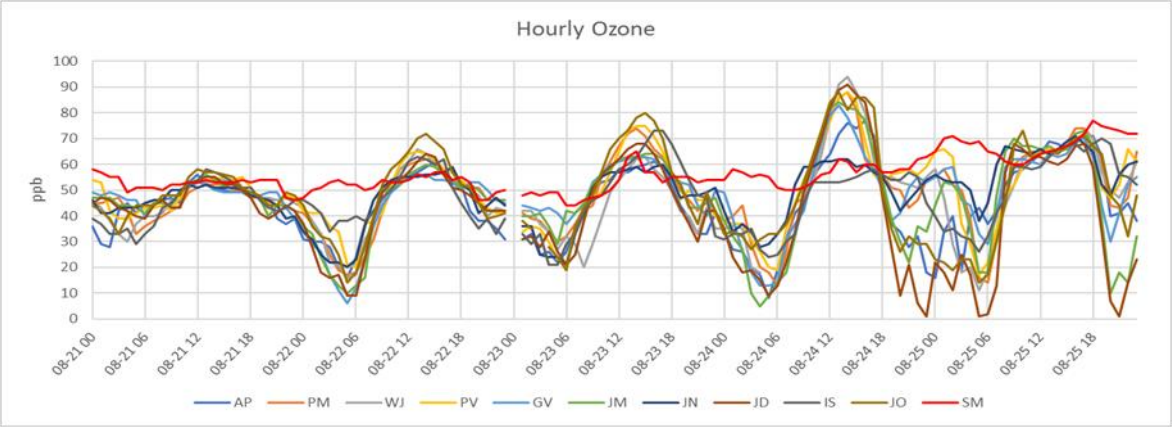

Figure 31. Time series of 1-hr ozone (ppb) at all LVV monitors during August 21-25, 2016.

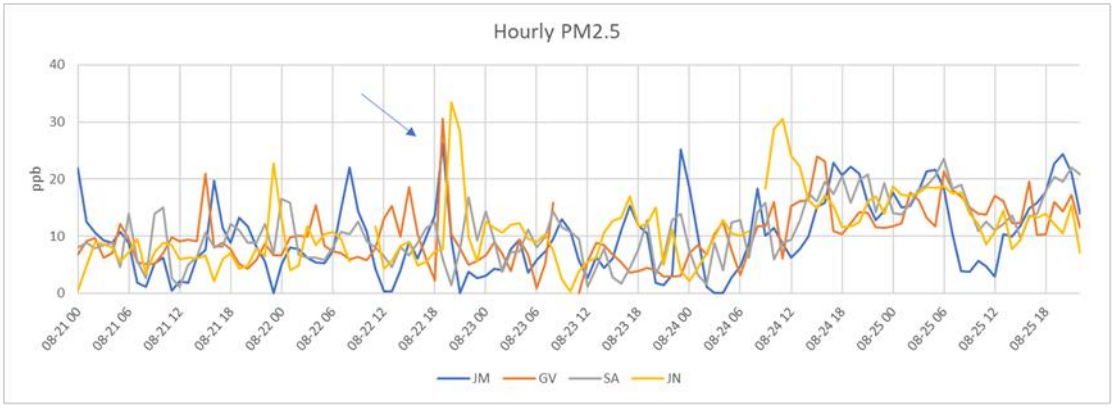

Figure 32. Time series of 1-hr $PM_{2.5}$ concentration ($\mu g/m^3$) at LVV FEM monitors during August 21-25, 2016.

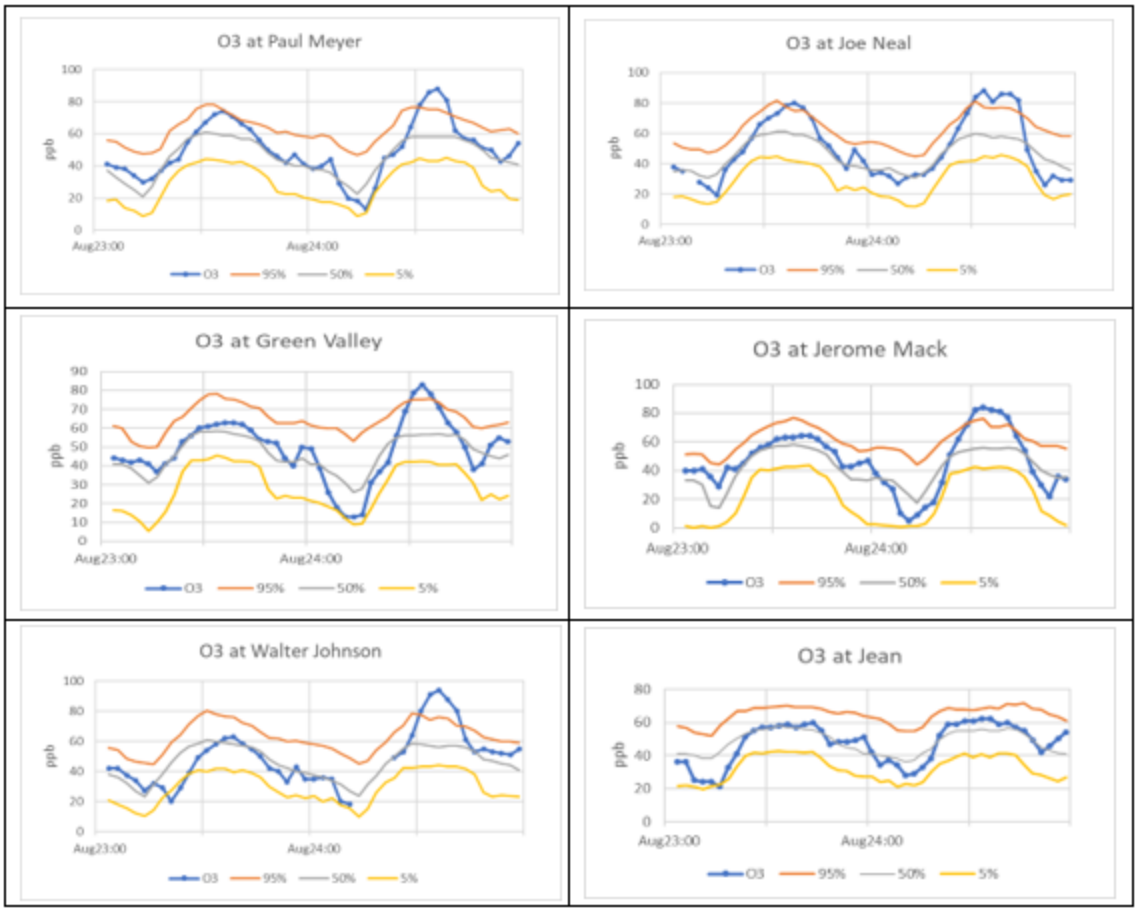

Figure 33. 6-yr hourly seasonal 95th, 50th, and 5th percentiles for ozone concentrations at the Paul Meyer, Joe Neal, Green Valley, Jerome Mack, Walter Johnson, and Jean monitoring sites during August 23-24, 2016.

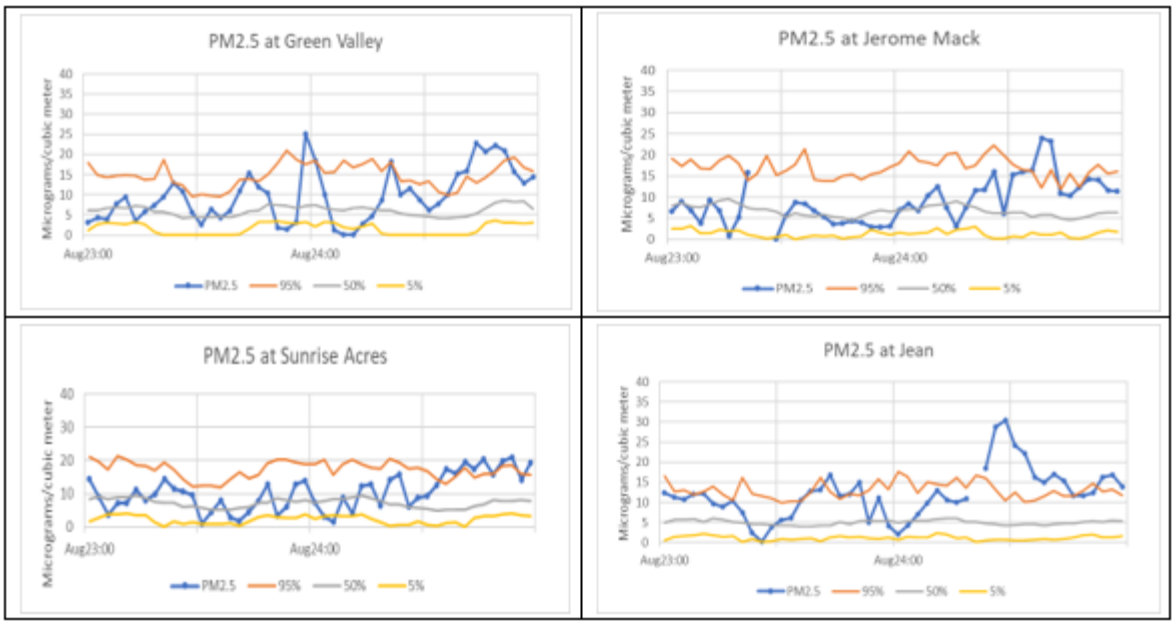

Figure 34. 6-yr hourly seasonal 95th, 50th, and 5th percentiles for $PM_{2.5}$ concentrations ($\mu g/m^3$) at LVV FEM monitors during August 23-24, 2016.

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.

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/Environmental%20Sustainability/Exceptional%20Events/20180623_ClarkCounty_Wildfire_EE.pdf **Appendices:** https://www.clarkcountynv.gov/Environmental%20Sustainability/Exceptional%20Events/20180623_ClarkCounty_Wildfire_EE_Appendix.pdf
June 27, 2018	**Main Document:** https://www.clarkcountynv.gov/Environmental%20Sustainability/Exceptional%20Events/20180627_ClarkCounty_Wildfire_EE.pdf **Appendices:** https://www.clarkcountynv.gov/Environmental%20Sustainability/Exceptional%20Events/20180627_ClarkCounty_Wildfire_EE_Appendix.pdf
July 14-17, 2018	**Main Document:** https://www.clarkcountynv.gov/Environmental%20Sustainability/Exceptional%20Events/20180714-17_ClarkCounty_Wildfire_EE.pdf **Appendices:** https://www.clarkcountynv.gov/Environmental%20Sustainability/Exceptional%20Events/20180714-17_ClarkCounty_Wildfire_EE_Appendix.pdf
July 25-27, 2018	**Main Document:** https://www.clarkcountynv.gov/Environmental%20Sustainability/Exceptional%20Events/20180725-27_ClarkCounty_Wildfire_EE.pdf **Appendices:** https://www.clarkcountynv.gov/Environmental%20Sustainability/Exceptional%20Events/20180725-27_ClarkCounty_Wildfire_EE_Appendix.pdf
July 30-31, 2018	**Main Document:** https://www.clarkcountynv.gov/Environmental%20Sustainability/Exceptional%20Events/20180730-31_ClarkCounty_Wildfire_EE.pdf **Appendices:** https://www.clarkcountynv.gov/Environmental%20Sustainability/Exceptional%20Events/20180730-31_ClarkCounty_Wildfire_EE_Appendix.pdf
August 6-7, 2018	**Main Document:** https://www.clarkcountynv.gov/Environmental%20Sustainability/Exceptional%20Events/20180806-07_ClarkCounty_Wildfire_EE.pdf **Appendices:** https://www.clarkcountynv.gov/Environmental%20Sustainability/Exceptional%20Events/20180806-07_ClarkCounty_Wildfire_EE_Appendix.pdf

3. 2020 Ozone Exceptional Events

Seven 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.

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/Environmental%20Sustainability/Exceptional%20Events/20200803_ClarkCounty_Wildfire_EE.pdf **Appendices:** https://www.clarkcountynv.gov/Environmental%20Sustainability/Exceptional%20Events/20200803_ClarkCounty_Wildfire_EE_Appendix.pdf
August 7, 2020	**Main Document:** https://www.clarkcountynv.gov/Environmental%20Sustainability/Exceptional%20Events/20200807_ClarkCounty_Wildfire_EE.pdf **Appendices:** https://www.clarkcountynv.gov/Environmental%20Sustainability/Exceptional%20Events/20200807_ClarkCounty_Wildfire_EE_Appendix.pdf
August 18-21, 2020	**Main Document:** https://www.clarkcountynv.gov/Environmental%20Sustainability/Exceptional%20Events/20200818-21_ClarkCounty_Wildfire_EE.pdf **Appendices:** https://www.clarkcountynv.gov/Environmental%20Sustainability/Exceptional%20Events/20200818-21_ClarkCounty_Wildfire_EE_Appendix.pdf
September 26, 2020	**Main Document:** https://www.clarkcountynv.gov/Environmental%20Sustainability/Exceptional%20Events/20200926_ClarkCounty_Wildfire_EE.pdf **Appendices:** https://www.clarkcountynv.gov/Environmental%20Sustainability/Exceptional%20Events/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

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 Mountains Edge Park	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, Mountains Edge Park, 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, Mountains Edge Park, 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 maximum daily 8-hr average (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**.

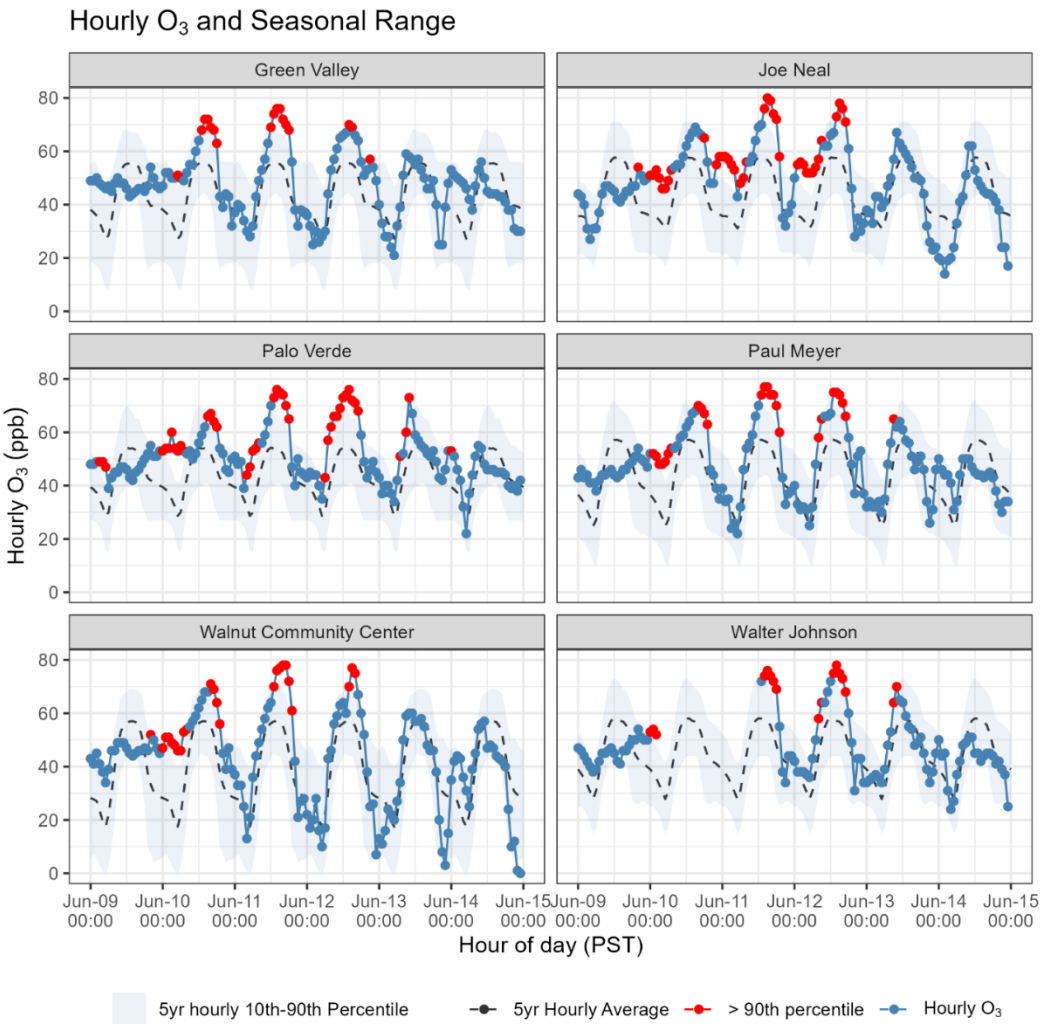

Figure 35. Hourly ozone concentrations (ppb) compared to 5-yr ozone season (May 1 – October 31) hourly means and 10-90th percentiles. Note: data from the Walnut Community Center site are only available for June 1 – October 31, 2021.

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).

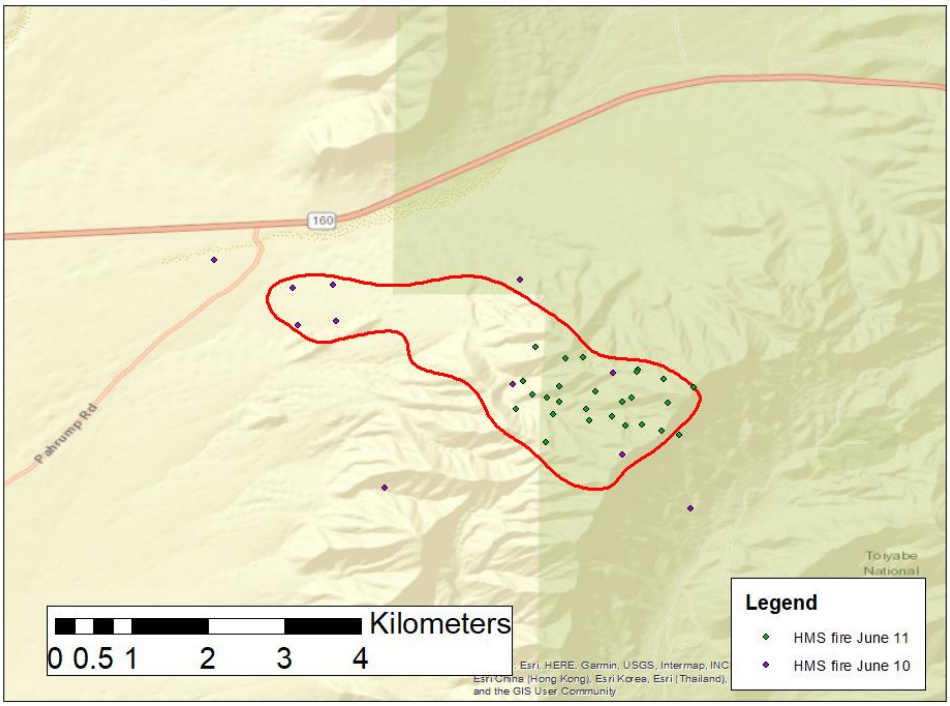

Figure 36. Sandy Valley Fire perimeter and active fire detections from June 10 and 11, 2021. From the National Oceanic and Atmospheric Administration (NOAA)'s Hazard Mapping System (HMS).

[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.

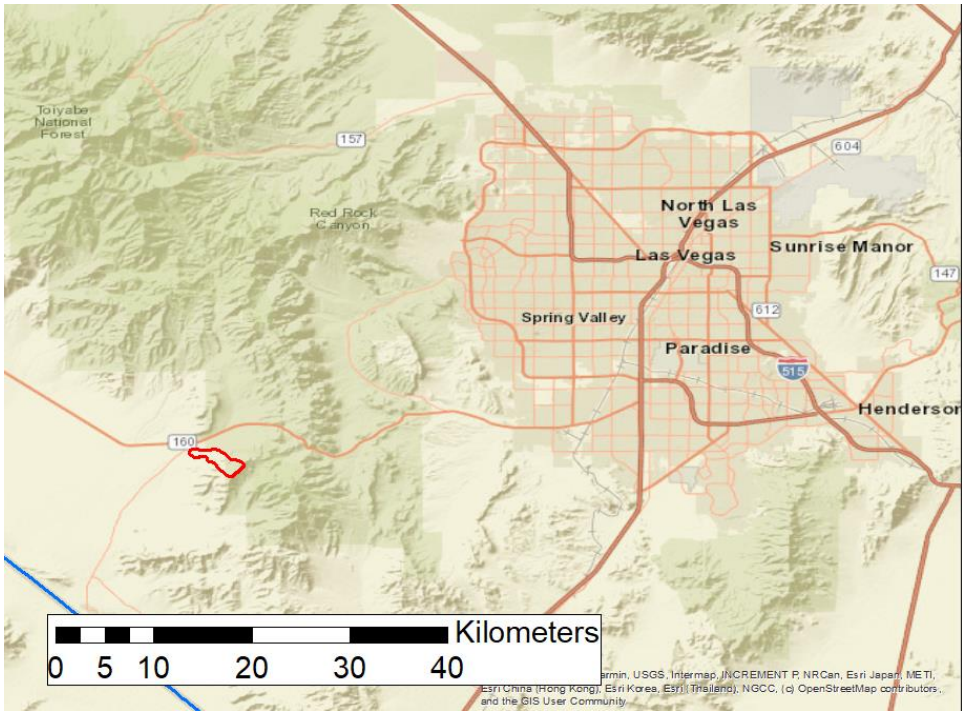

Figure 37. Sandy Valley Fire perimeter with HMS fire detections in proximity to Las Vegas, NV.

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.

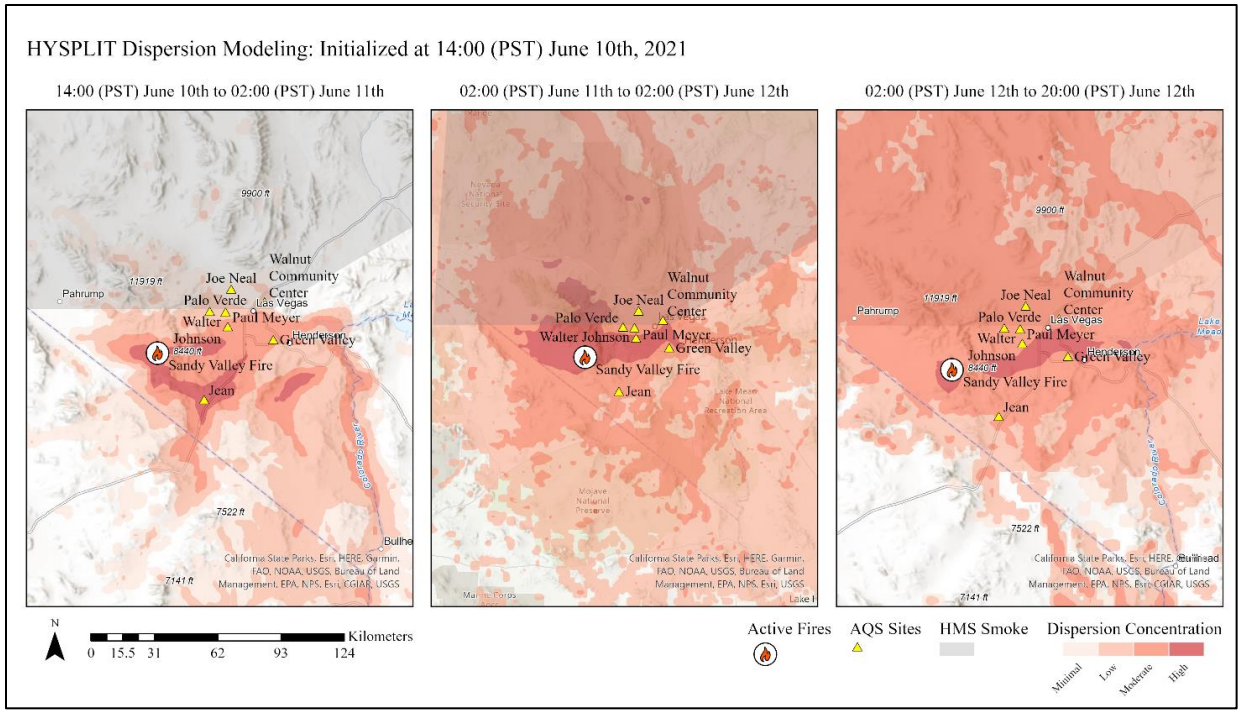

Figure 38. HYSPLIT dispersion modeling from the Sandy Valley Fire (labeled as "Active Fires"). HRRR 3 km meteorological data was used, and dispersion was initiated on June 10 at 14:00 PST to correspond with the ignition of the Sandy Valley Fire. The left panel shows the first 12 hours of dispersion after 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).

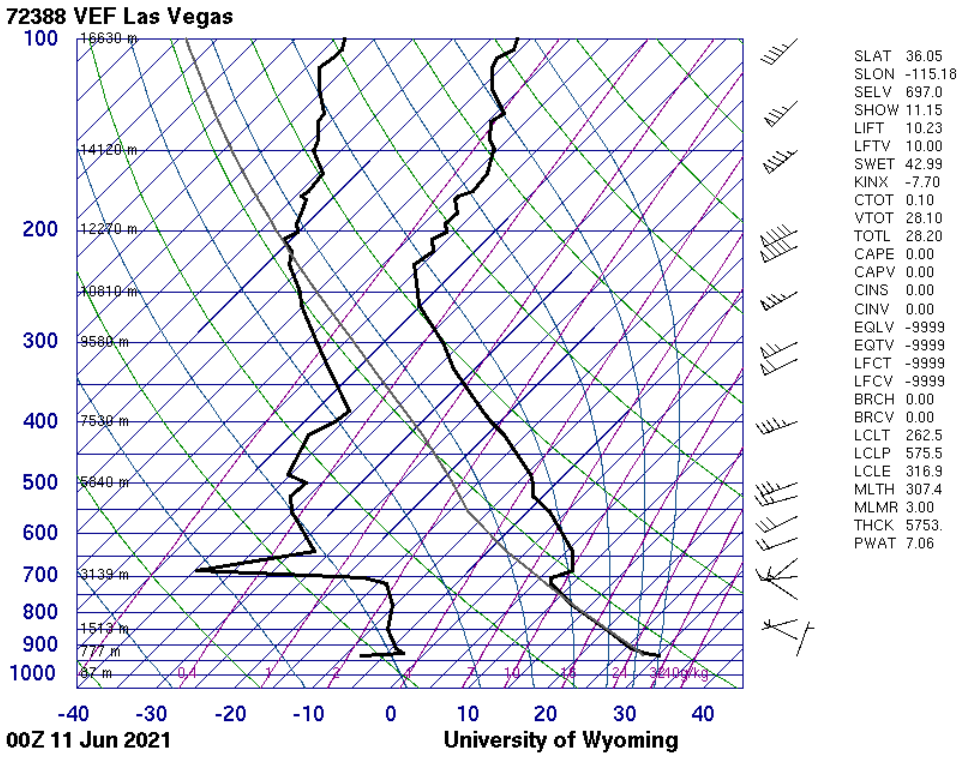

Figure 39. Sounding from Las Vegas, NV, at 00:00 UTC on June 11 (16:00 PST on June 10), 2021.

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.

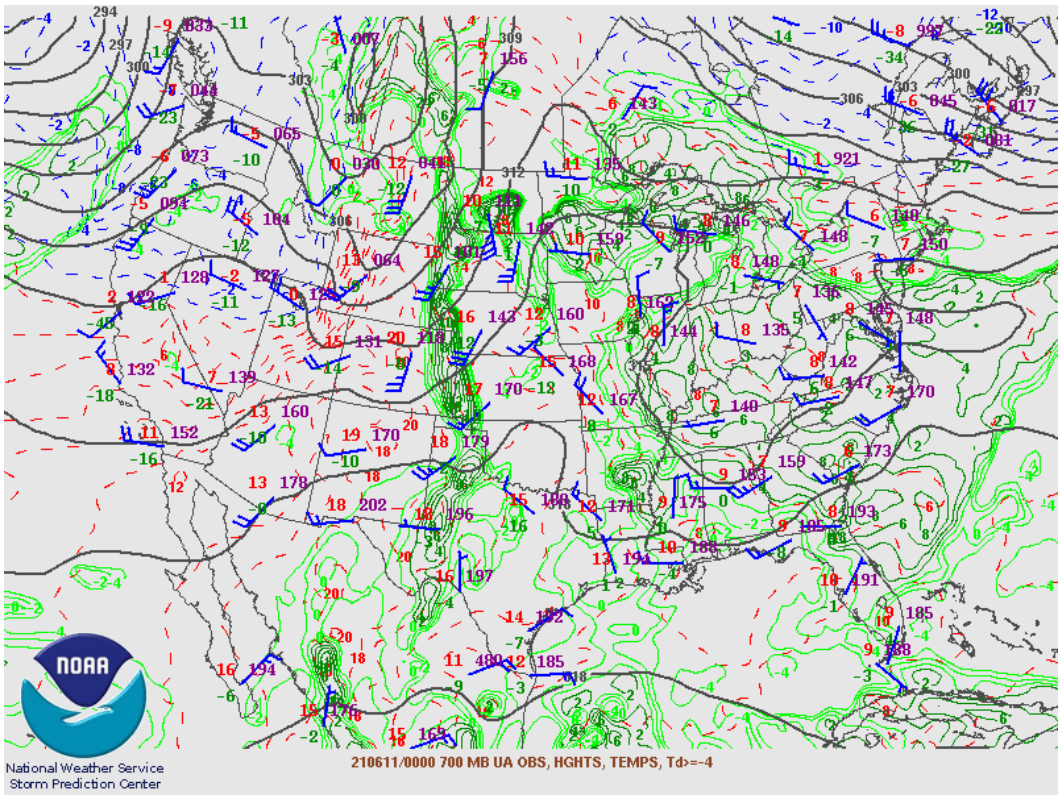

Figure 40. 700-mb map for 00:00 UTC on June 11, 2021 (16:00 PST on June 10, 2021).

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).

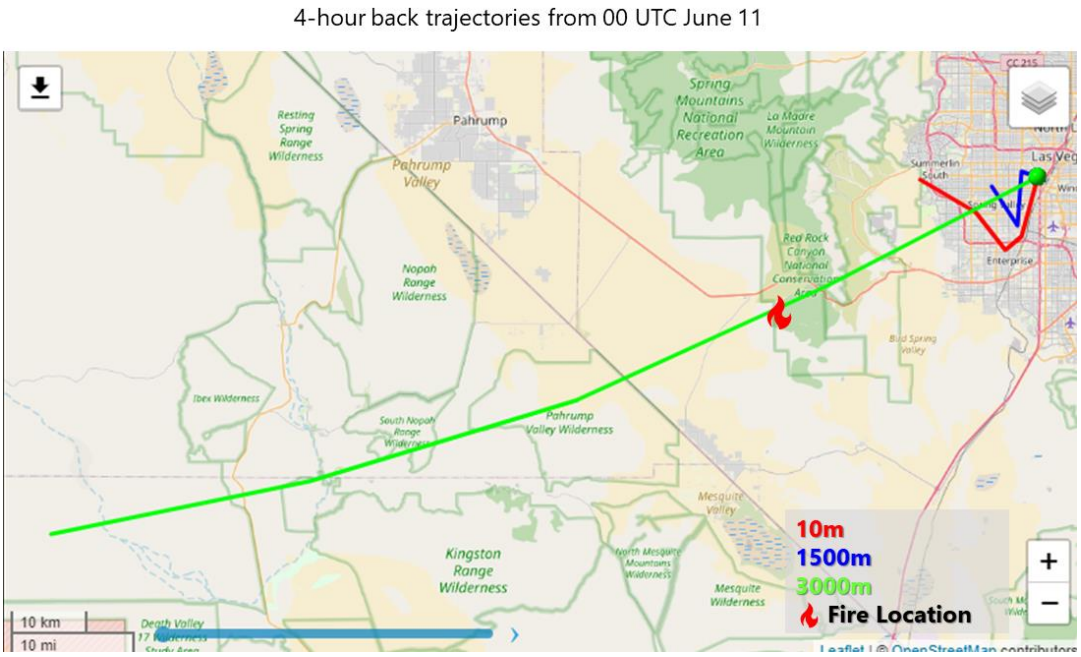

Figure 41. HYSPLIT back trajectories from 10, 1,500, and 3,000 meters using HRRR 3-km meteorological data and initiated at 00:00 UTC on June 11 back through 20:00 UTC on June 10 (16:00 PST on June 10 back through 12:00 PST on June 10).

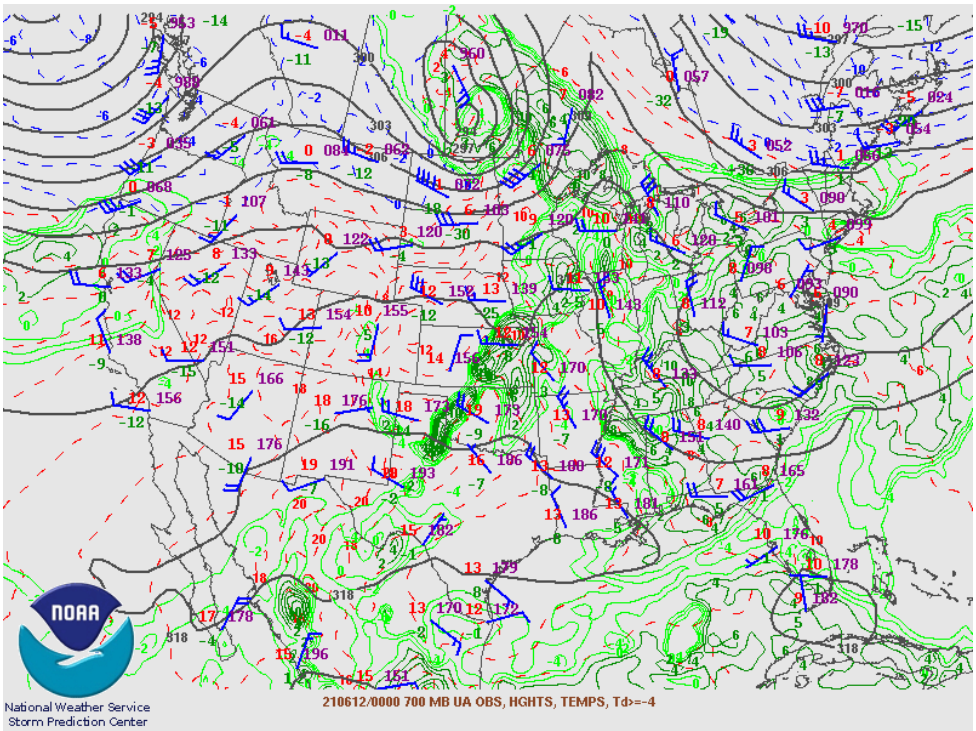

Figure 42. 700-mb map valid 00:00 UTC on June 12, 2021 (16:00 PST on June 11).

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).

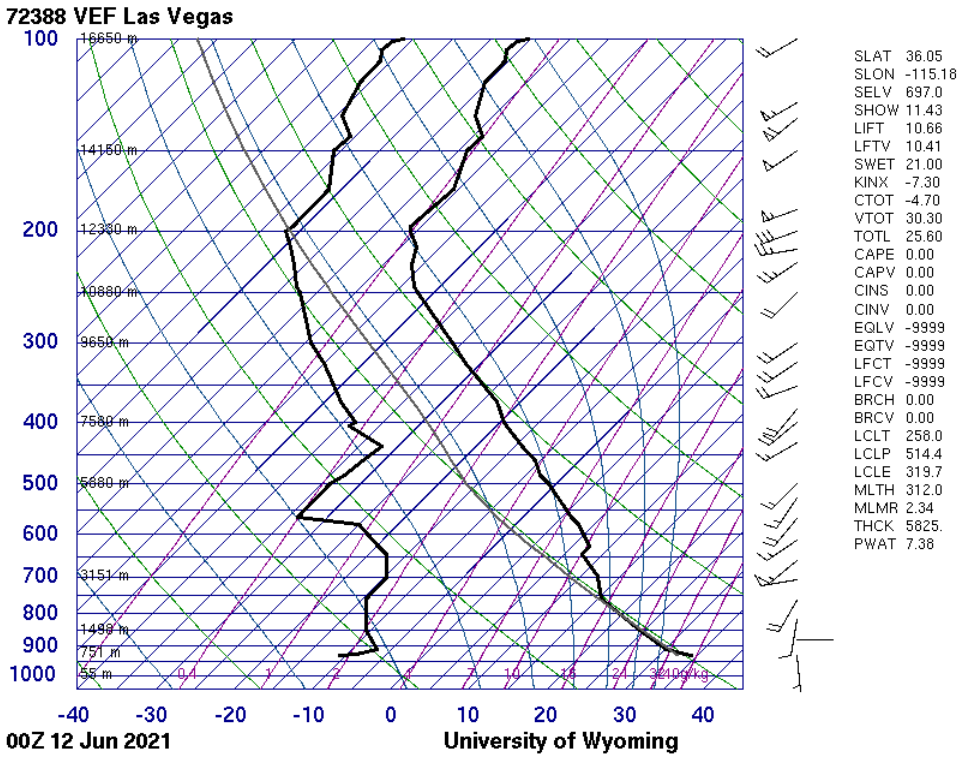

Figure 43. Sounding from Las Vegas, NV, at 00:00 UTC on June 12 (16:00 PST on June 11), 2021.

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.

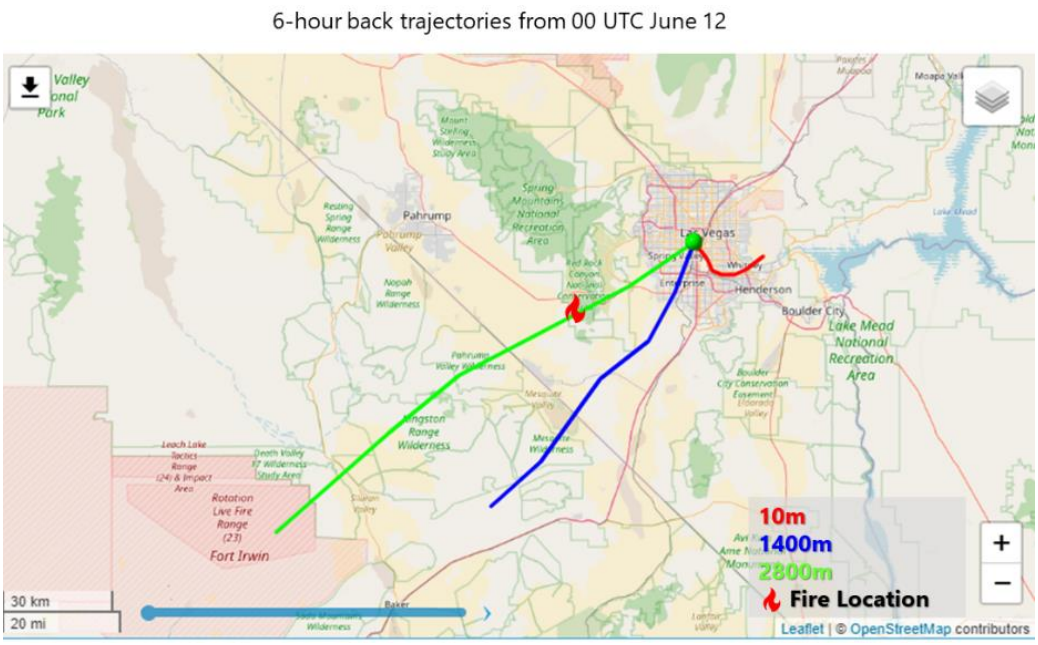

Figure 44. HYSPLIT back trajectories from 10, 1,400, and 2,800 meters using HRRR 3-km meteorological data and initiated at 00:00 UTC on June 12 back through 18:00 UTC on June 11 (16:00 PST on June 11 back through 10:00 PST on June 11).

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.

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.

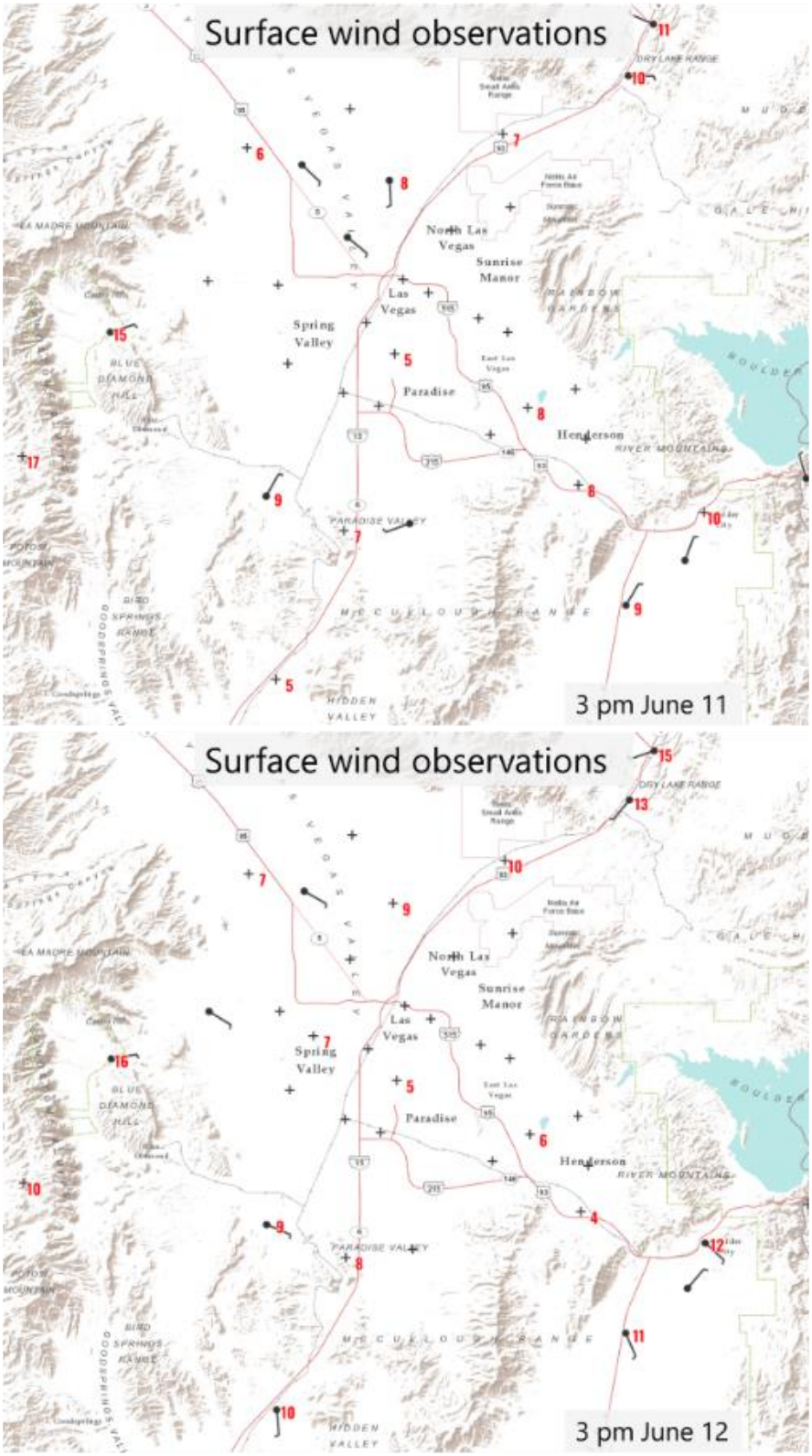

Figure 45. Light and variable surface winds are observed during the afternoons of June 11 and June 12, 2021, in the Las Vegas Valley. Wind speeds are in mph.

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).

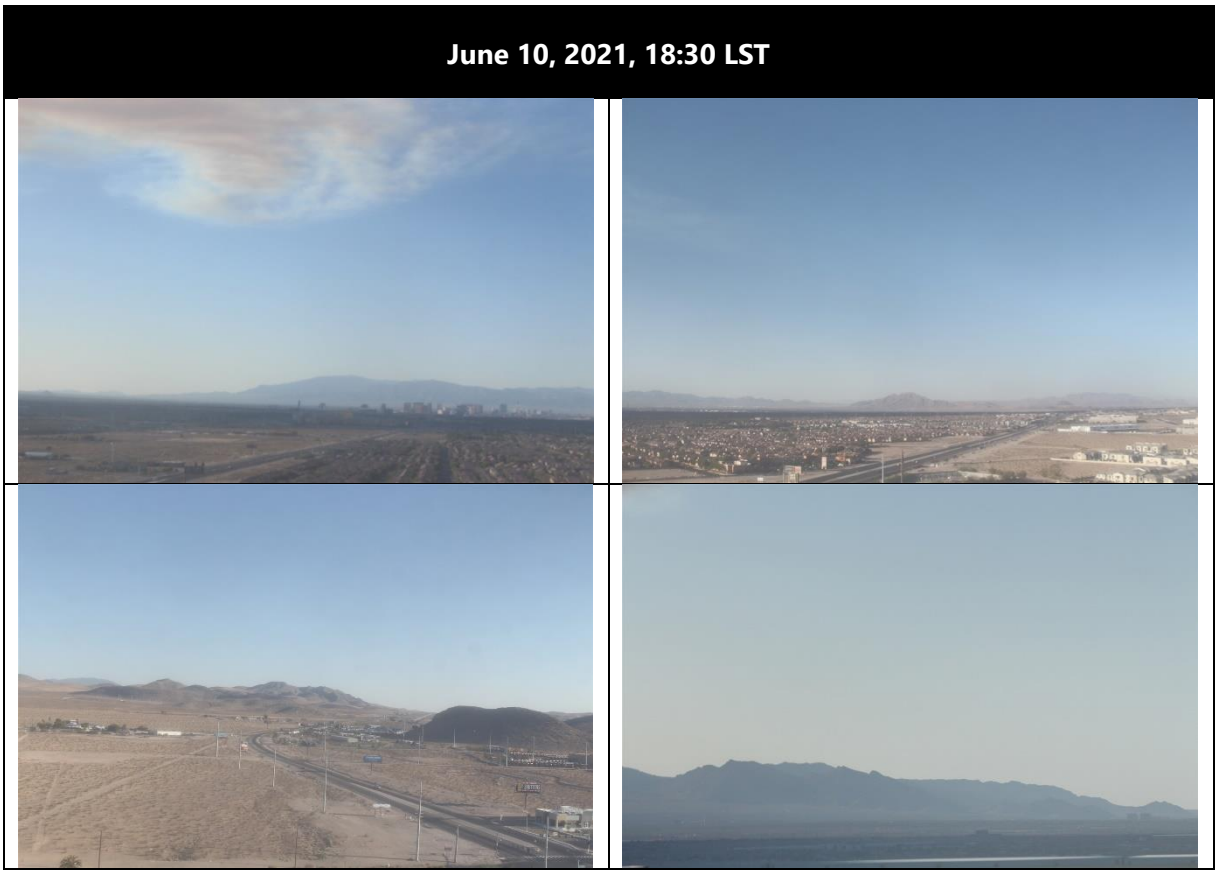

Figure 46. Camera Images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions taken from the M Resort Hotel in Clark County, NV, on June 10, 2021, at 18:30 PST. (Local standard time [LST] are used interchangeably with PST in this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

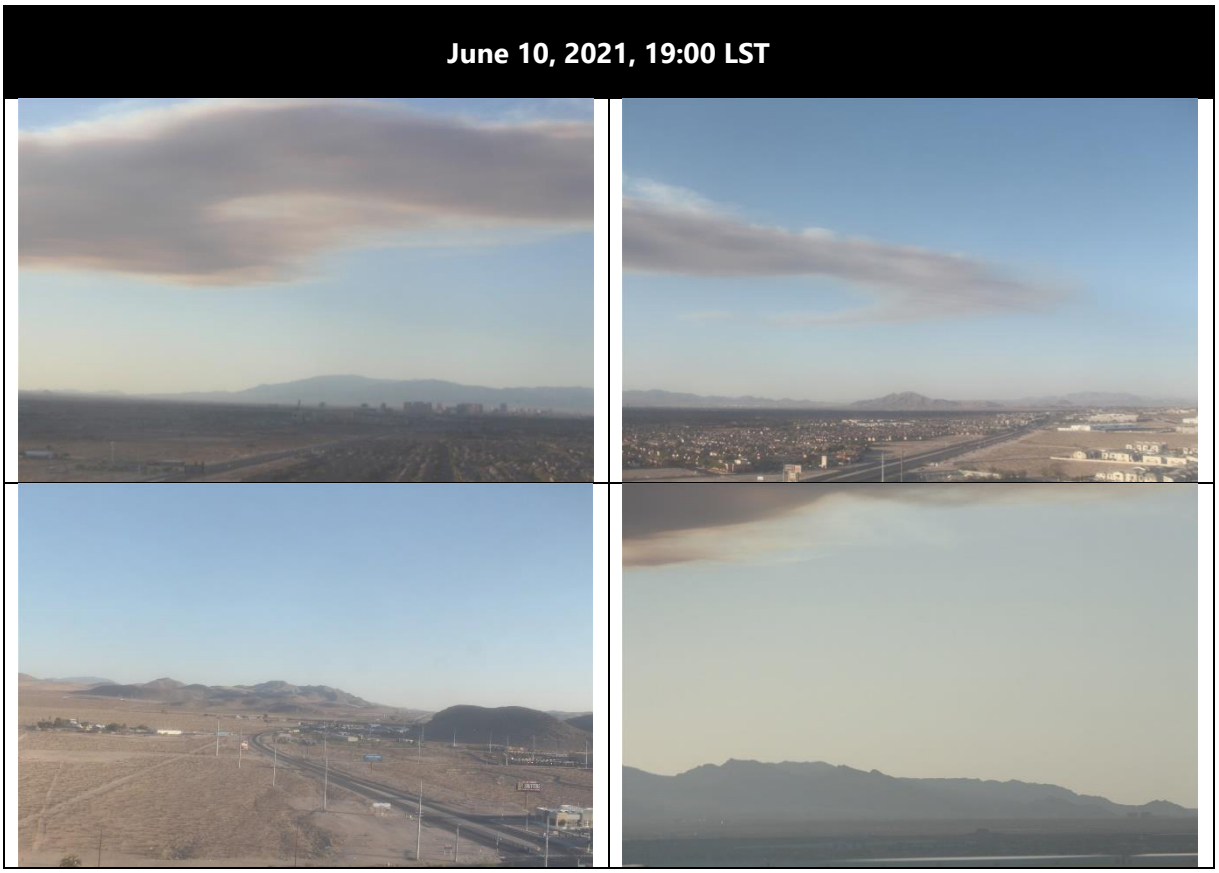

Figure 47. Camera Images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions taken from the M Resort Hotel in Clark County, NV, on June 10, 2021, at 19:00 PST.

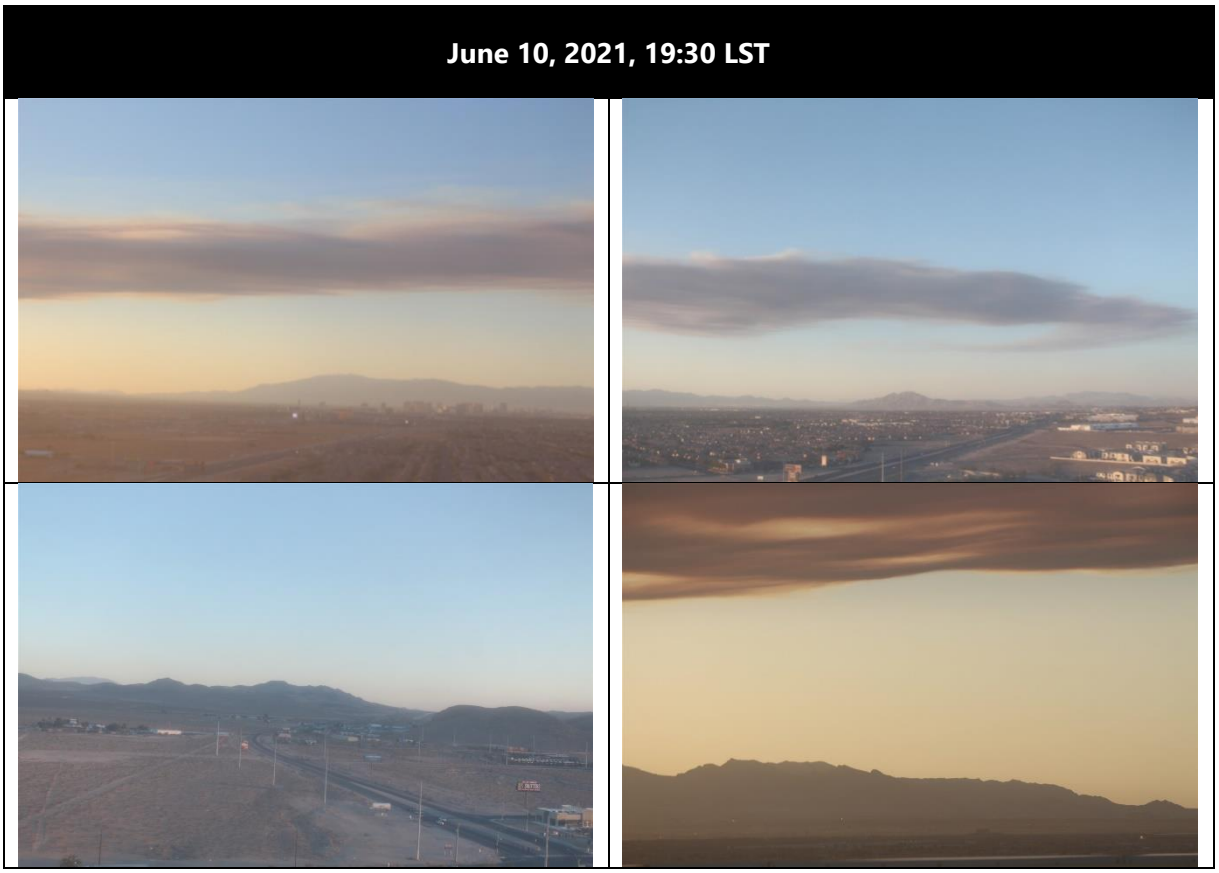

Figure 48. Camera Images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions taken from the M Resort Hotel in Clark County, NV, on June 10, 2021, at 19:30 PST.

$PM_{2.5}$, 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.

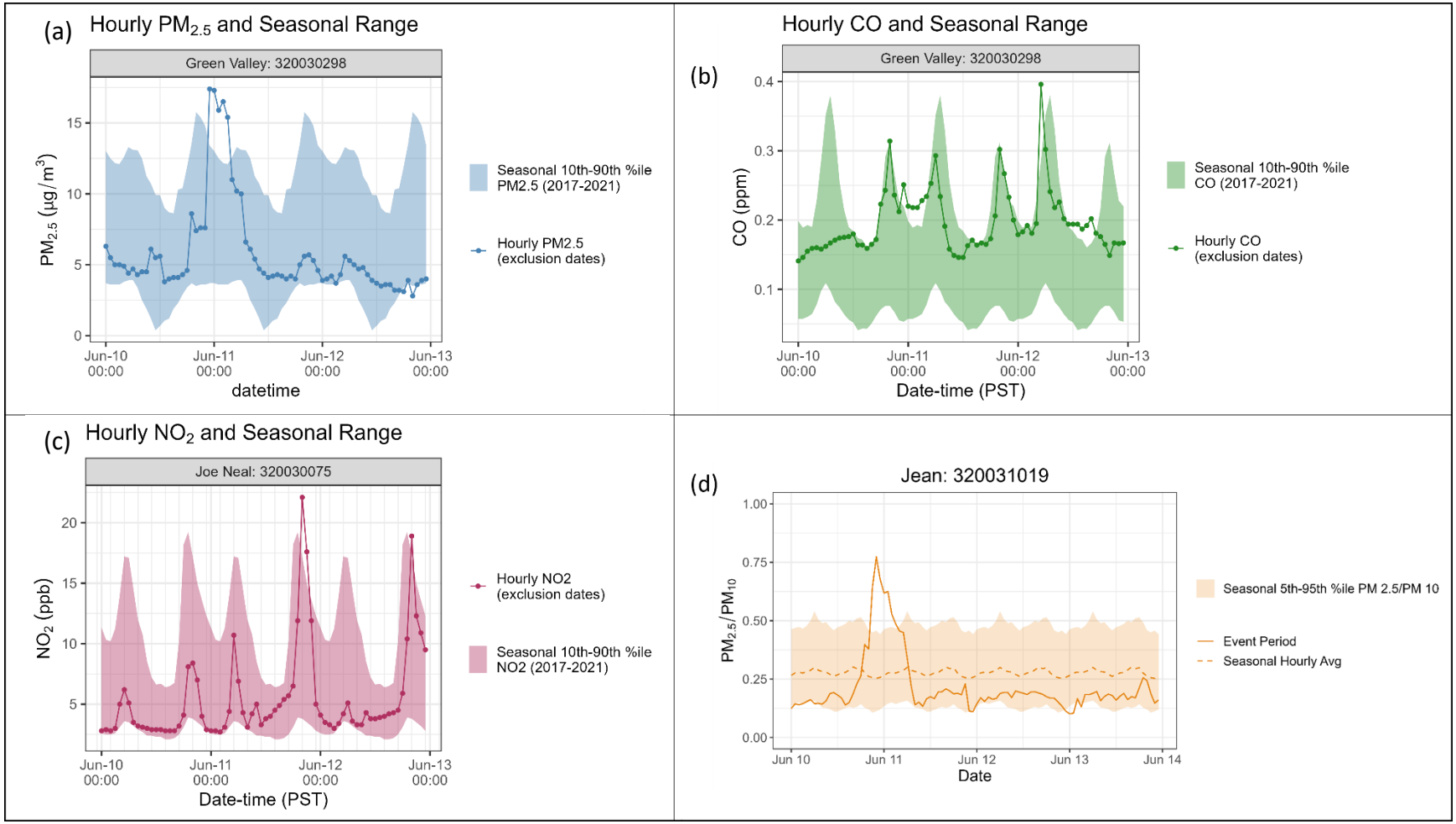

Figure 49. (a) Hourly $PM_{2.5}$ measurements overlaid on the 10th-90th percentile diurnal concentration at the Green Valley site. (b) Hourly CO measurements overlaid on the 10th-90th percentile diurnal concentration at the Green Valley site. (c) Hourly NO_2 measurements overlaid on the 10th-90th percentile 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.

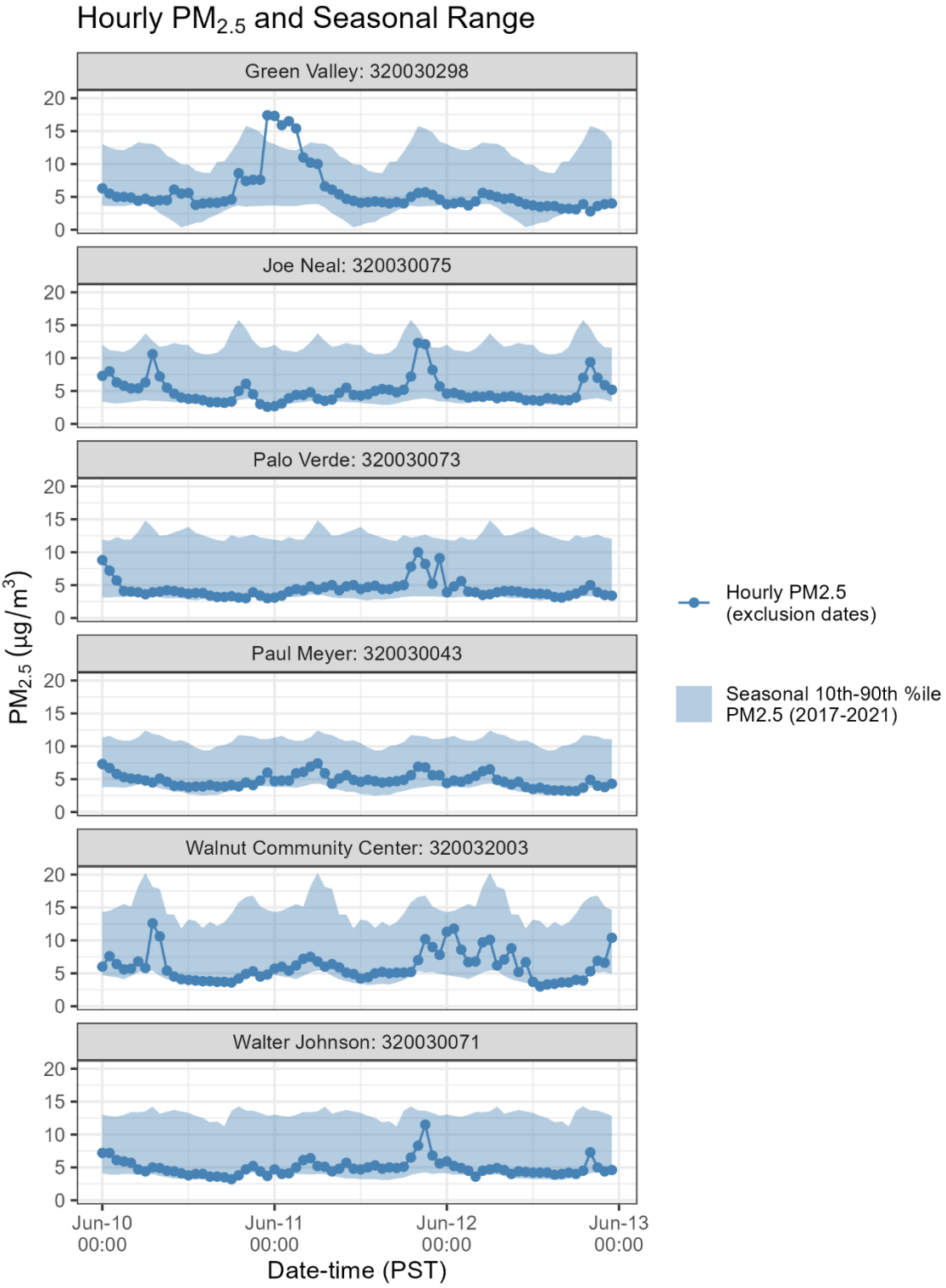

Figure 50. Hourly $PM_{2.5}$ measurements overlaid on the 10th-90th percentile diurnal concentration at all affected sites.

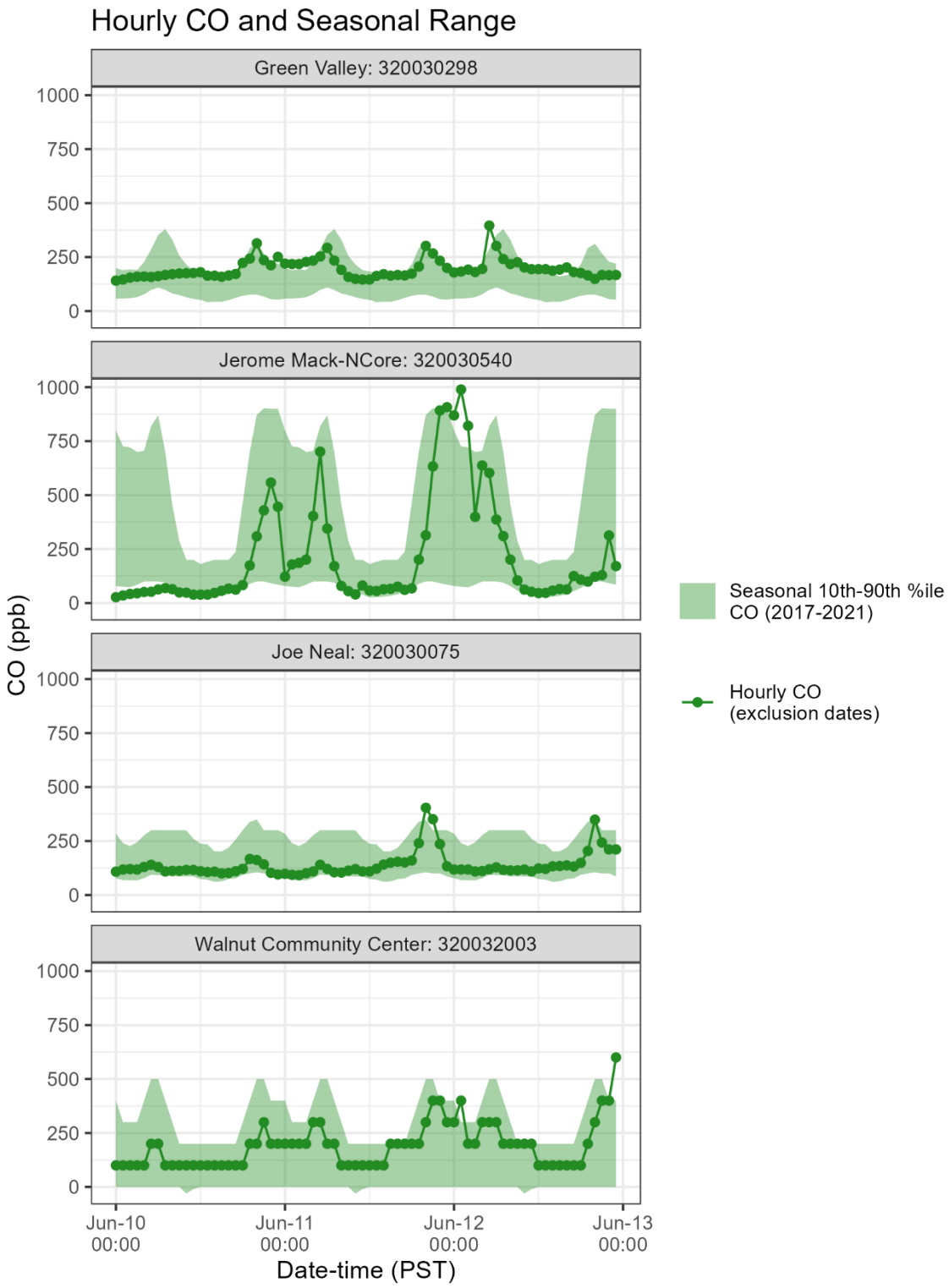

Figure 51. Hourly CO measurements overlaid on the 10th-90th percentile diurnal concentration at all affected sites.

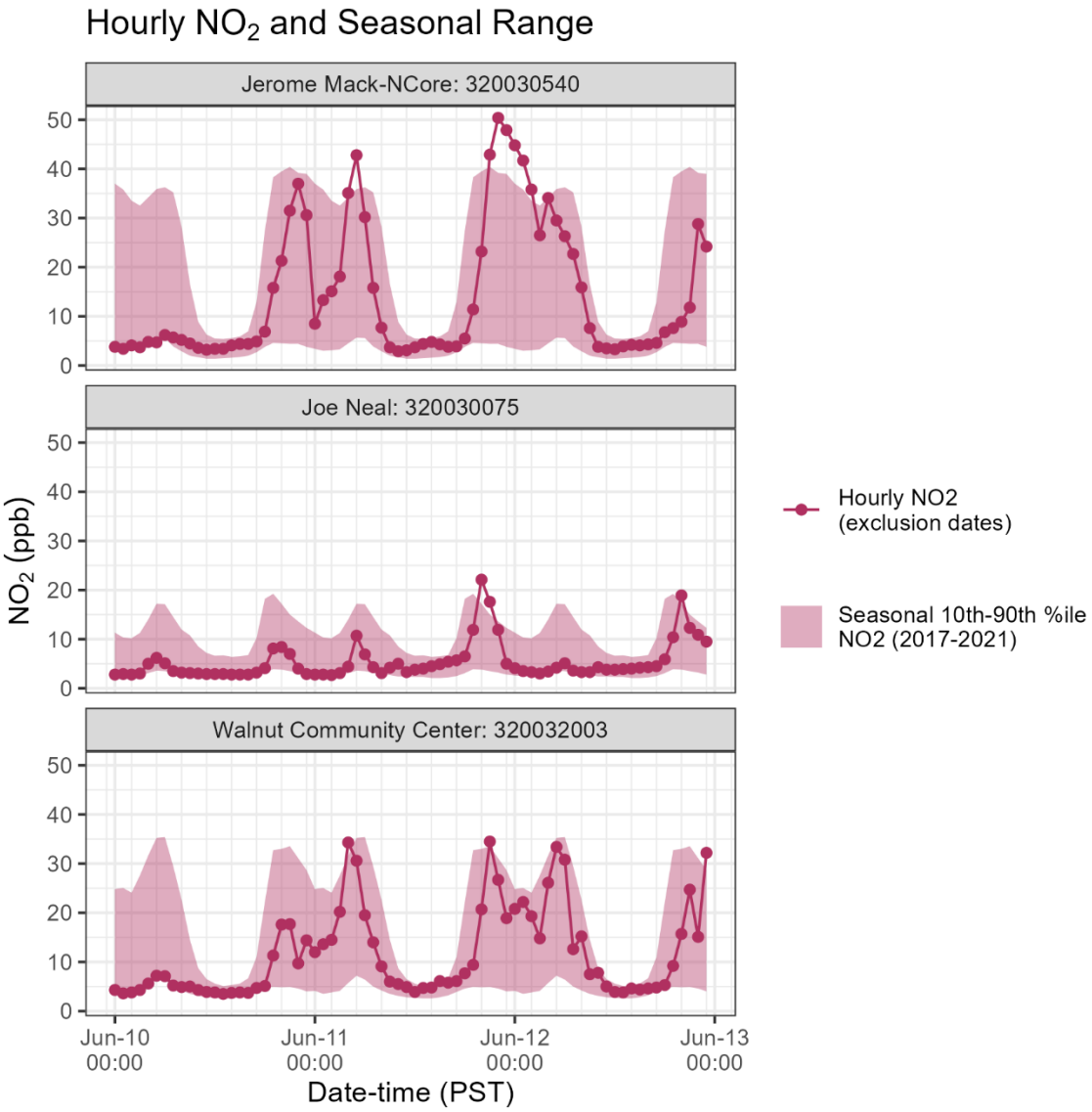

Figure 52. Hourly NO_2 measurements overlaid on the 10th-90th percentile diurnal concentration at all affected sites.

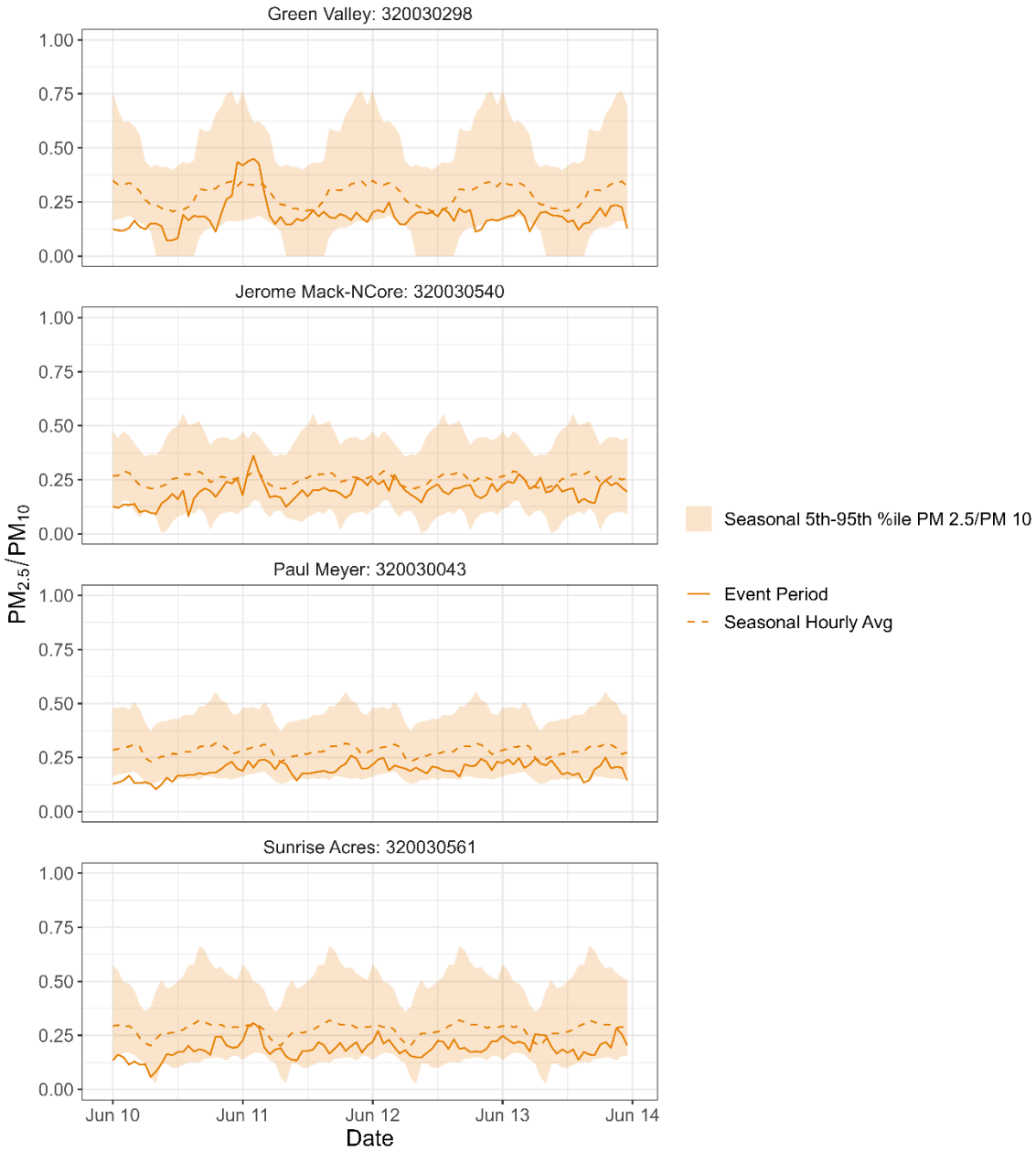

Figure 53. Hourly $PM_{2.5}$-to-PM_{10} measurement ratios overlaid on the 10th-90th percentile diurnal concentration at all affected sites.

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.

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 Mountains Edge Park. 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 Mountains Edge Park 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.

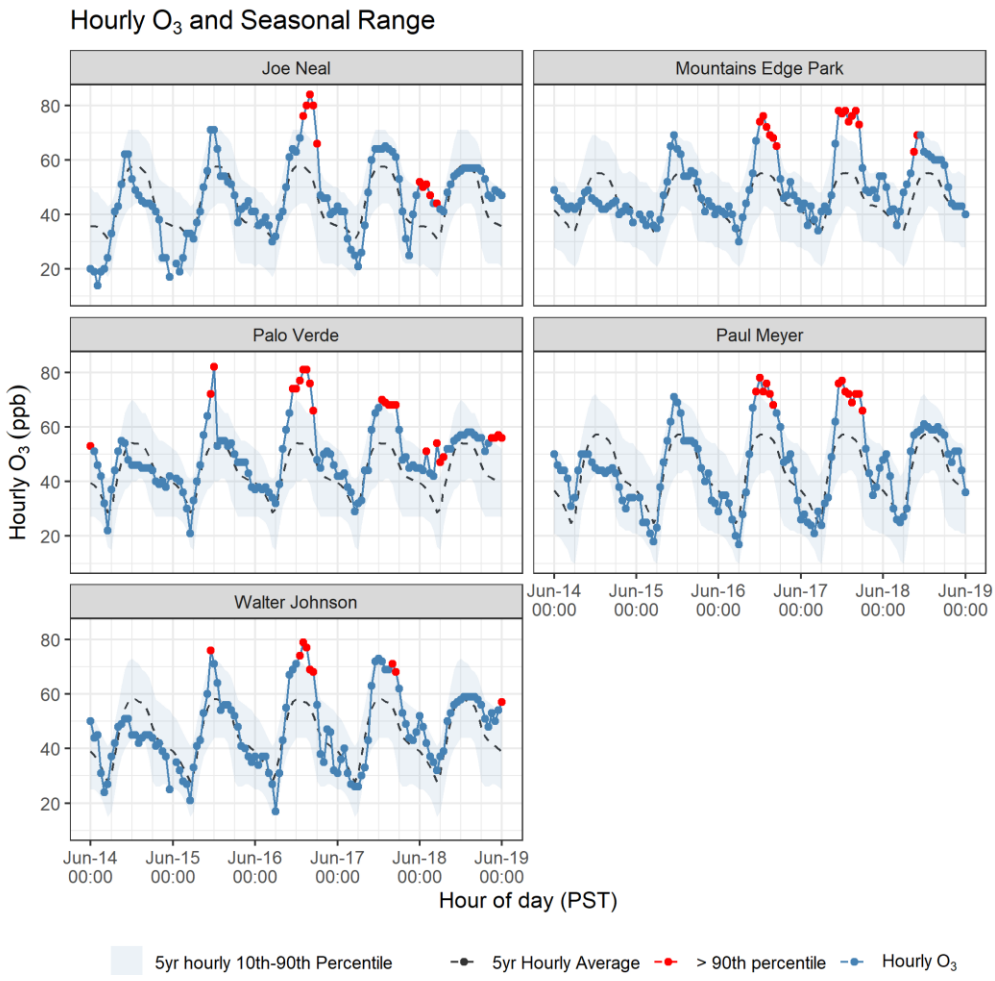

Figure 54. Hourly ozone concentrations (ppb) compared to 5-yr* ozone season (May 1-October 31, 2017-2021) hourly means and 10-90th percentiles. *Note: data from the Mountains Edge Park site are only available for June 1-October 31, 2021.

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]

[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.

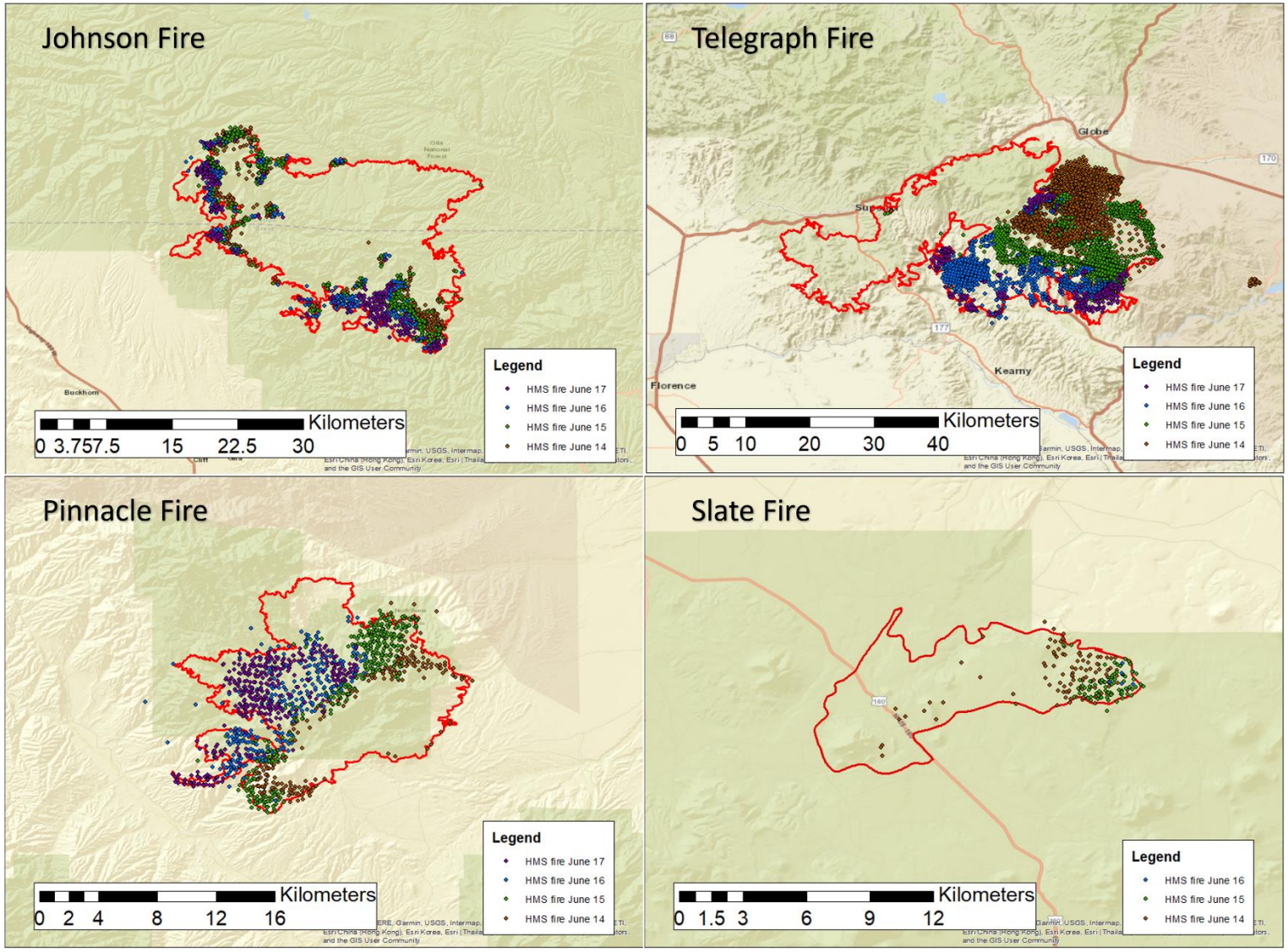

Figure 55. Full fire perimeters (red) and HMS fire detections for the Johnson, Telegraph, Pinnacle, and Slate Fires for June 14-17, 2021.

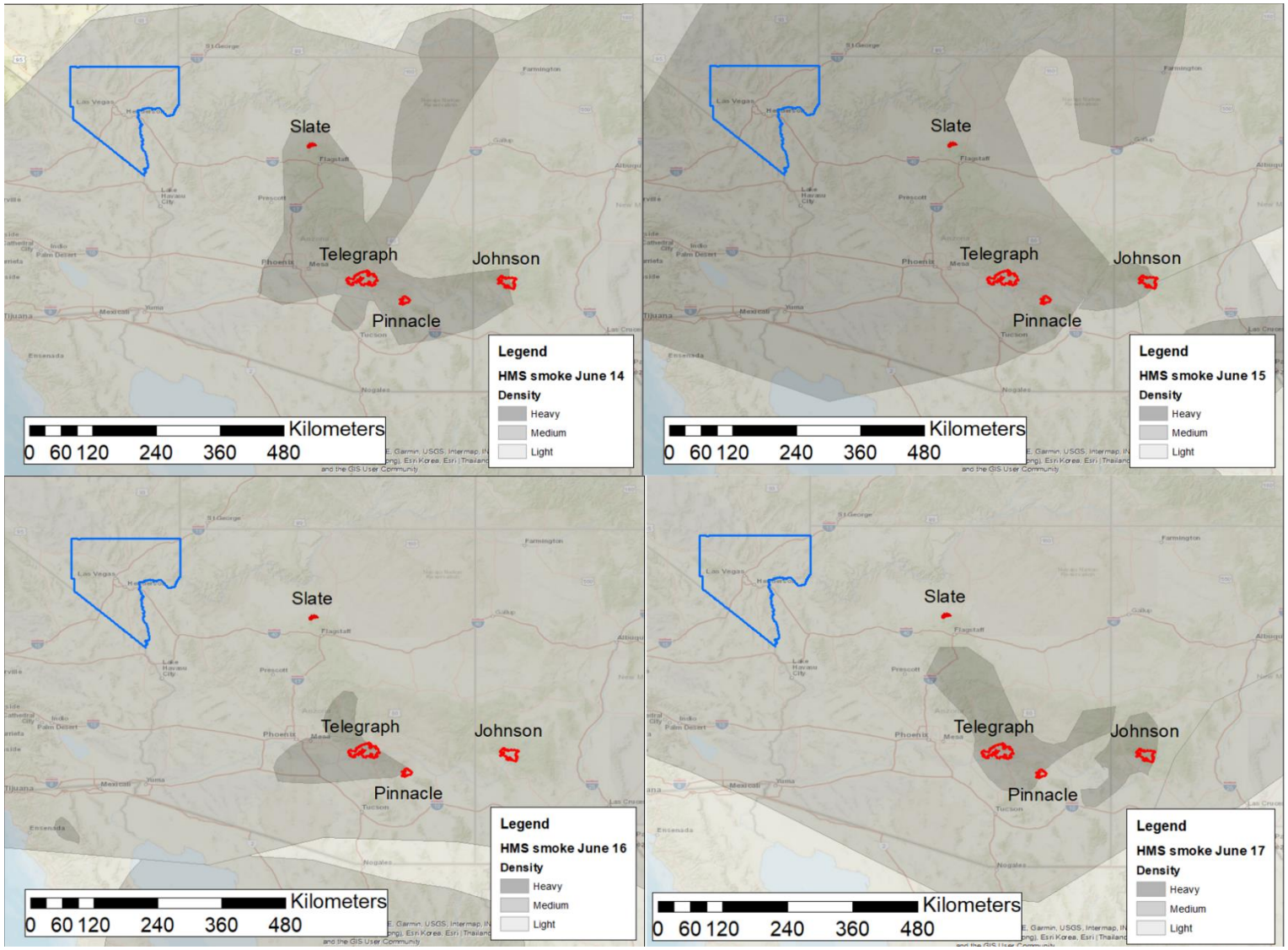

Figure 56. HMS smoke boundaries for June 14-17, 2021, are included with qualitative smoke density. Fire perimeters from the major fires contributing to the exclusion date are shown in red and the Clark County, NV, boundary is shown in blue.

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.

[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/

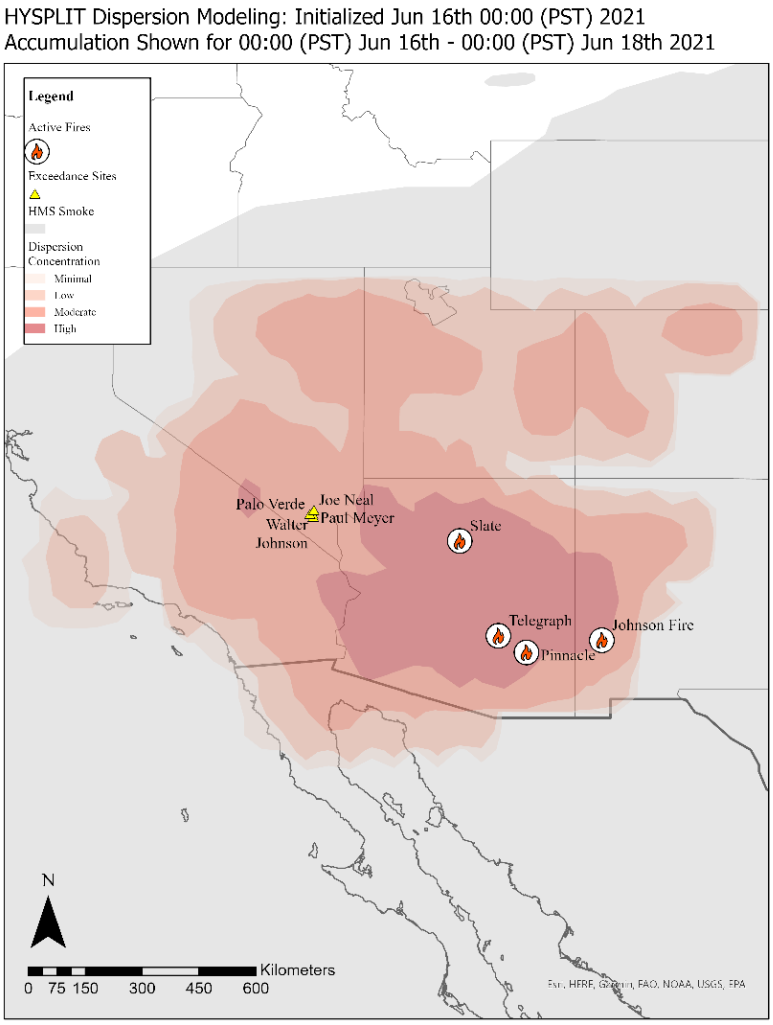

Figure 57. HYSPLIT dispersion modeling for the large fires (labeled as "Active Fires") in Arizona and New Mexico. GDAS 1.0° meteorological data was used, and dispersion was initiated on June 6, 2021, at 00:00 PST to model the regional smoke observed in satellite and HMS products. HMS smoke is shown in 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 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.

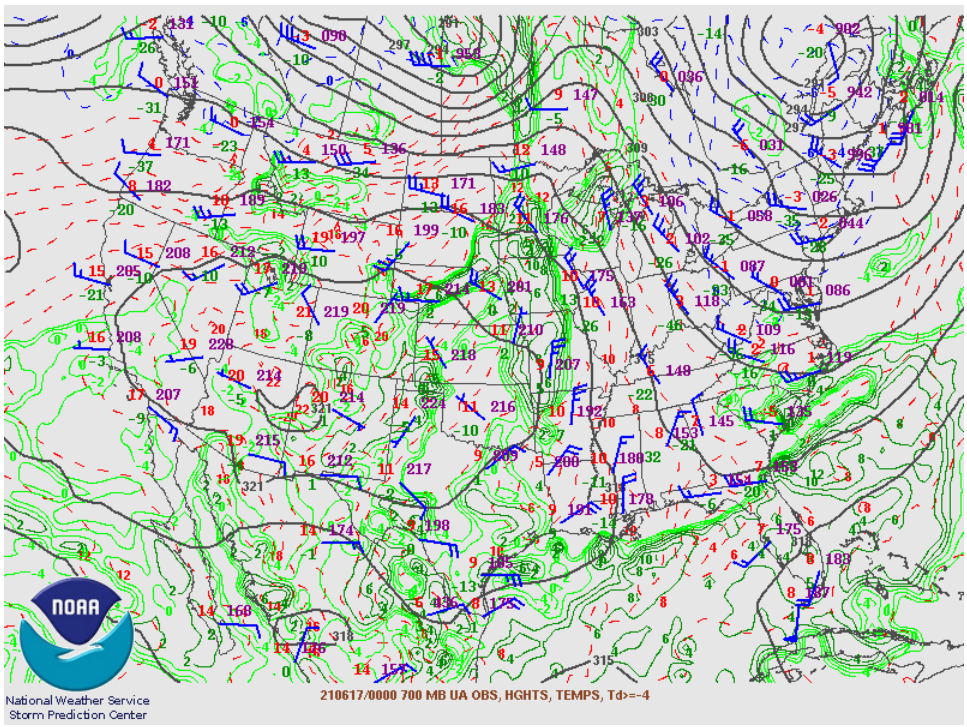

Figure 58. Map of 700-mb (approx. 10,000 feet ASL) air flow. Map valid at 00:00 UTC on June 17, 2021 (16:00 PST on June 16, 2021).

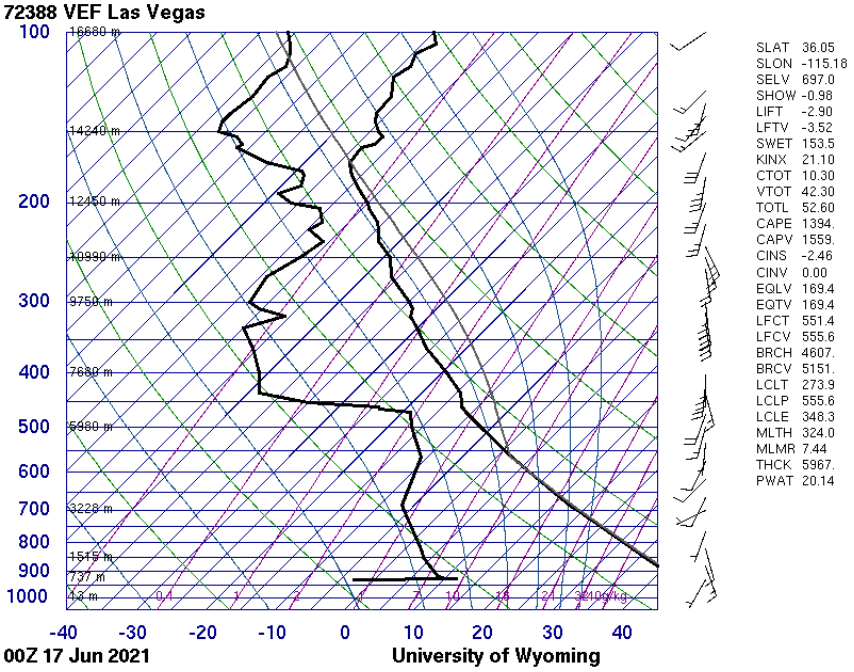

Figure 59 Sounding from Las Vegas, Nevada, at 00:00 UTC on June 17 (16:00 PST on June 16), 2021, where x-axis shows temperature (°C) and y-axis shows pressure (mb). Retrieved from https://weather.uwyo.edu/upperair/sounding.html.

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.

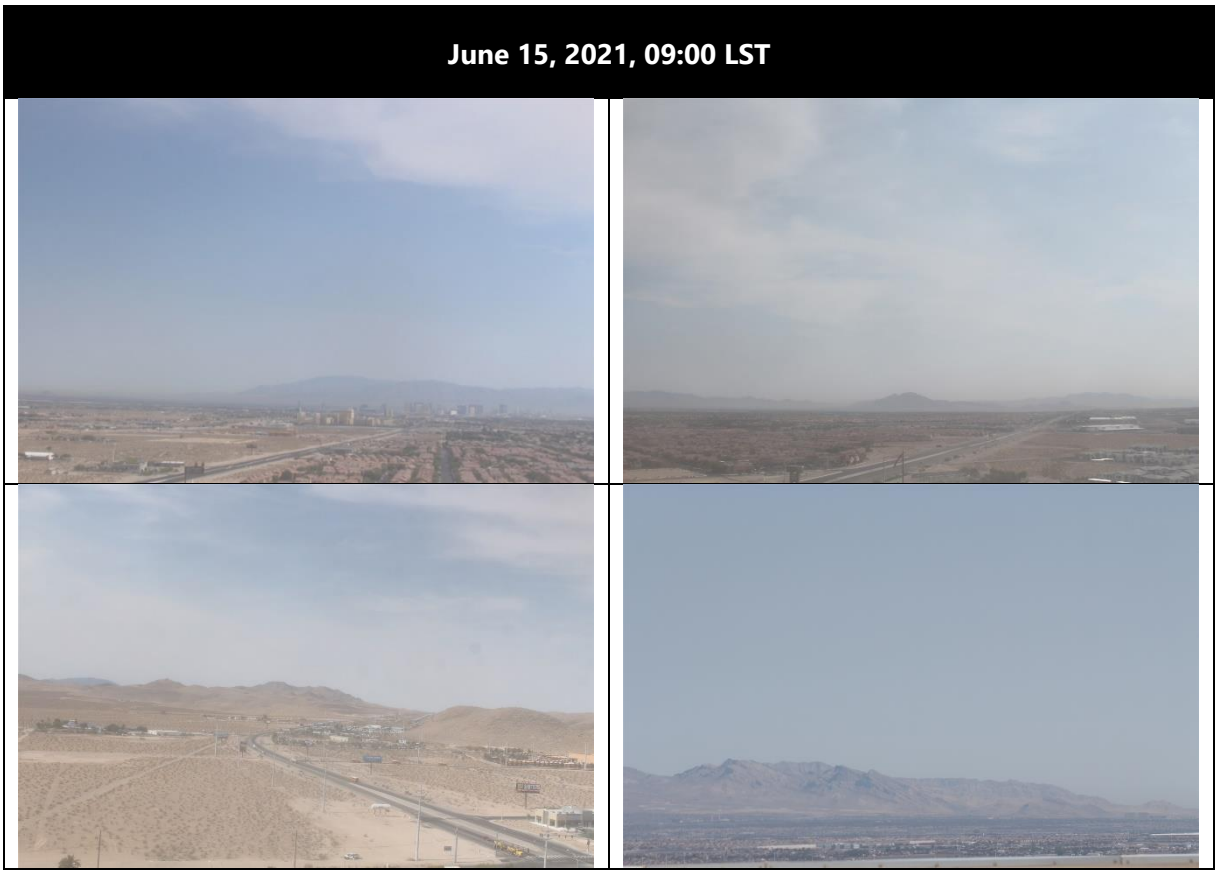

Figure 60. Camera images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions, taken from the M Resort Hotel in Clark County, NV, on June 15, 2021, at 09:00 LST.

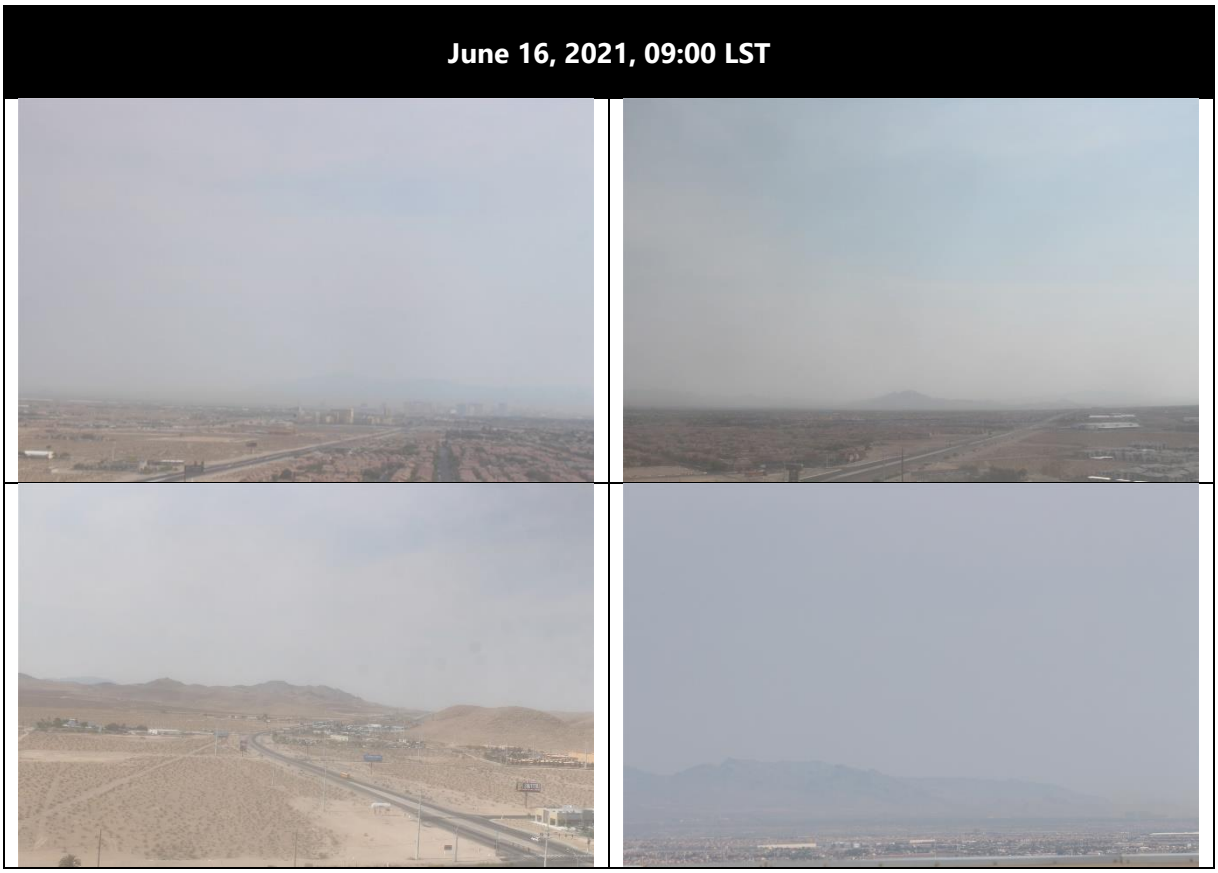

Figure 61. Camera images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions, taken from the M Resort Hotel in Clark County, NV, on June 16, 2021, at 09:00 LST.

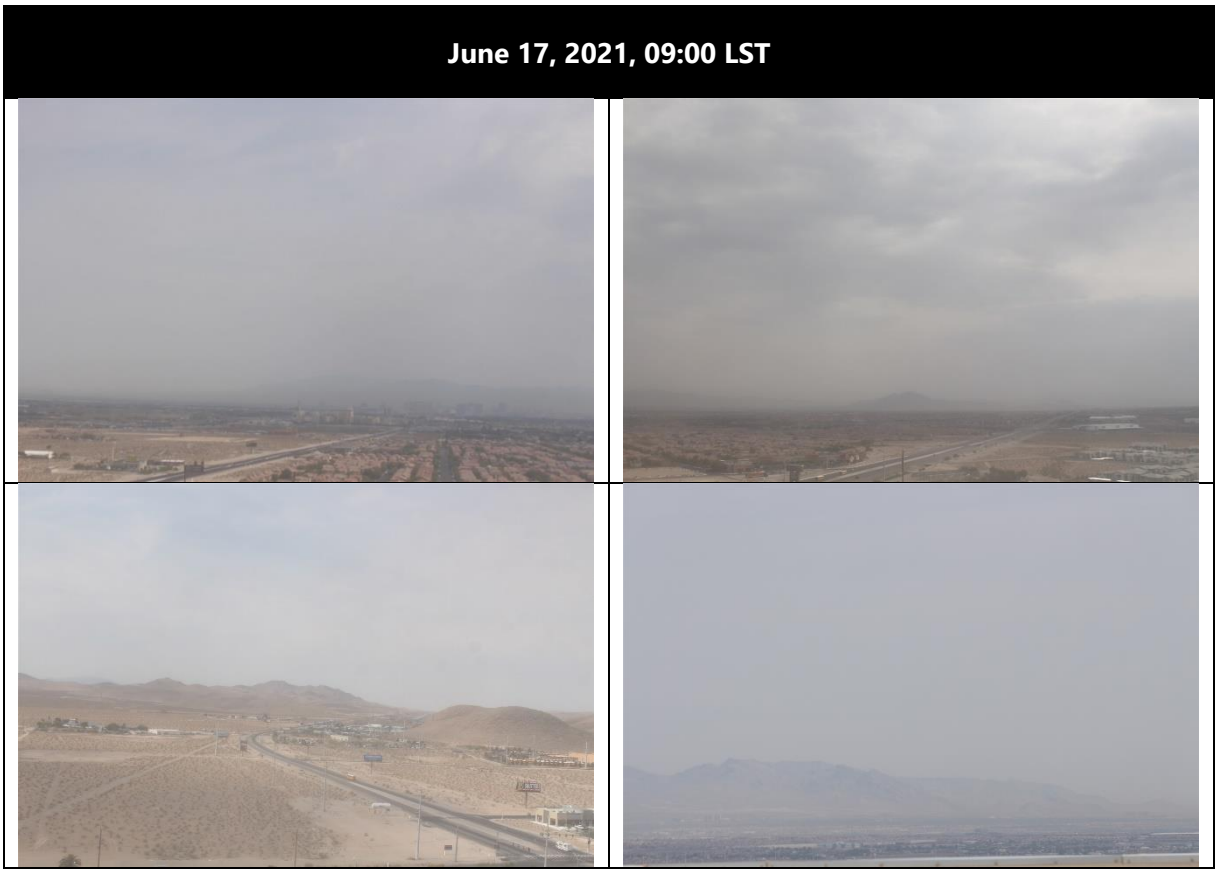

Figure 62. Camera images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions, taken from the M Resort Hotel in Clark County, NV, on June 17, 2021, at 09:00 LST.

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.

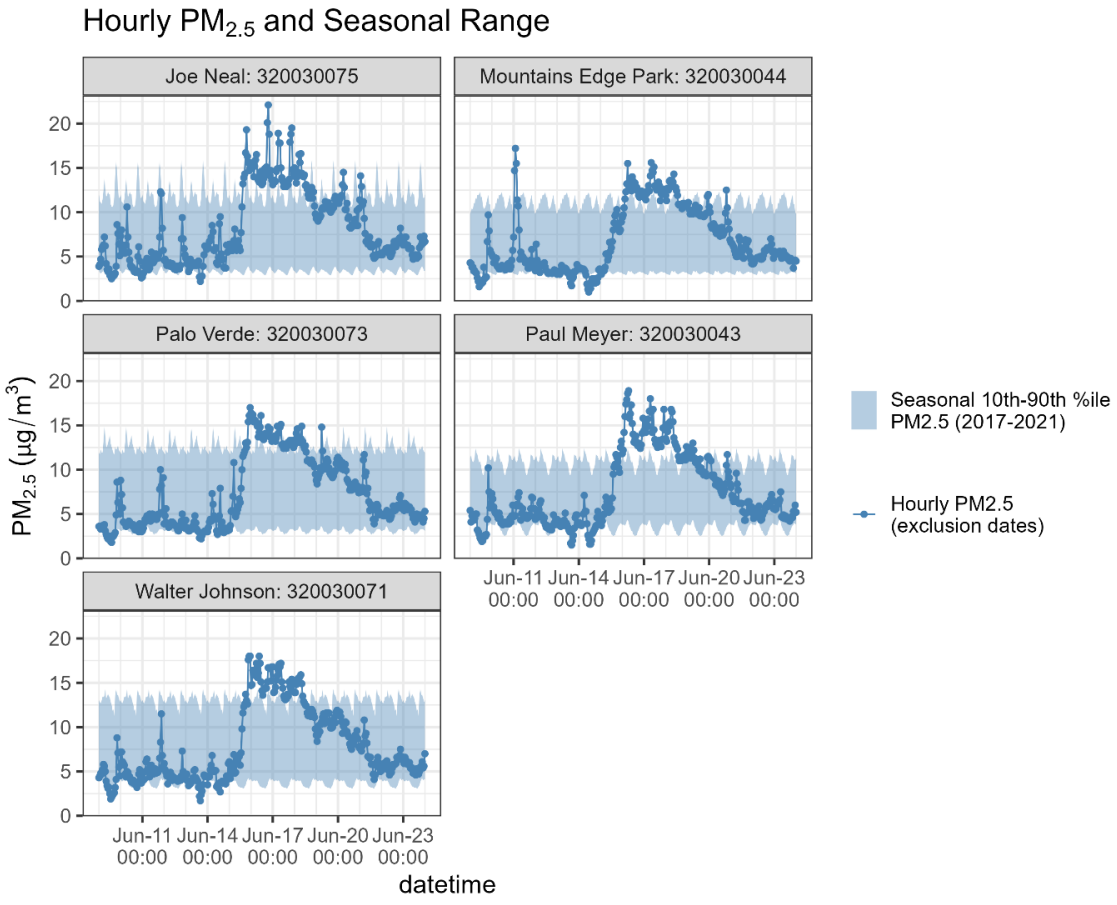

Figure 63. Hourly $PM_{2.5}$ measurements overlaid on the 10th-90th percentile diurnal concentration at each event-affected measurement site. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

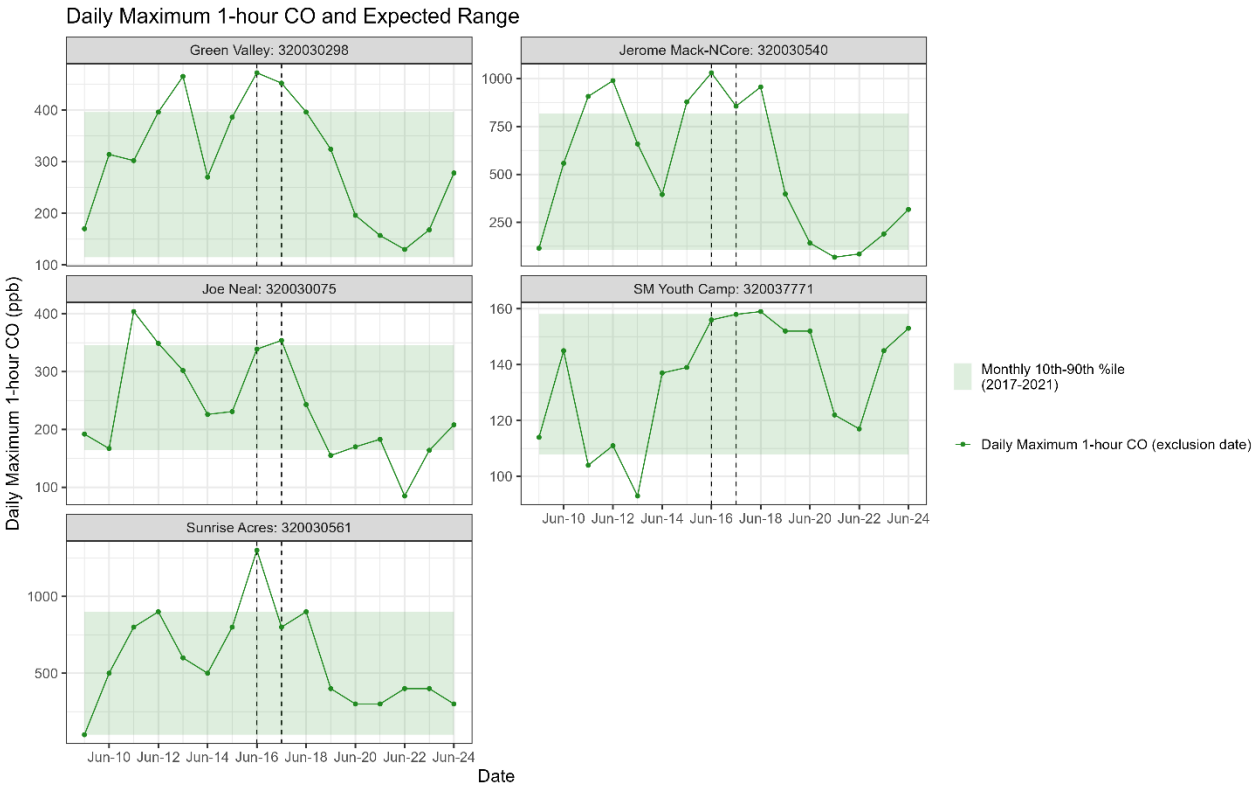

Figure 64. Daily maximum hour CO measurements overlaid on the month of June 10th-90th percentile daily maximum concentration at all Clark County CO measurement sites. The 10th-90th percentile concentration is calculated across June 2017-2021.

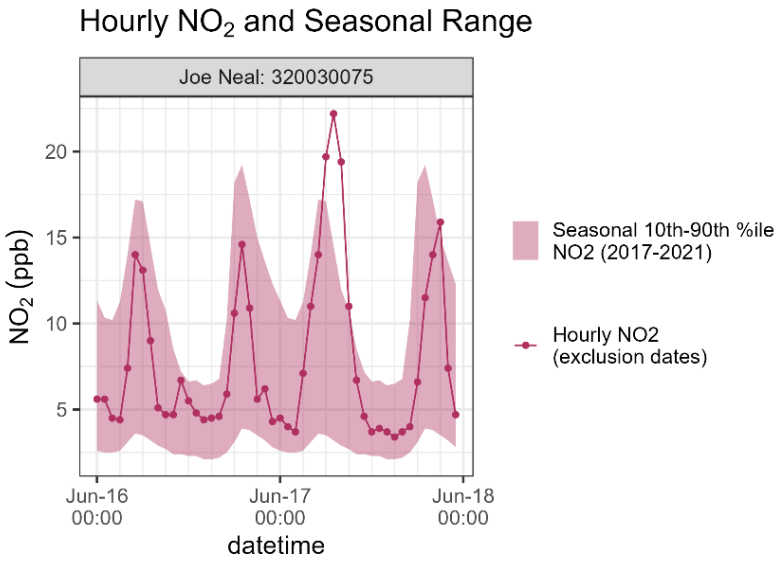

Figure 65. Hourly NO_2 measurements overlaid on the 10th-90th percentile diurnal concentration at the Joe Neal site. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

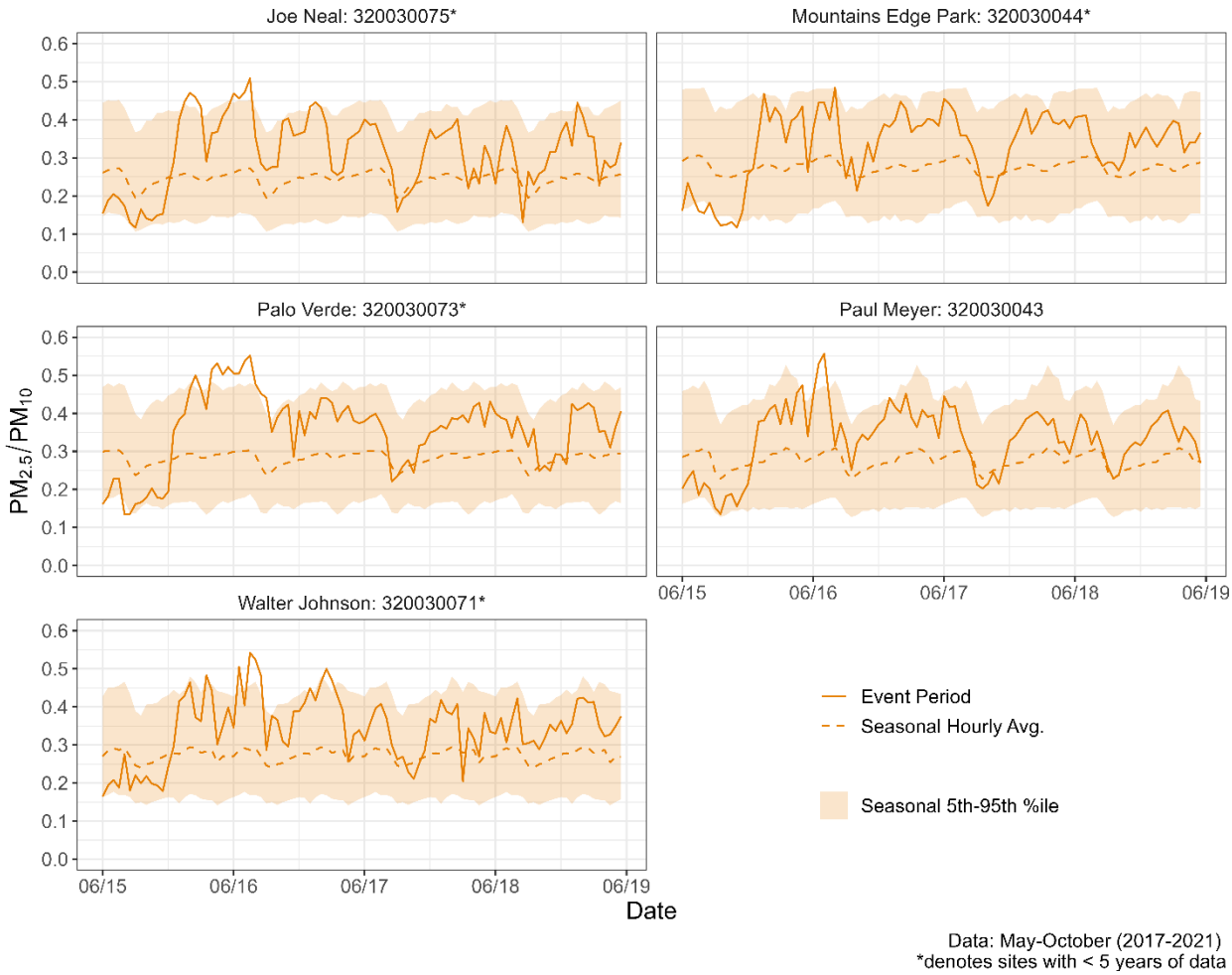

Figure 66. Ratio of $PM_{2.5}$-to-PM_{10} concentrations at the affected sites during the June 16 and June 17 event period. The 5-yr average $PM_{2.5}$-to-PM_{10} diurnal ratio is displayed as a dotted line, and the 5th-95th percentile range is shown as a shaded ribbon. The 5th-95th percentile concentration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

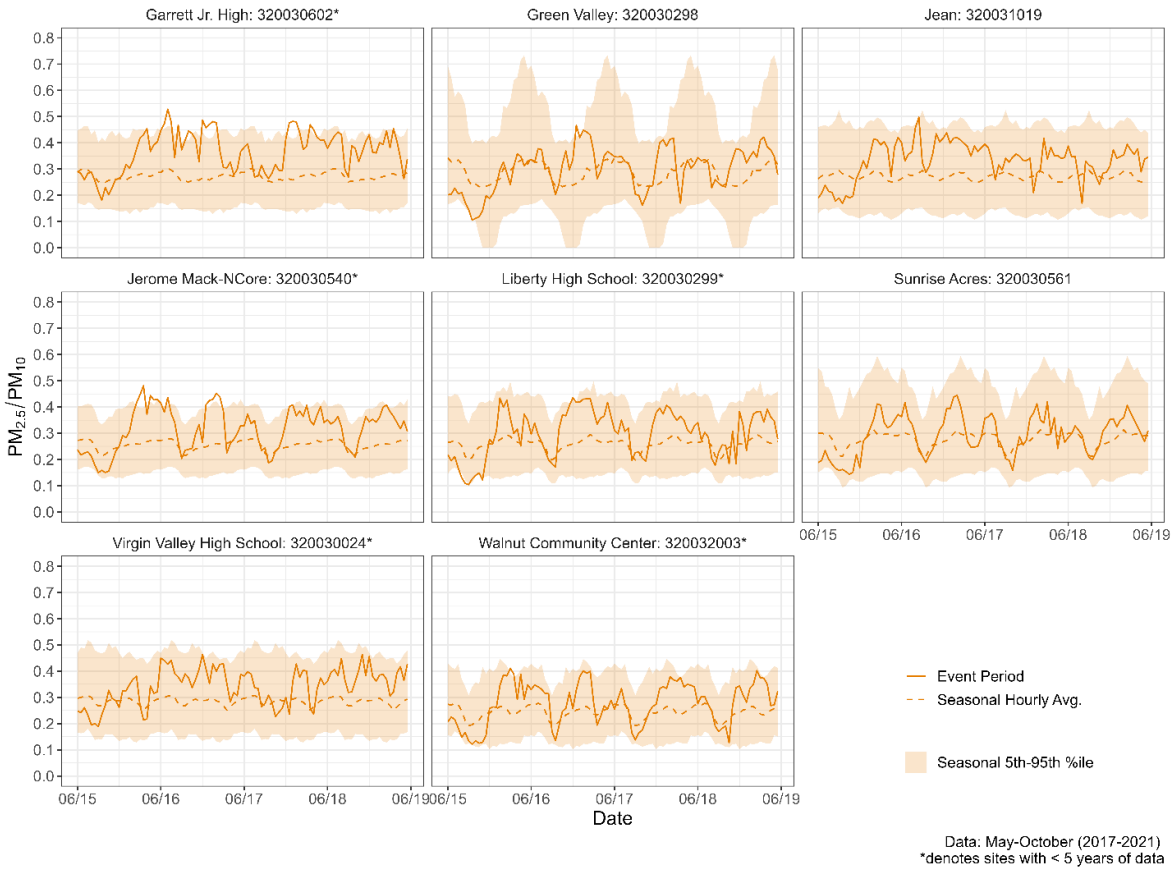

Figure 67. Ratio of $PM_{2.5}$-to-PM_{10} concentrations at the non-affected sites during the June 16 and June 17 event period. The 5-yr average $PM_{2.5}$-to-PM_{10} diurnal ratio is displayed as a dotted line, and the 5th-95th percentile range is shown as a shaded ribbon. The 5th-95th percentile concentration 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 Mountains Edge Park 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	Mountains Edge Park	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.

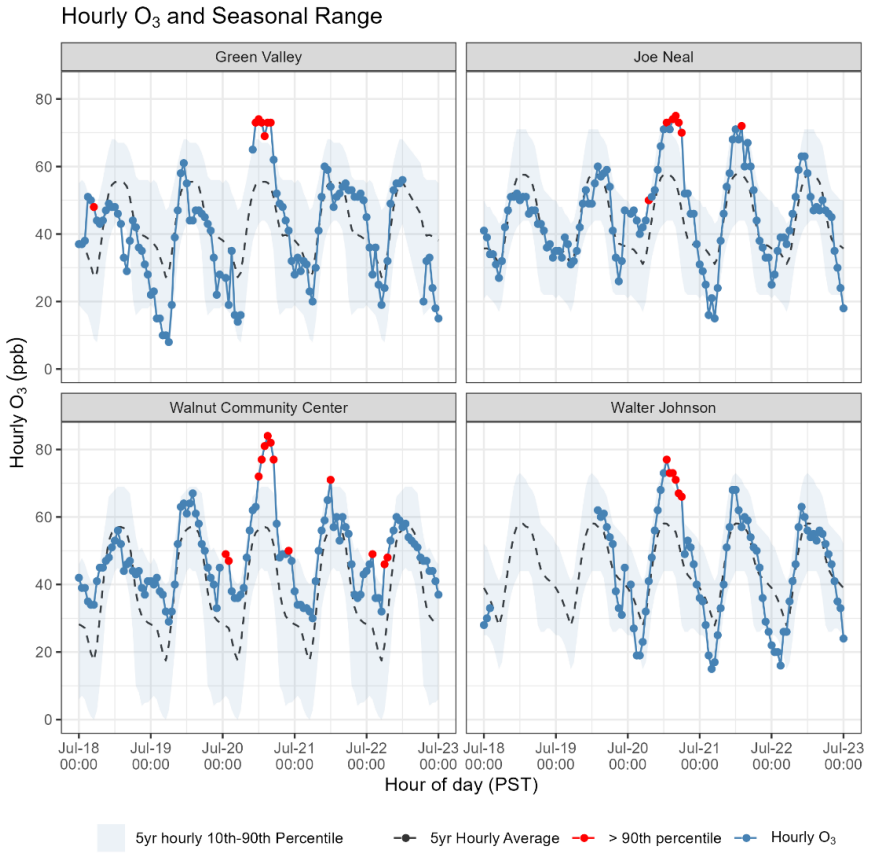

Figure 68. Hourly ozone concentrations (ppb) compared to 5-yr* ozone season (May 1-October 31) hourly means and 10th-90th percentiles. *Note: data from the Walnut Community Center site are only available for June 1-October 31, 2021.

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]

[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.

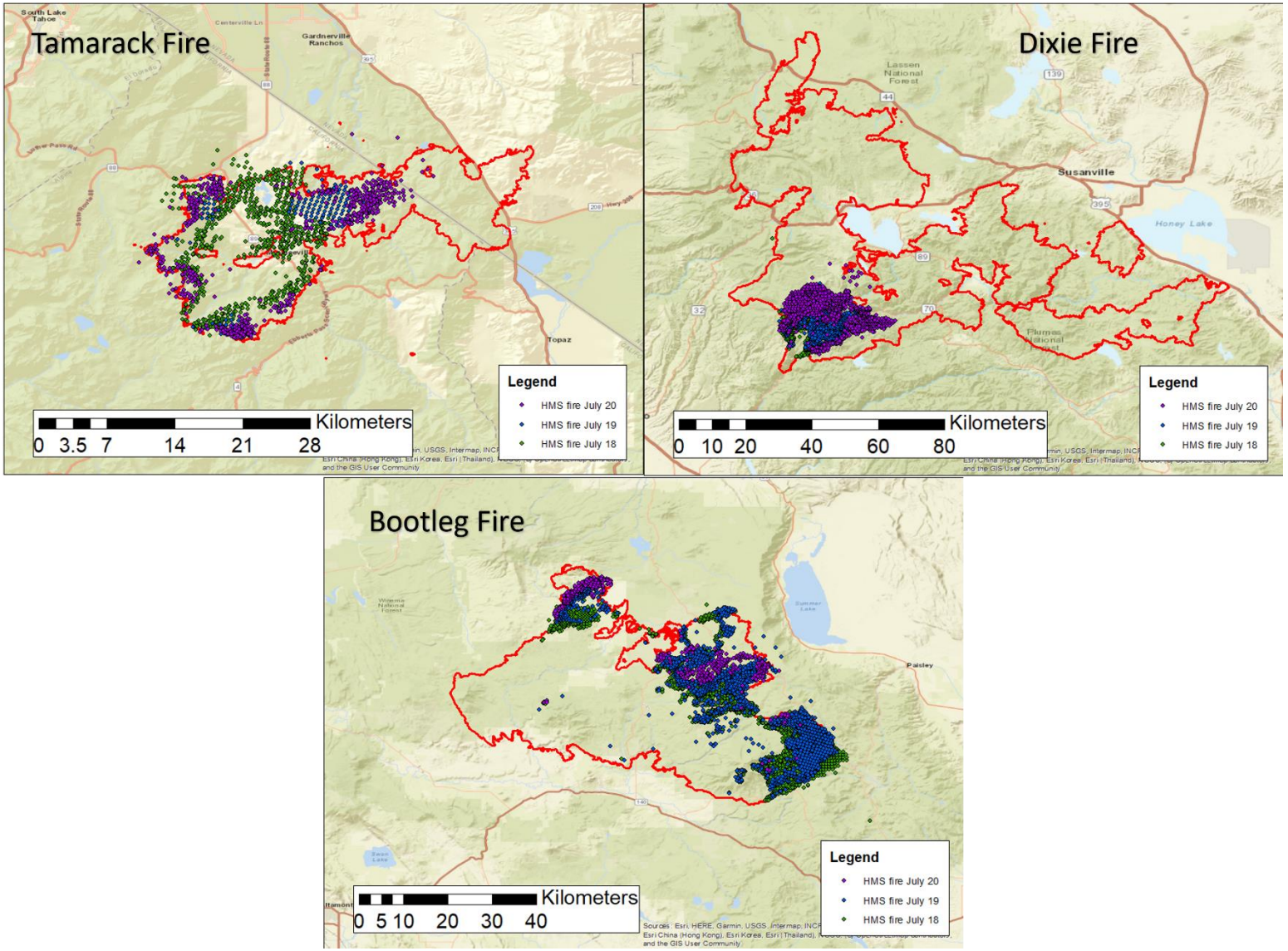

Figure 69. Final fire perimeters (red) and HMS fire detections for the Tamarack, Dixie, and Bootleg Fires from July 18-20, 2021.

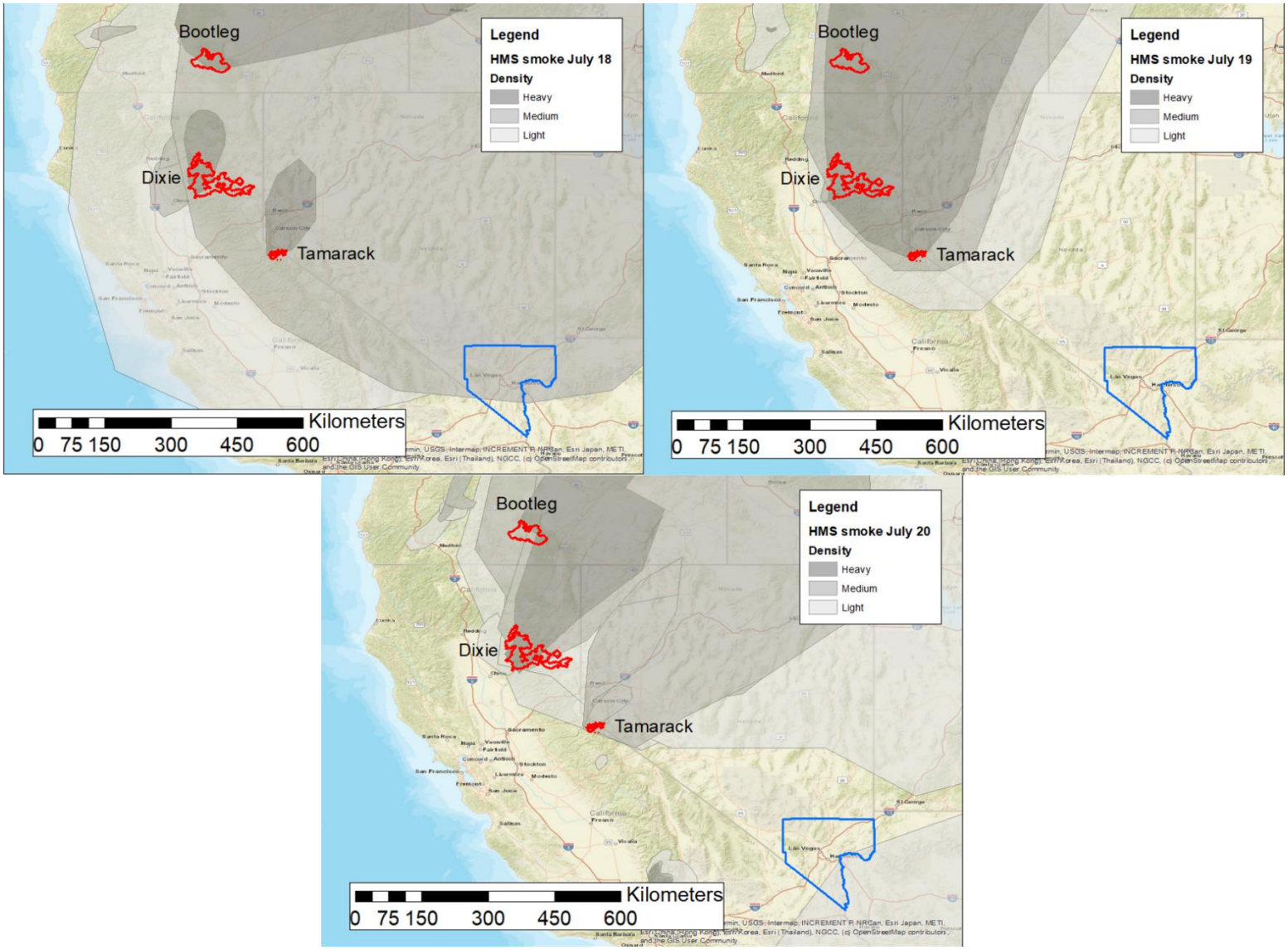

Figure 70. Maps of HMS smoke boundaries for July 18-20, 2021, with qualitative smoke density. Fire perimeters from the major fires contributing to the exclusion date are shown in red and the Clark County, NV, boundary is shown in blue.

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.

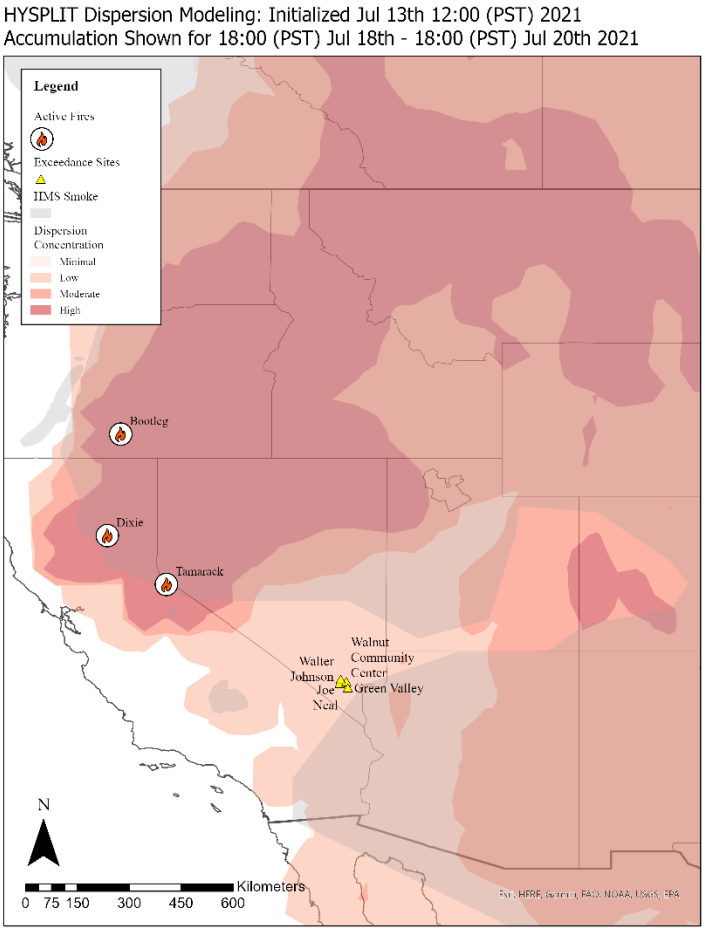

Figure 71. HYSPLIT dispersion modeling for three large fires (labeled as "Active Fires") in California and Oregon. GDAS 1.0° meteorological data was used, and dispersion was initiated on July 13, 2021, at 12:00 PST to model the regional smoke observed in satellite and HMS products. HMS smoke is shown 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.

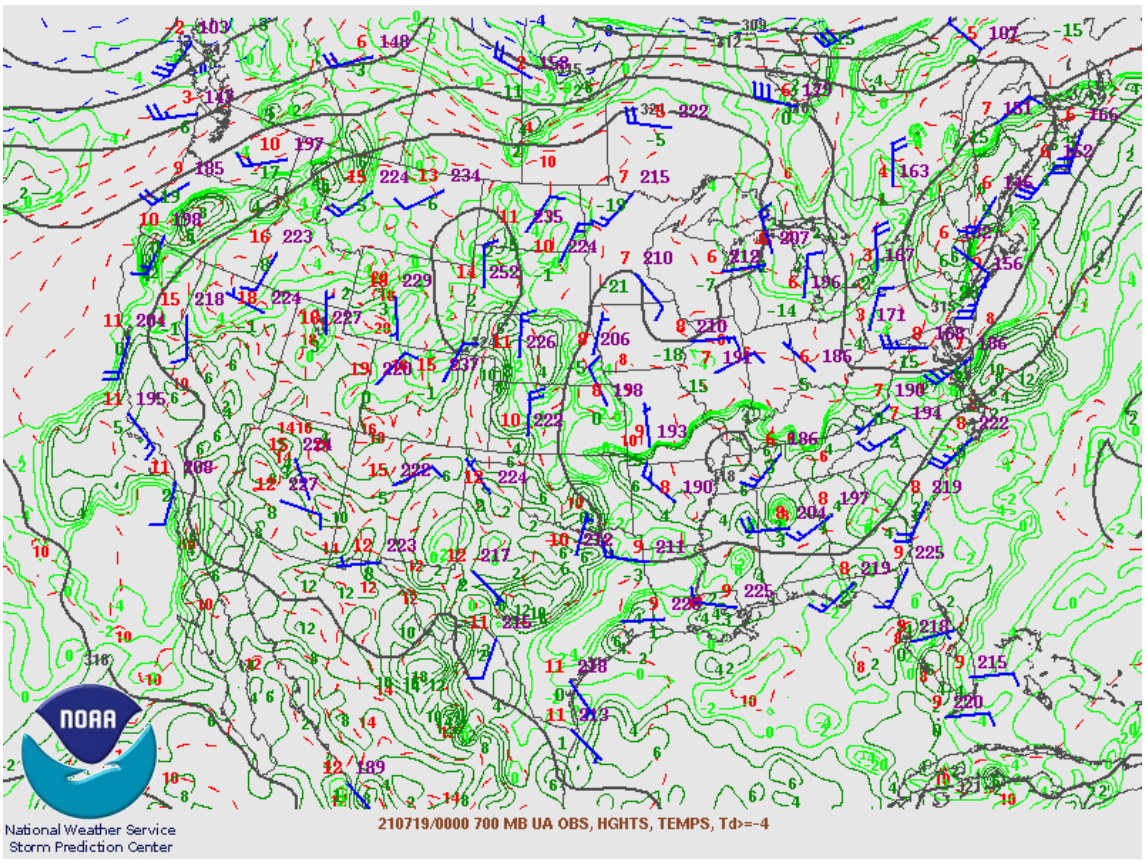

Figure 72. 700-mb map valid at 00:00 UTC on July 19, 2021 (16:00 PST on July 18, 2021). Upper-level high pressure along the Nevada/Utah border generated southeasterly winds aloft into southern Nevada, allowing smoke to be transported into Clark County.

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).

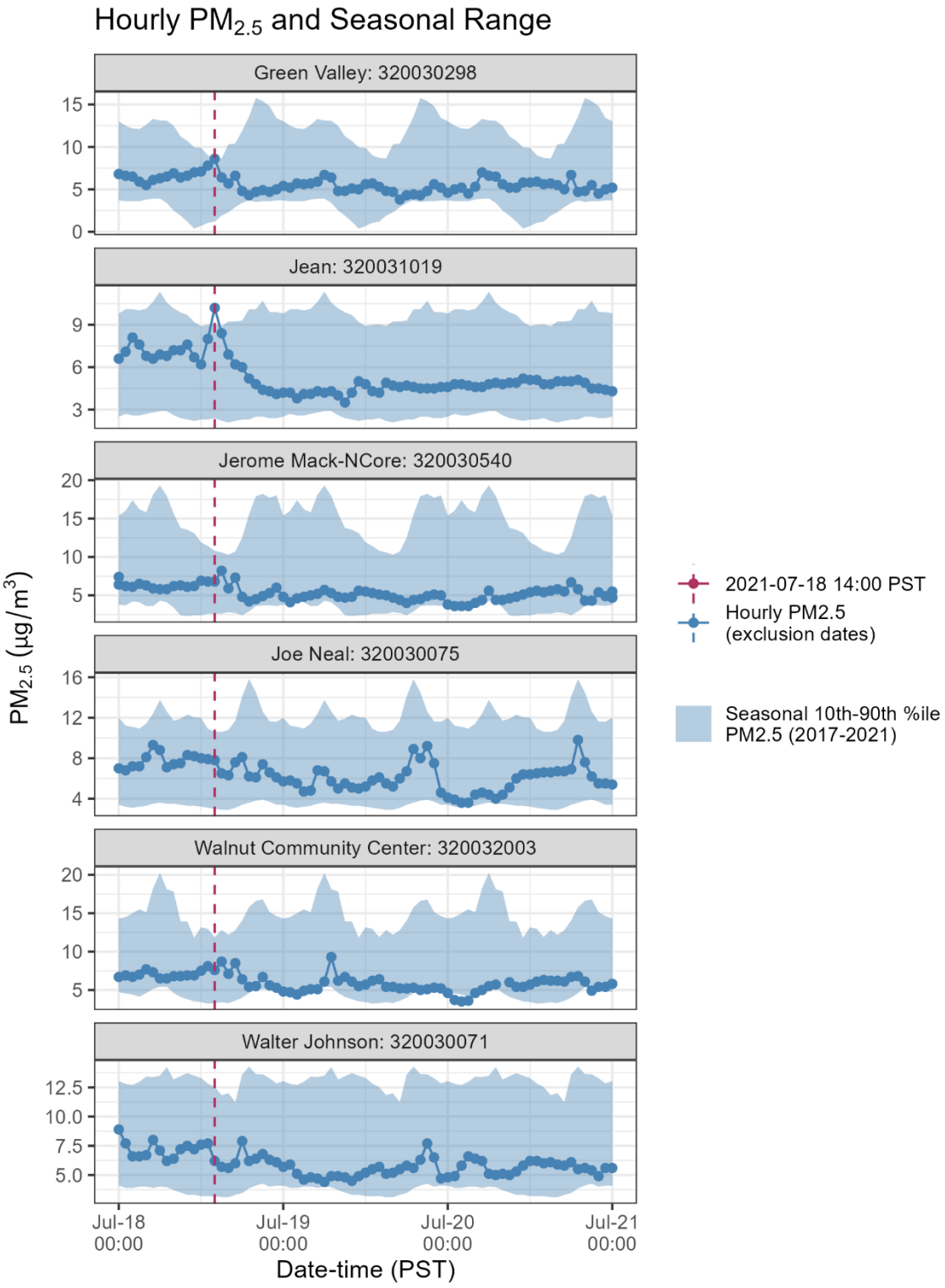

Figure 73. Hourly $PM_{2.5}$ measurements overlaid on the 10th-90th percentile diurnal concentration at the affected sites. The dashed line is 14:00 PST on July 18, 2021. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

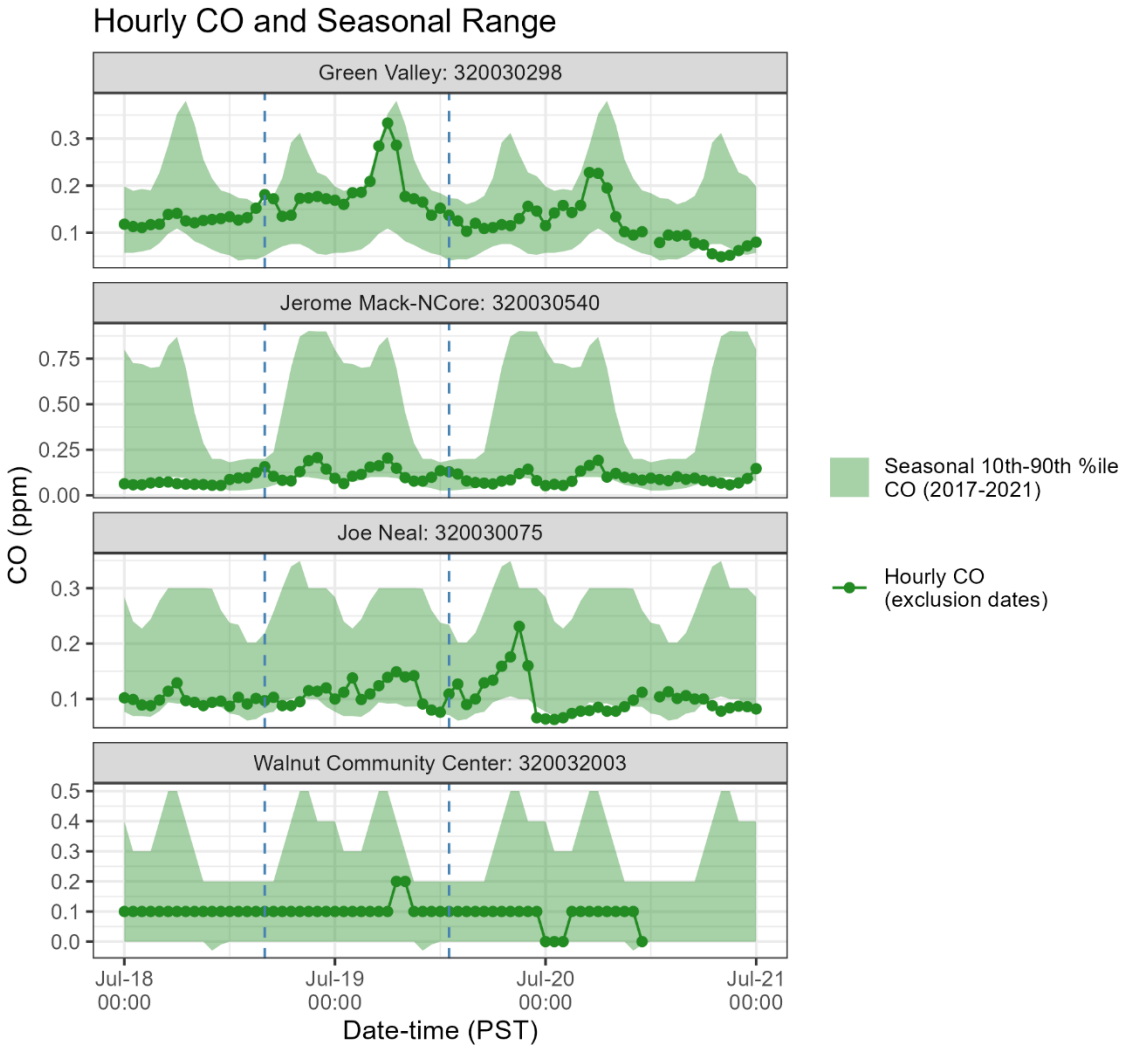

Figure 74. Hourly CO measurements overlaid on the 10th-90th percentile diurnal concentration at representative (Jerome Mack-NCore) and affected sites (Green Valley, Joe Neal, and Walnut Community Center). The dashed lines are (1) 13:00 PST on July 18, 2021, and (2) 16:00 PST on July 19, 2021. The 10th-90th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

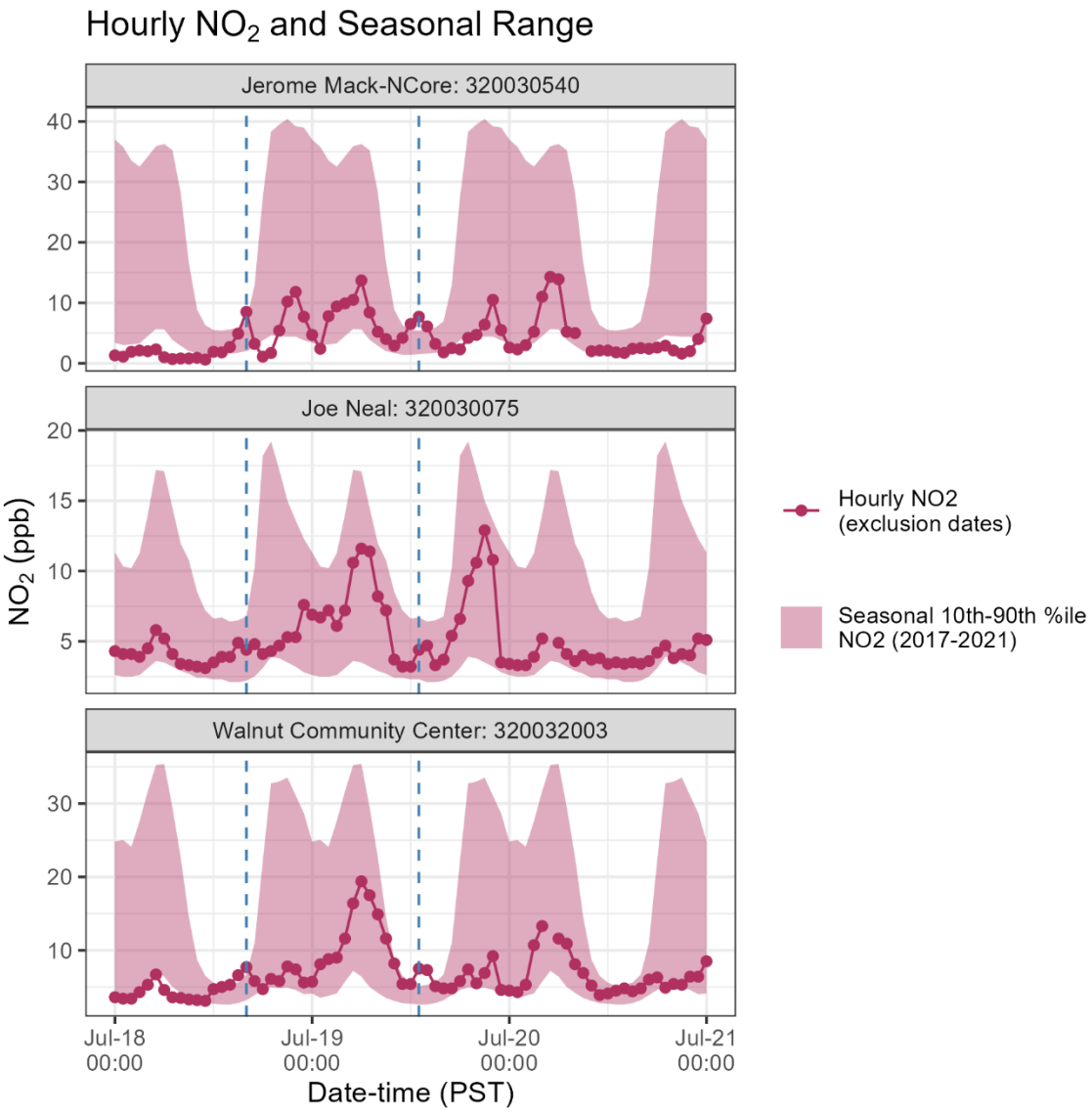

Figure 75. Hourly NO_2 measurements overlaid on the 10th-90th percentile diurnal concentration at representative (Jerome Mack-NCore) and affected sites (Joe Neal and Walnut Community Center). The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

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.

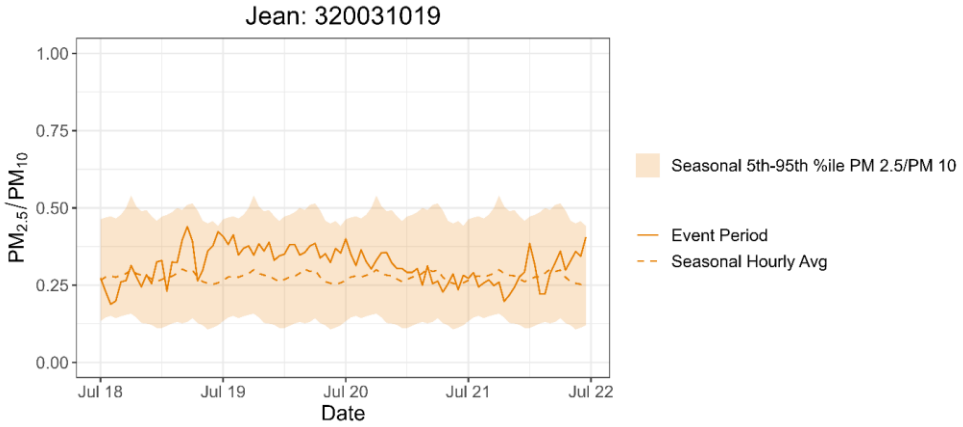

Figure 76. Ratio of $PM_{2.5}$-to-PM_{10} concentrations at the Jean site before and during the July 20 event period. The 5-yr average $PM_{2.5}$-to-PM_{10} diurnal ratio is displayed as a dotted line, and the 5th-95th percentile range is shown as a shaded ribbon. The 5th-95th percentile concentration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

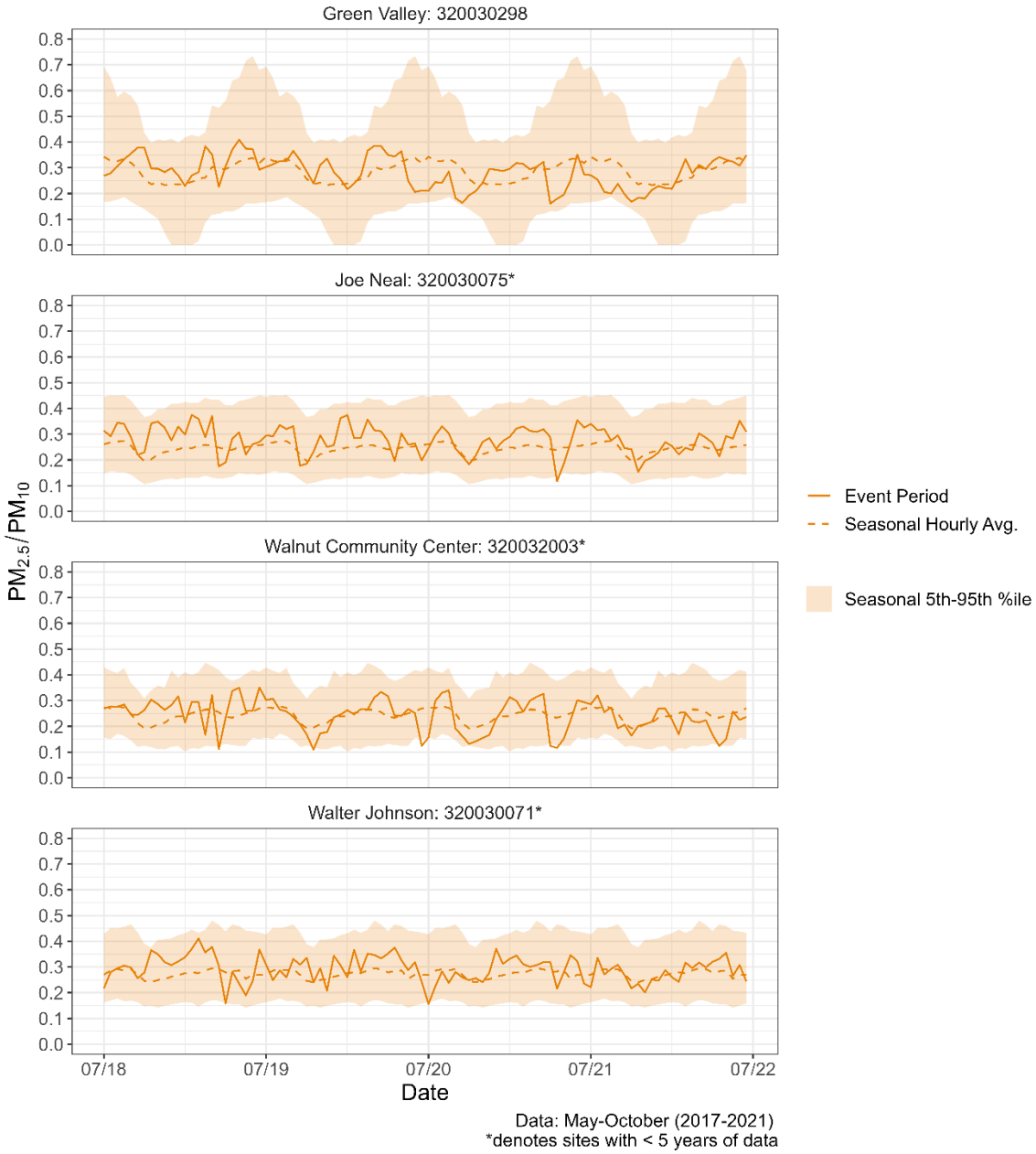

Figure 77. Ratio of $PM_{2.5}$-to-PM_{10} concentrations at all affected sites before and during the July 20 event period. The 5-yr average $PM_{2.5}$-to-PM_{10} diurnal ratio is displayed as a dotted line, and the 5th-95th percentile range is shown as a shaded ribbon. The 5th-95th percentile concentration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

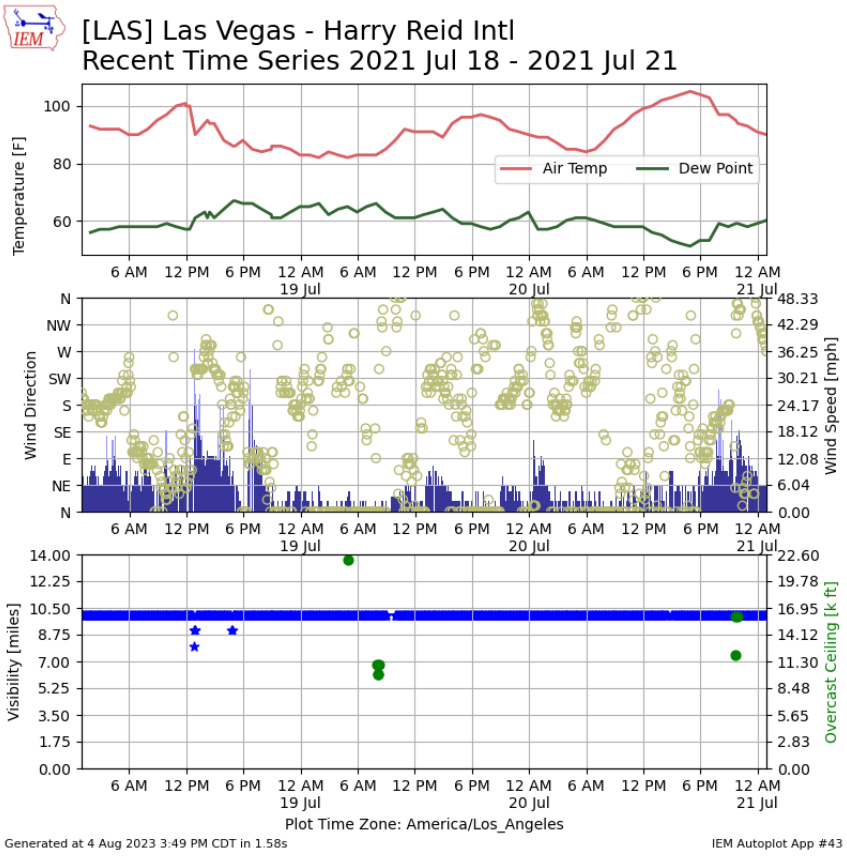

Figure 78. Timeseries of hourly ASOS temperature, wind, visibility measurements at the Harry Reid International Airport, beginning July 18, 2021. Light and variable winds from the evening of July 18 through July 20 allowed pollutants to accumulate in southern Clark County, NV.

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 ($\mu g/m^3$)	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 Mountains Edge Park, 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 Mountains Edge Park, 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**.

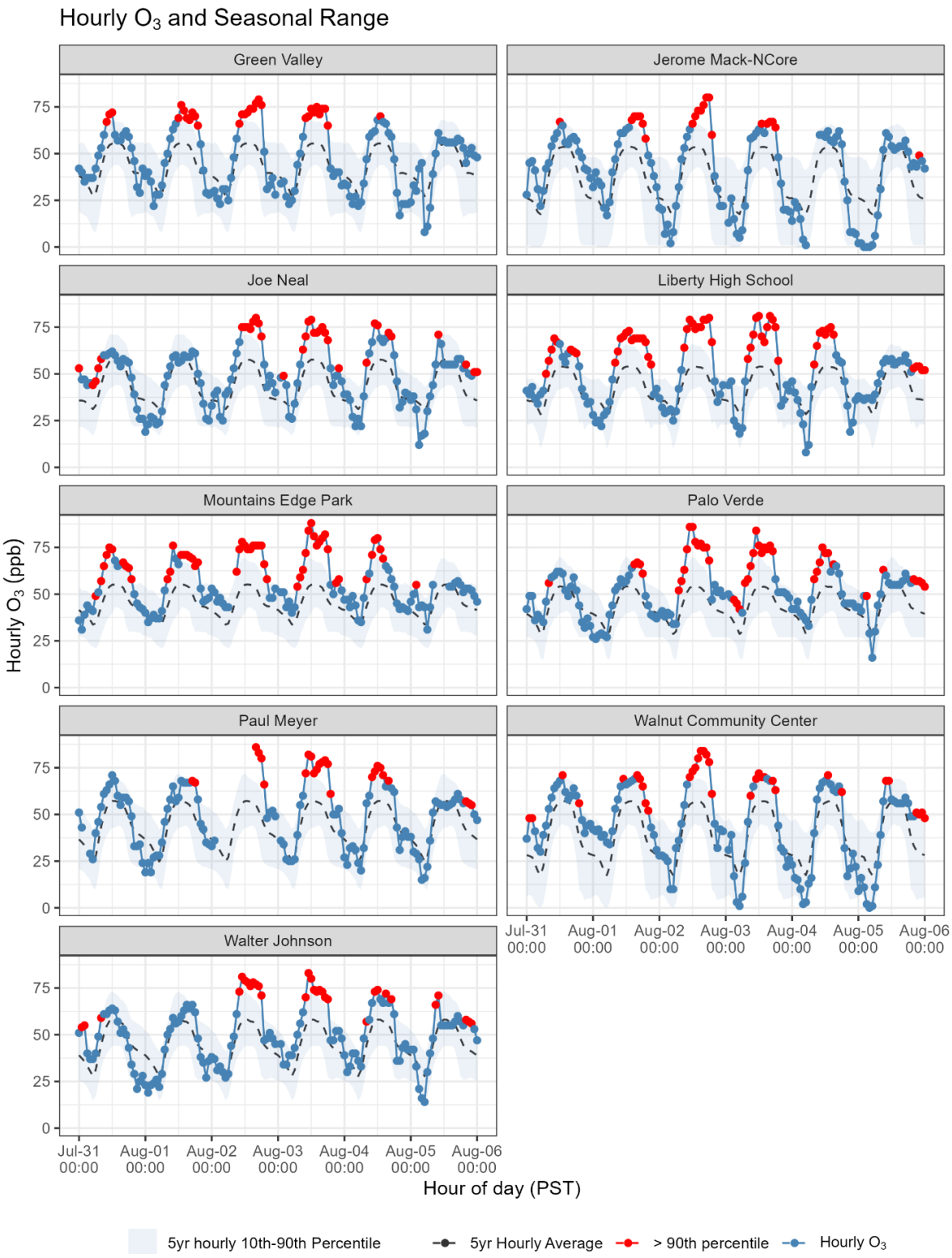

Figure 79. Hourly ozone concentrations (ppb) compared to 5-yr* ozone season (May 1-October 31) hourly means and 10-90th percentiles. *Note: data from the Liberty High School, Mountains Edge Park, and Walnut Community Center sites began less than five years ago.

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]

[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.

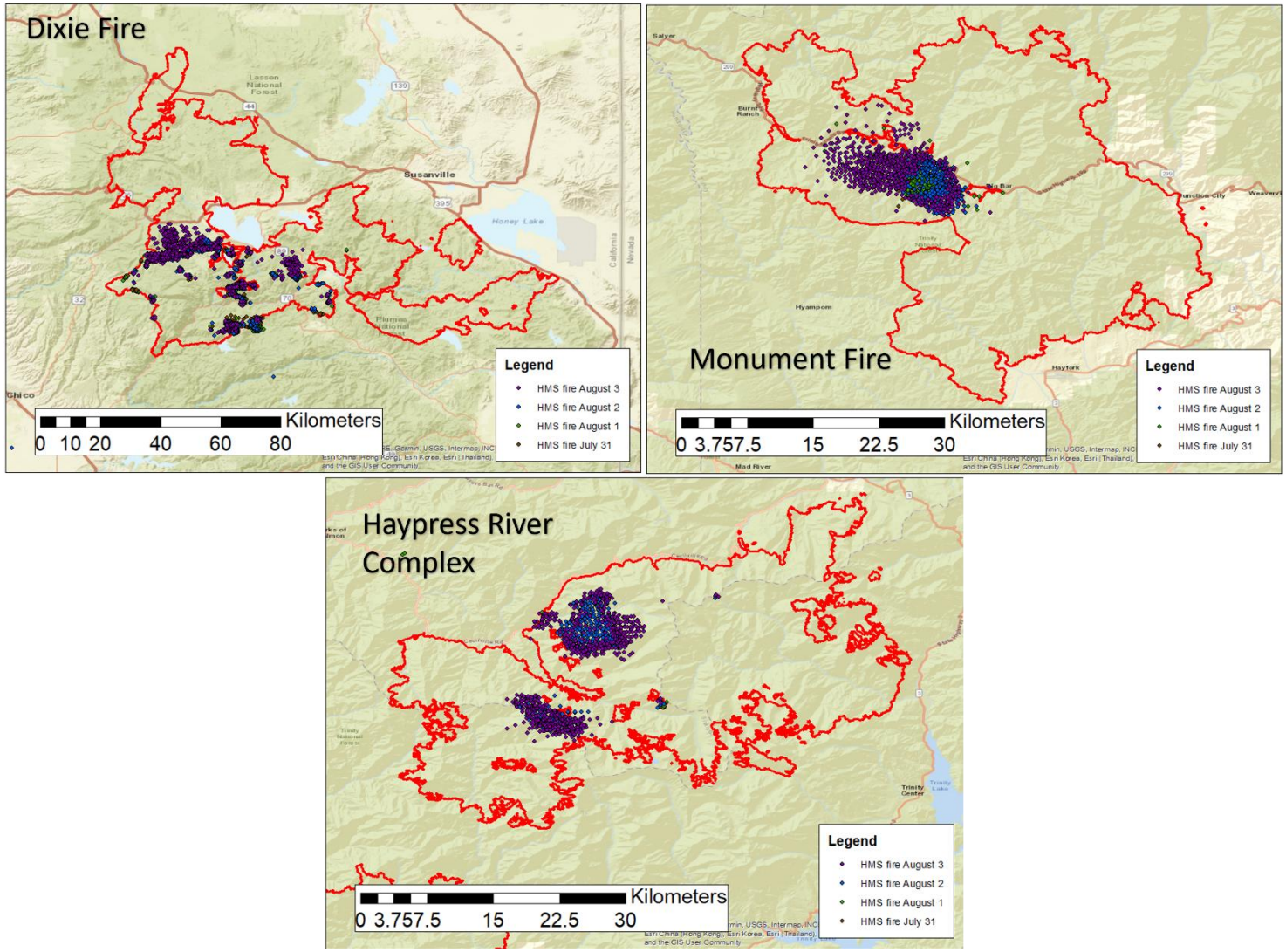

Figure 80. Final fire perimeters (red) and HMS fire detections for the Dixie, Monument, and Haypress River Complex Fires during July 31-August 3, 2021.

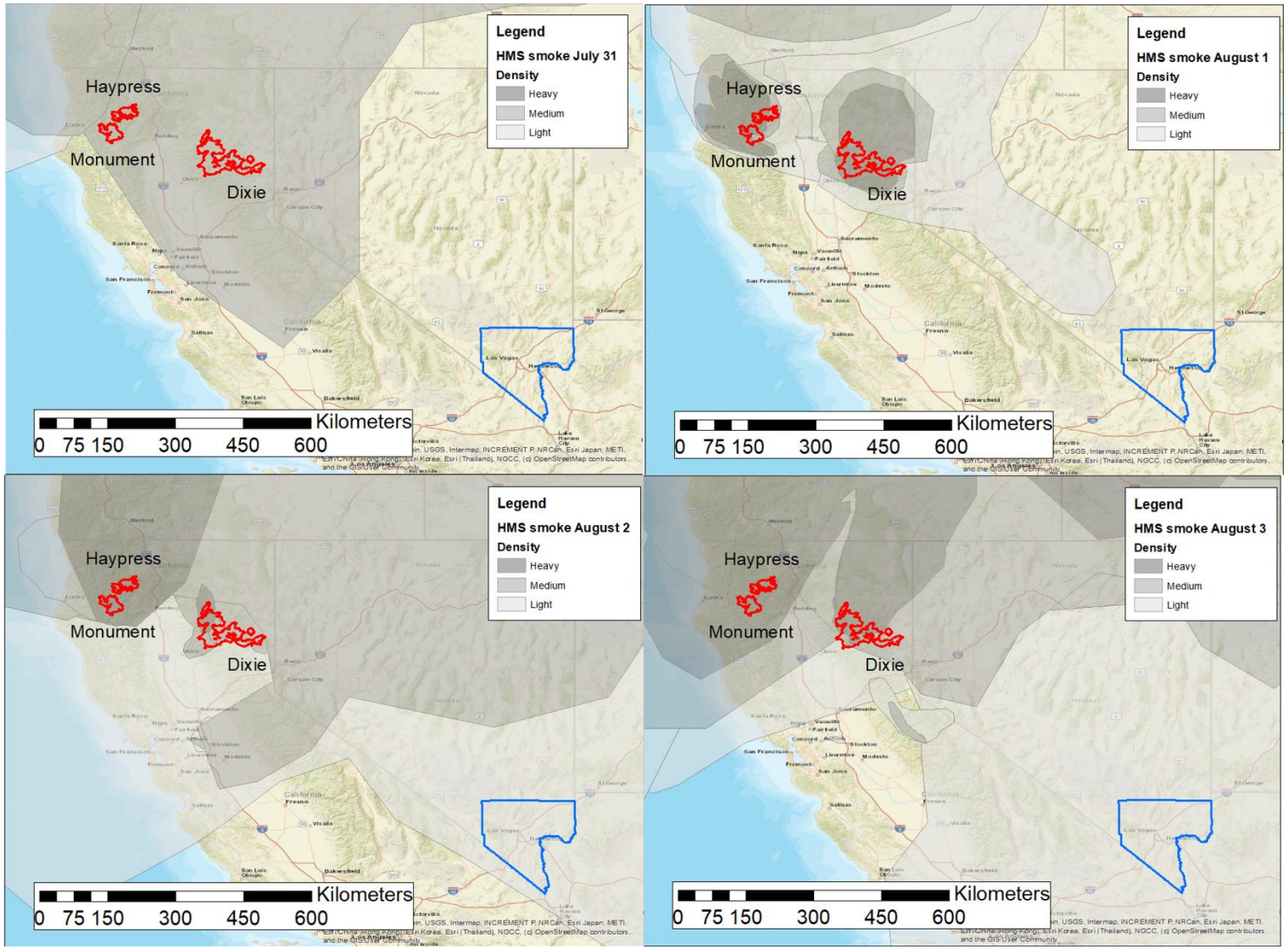

Figure 81. HMS smoke boundaries for July 31-August 3, 2021, with qualitative smoke density. Fire perimeters from the major fires contributing to the exclusion date are shown in red and the Clark County, NV, boundary is shown in blue.

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.

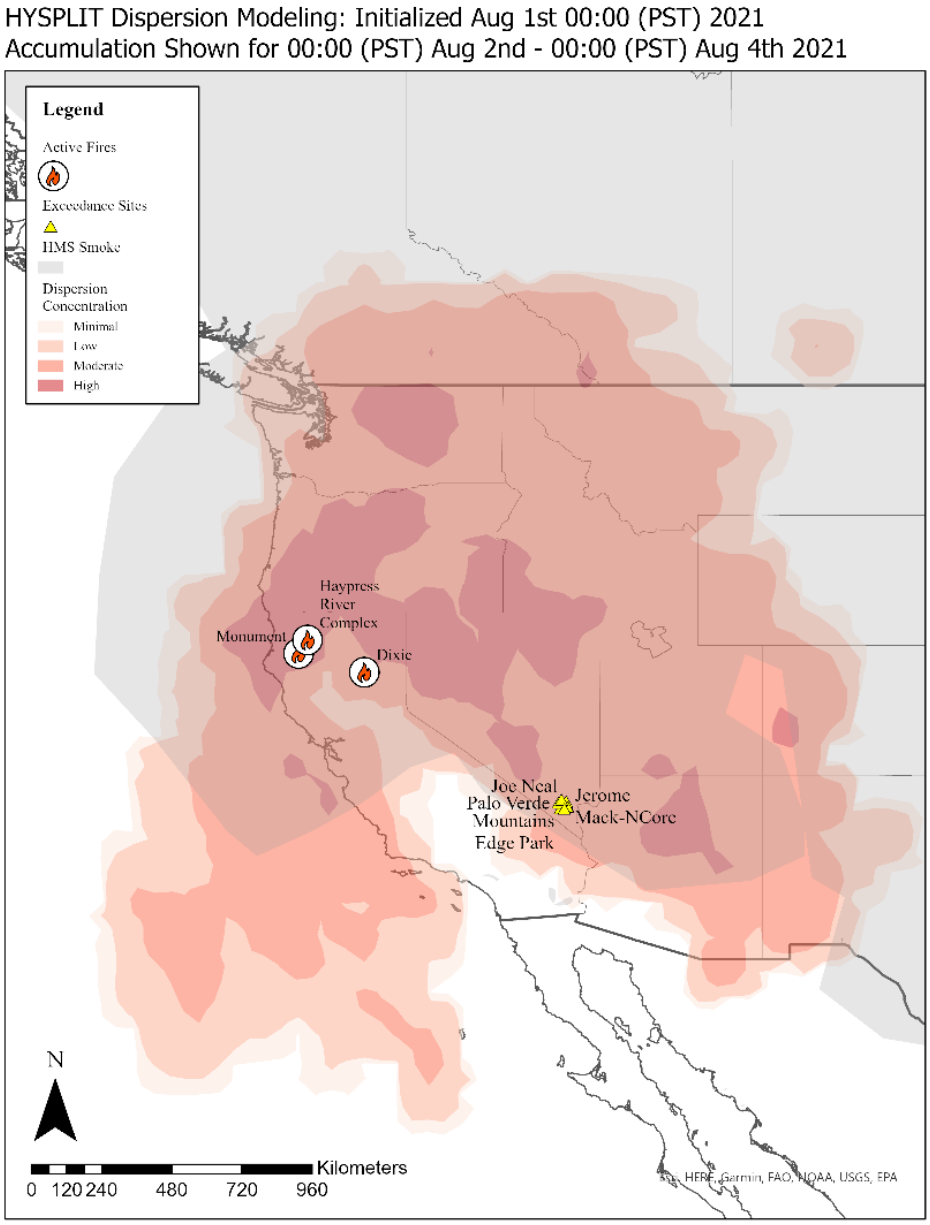

Figure 82. Results of the HYSPLIT dispersion modeling for three large fires (labeled as "Active Fires") in California. GDAS 1.0° meteorological data was used, and dispersion was initiated on August 1, 2021, at 00:00 PST to model the regional smoke observed in satellite and HMS products. HMS smoke is 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).

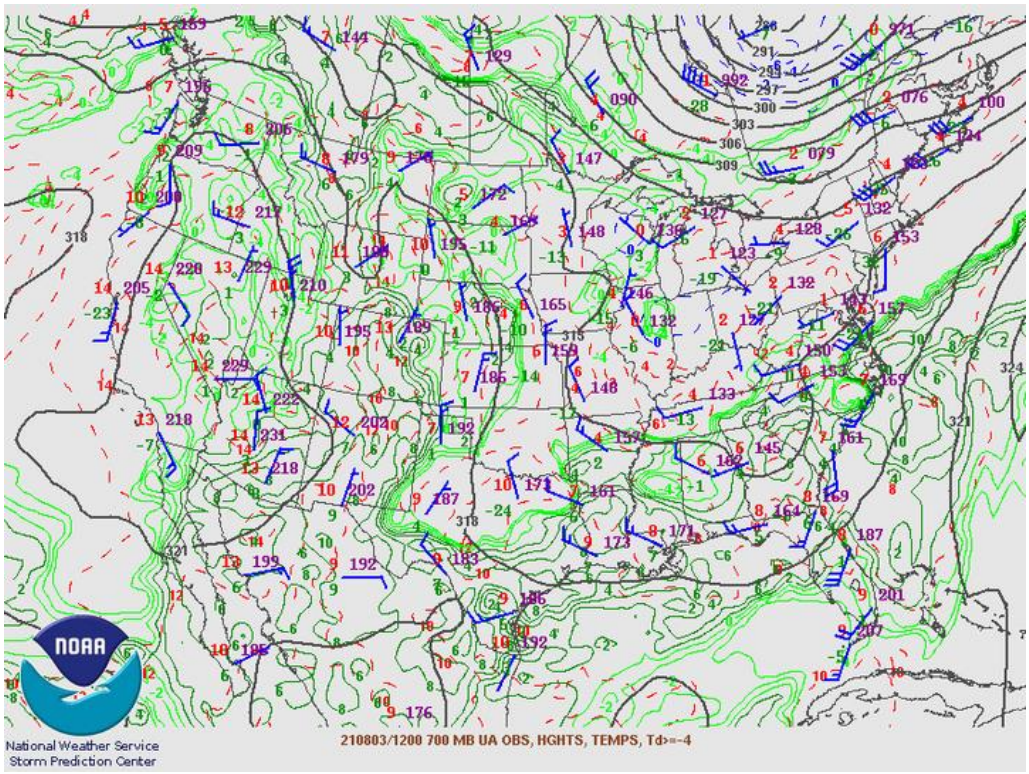

Figure 83. 700-mb map valid at 12:00 UTC (04:00 PST) on August 3, 2021. Upper-level high pressure over Nevada aided widespread transport of smoke into Clark County, NV.

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.

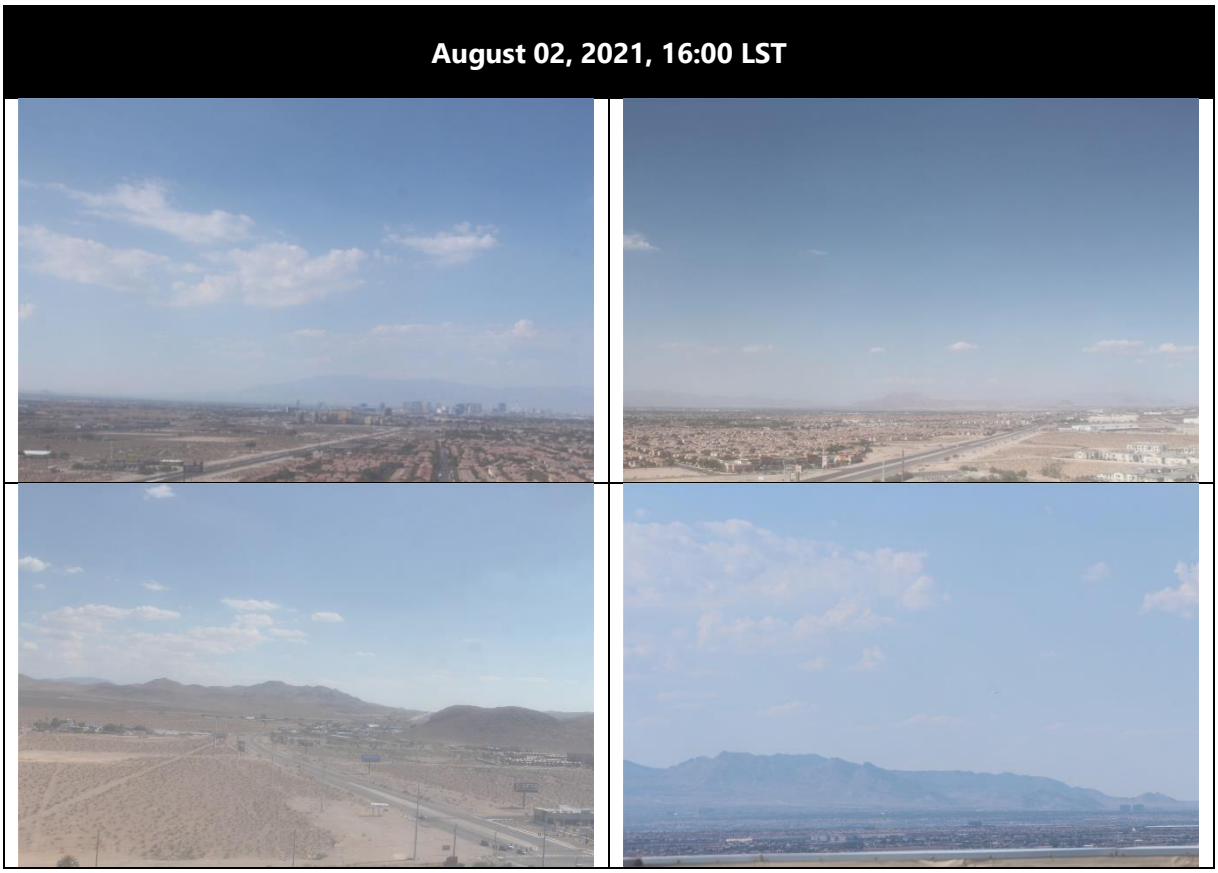

Figure 85. Camera images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions taken from the M Resort Hotel in Clark County, NV, on August 2 at 16:00 LST.

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.

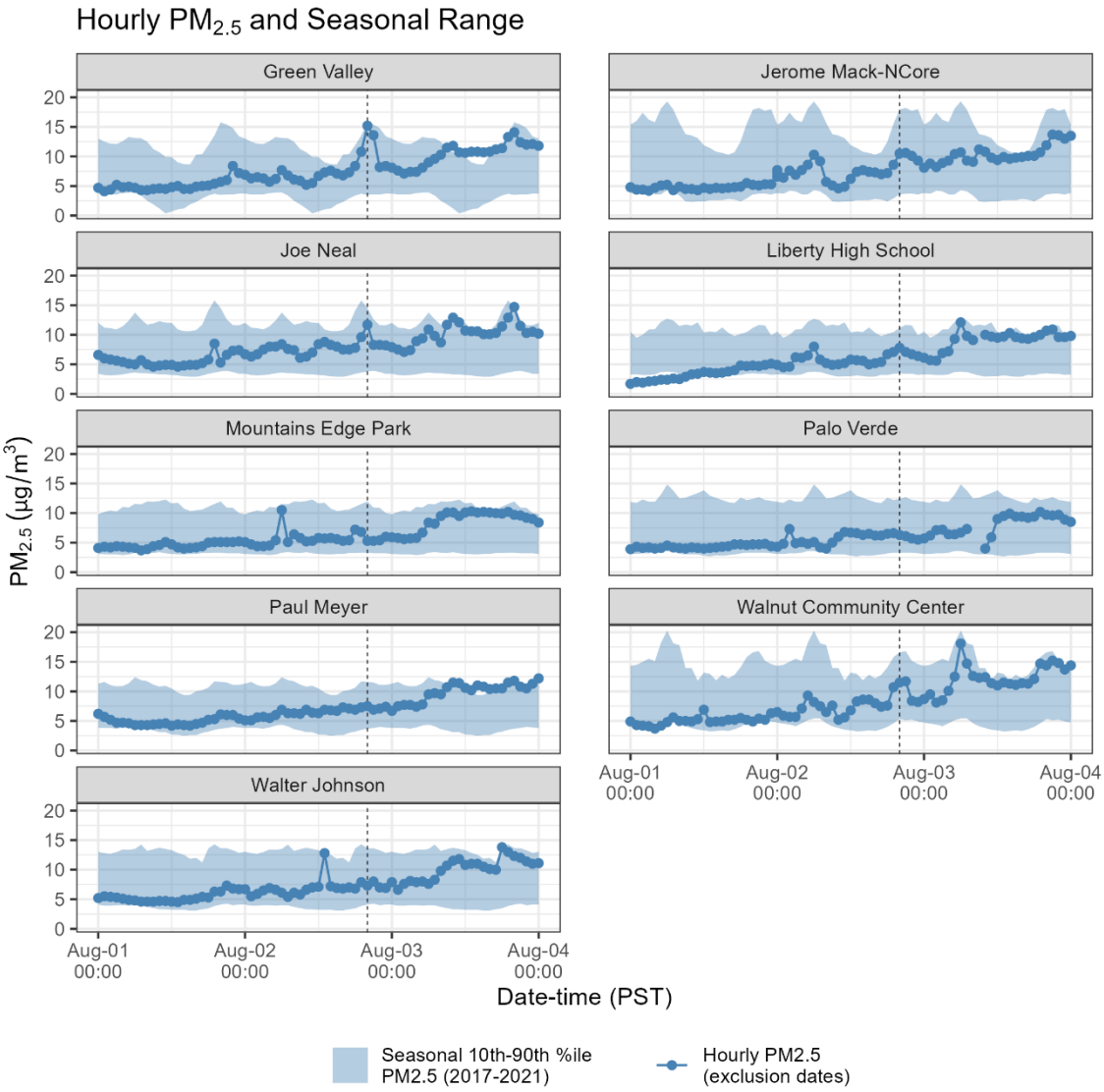

Figure 87. Hourly $PM_{2.5}$ measurements overlaid on the 10th-90th percentile diurnal concentration at affected sites. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021. The dashed line is August 2, 2021, at 20:00 PST.

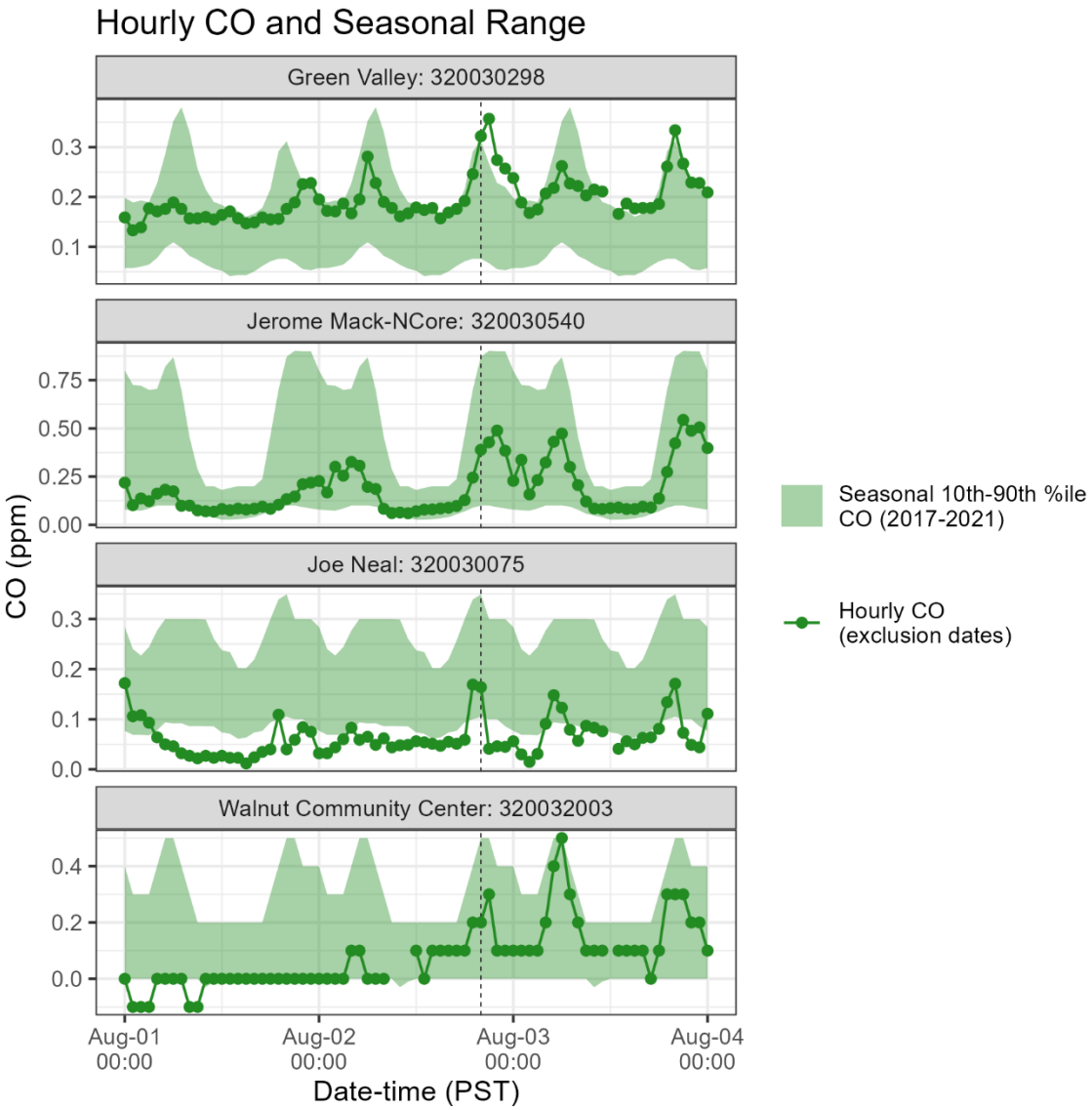

Figure 88. Hourly CO measurements overlaid on the 10th-90th percentile diurnal concentration at affected sites. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021. The dashed line is August 2, 2021, at 20:00 PST.

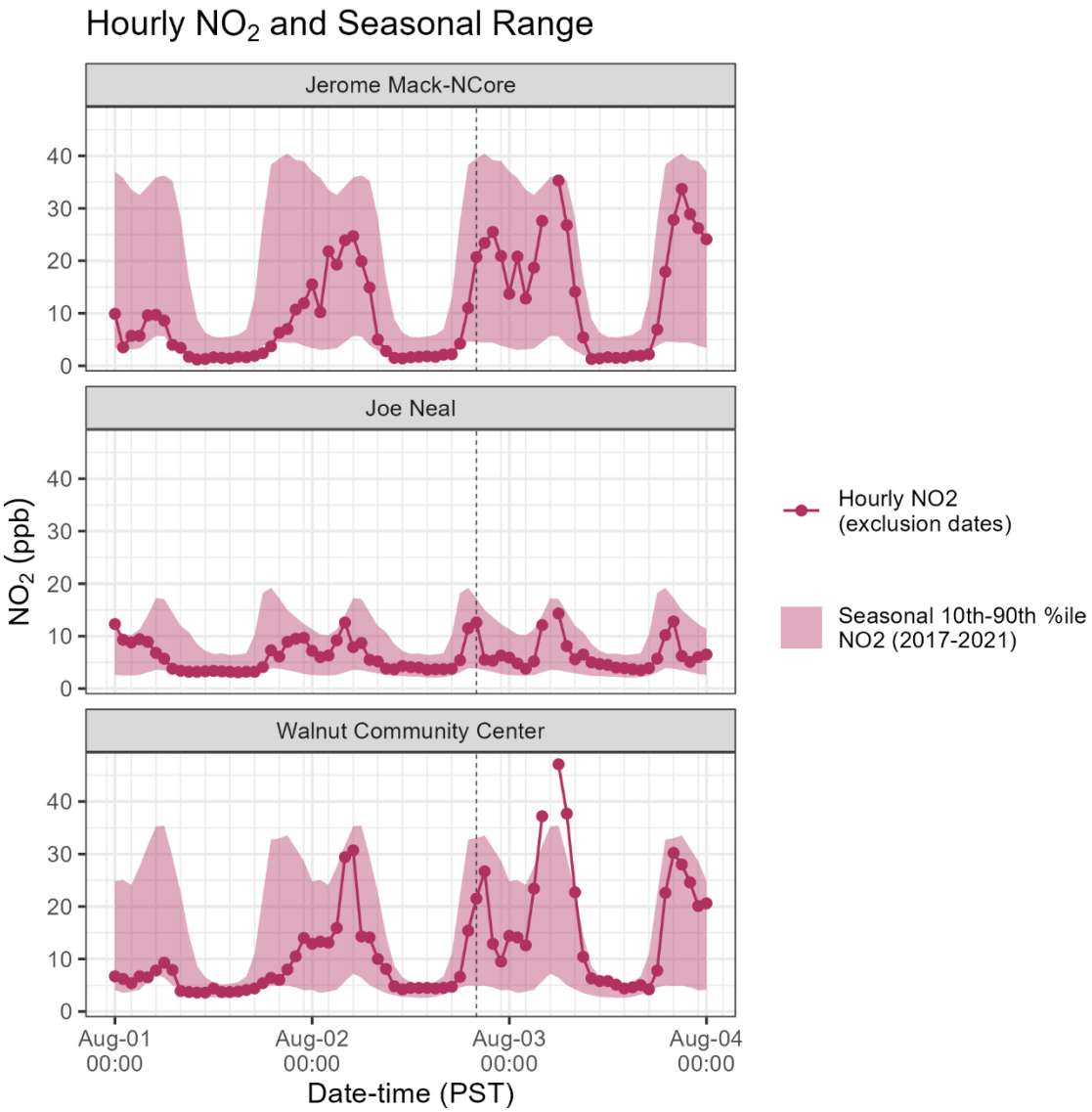

Figure 89. Hourly NO_2 measurements overlaid on the 10th-90th percentile diurnal concentration at affected sites. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021. The dashed line is August 2, 2021, at 20:00 PST.

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.

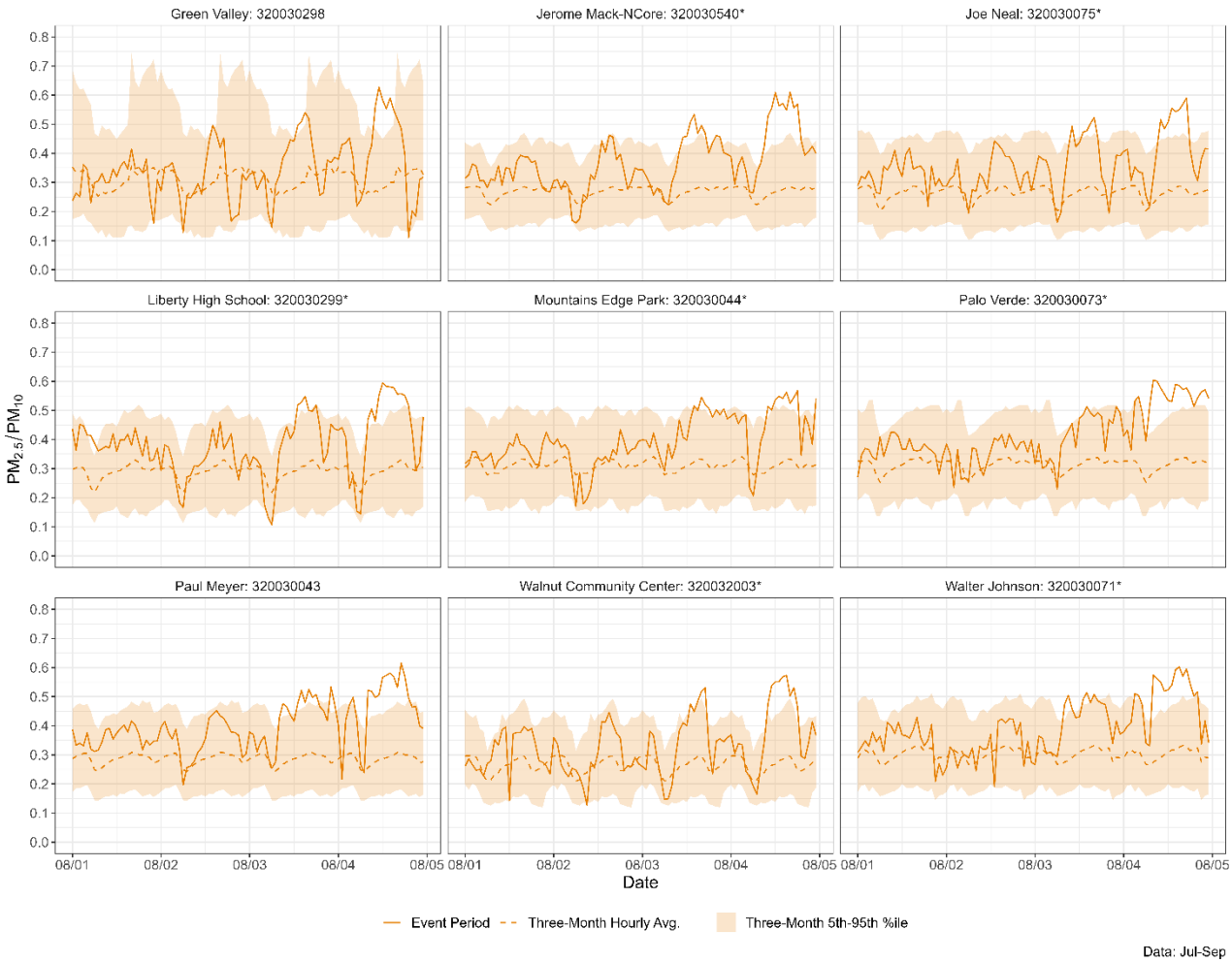

Figure 90. Ratio of $PM_{2.5}$-to-PM_{10} concentrations at affected sites, before and during the August 2 and 3 event period. The 5-yr* average $PM_{2.5}$-to-PM_{10} diurnal ratio is displayed as a dotted line, and the 5th-95th percentile range is shown as a shaded ribbon. The 5th-95th percentile concentration 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*	--	--	--	--
	Mountains Edge Park	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*	--	--	--	--
	Mountains Edge Park	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.

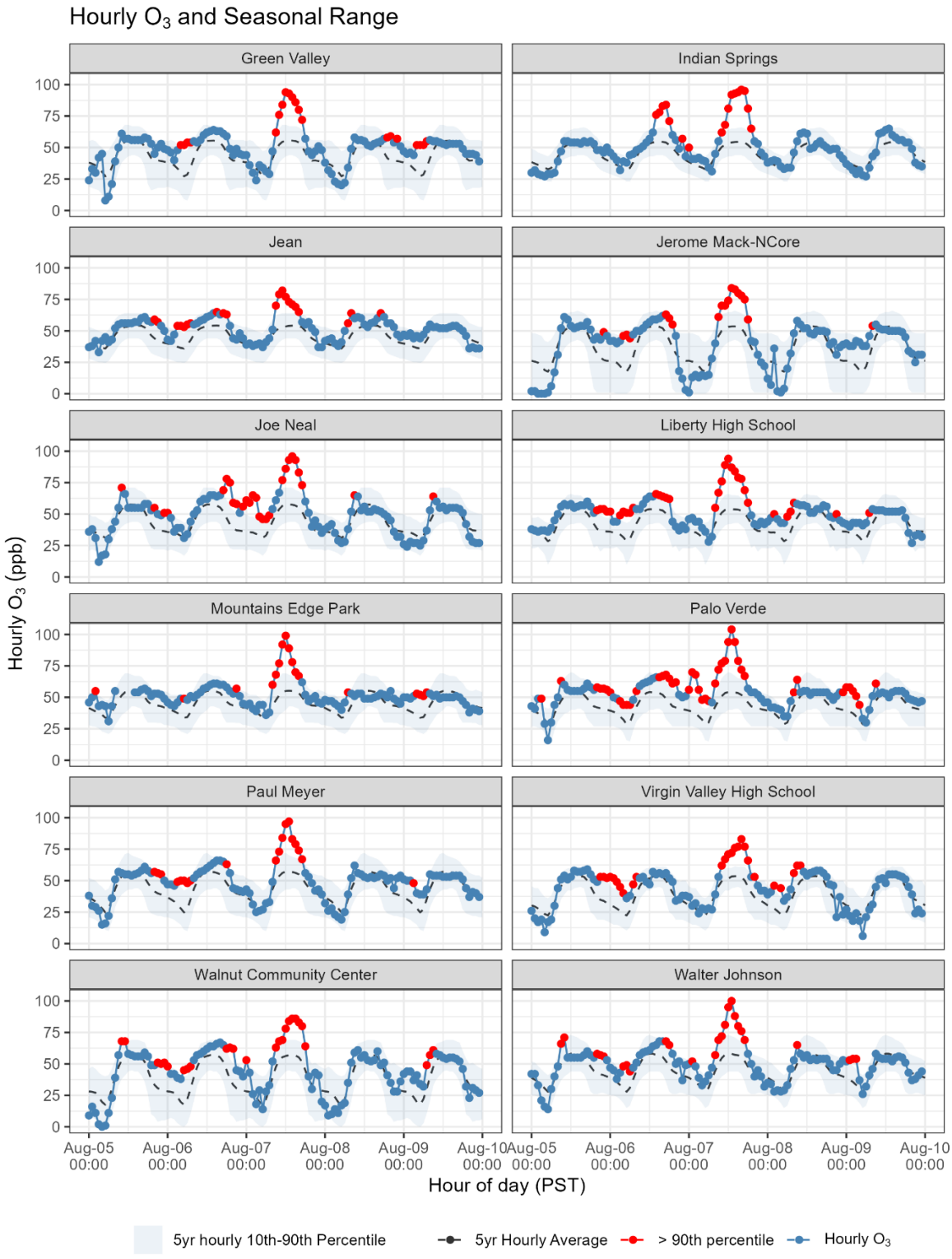

Figure 91. Hourly ozone concentrations (ppb) compared to 5-yr* ozone season (May 1-October 31) hourly means and 10-90th percentiles. *Note: data collection began in 2020 at the Mountains Edge Park site, and in 2021 at the Liberty High School, Virgin Valley High School, and Walnut Community Center sites.

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]

[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.

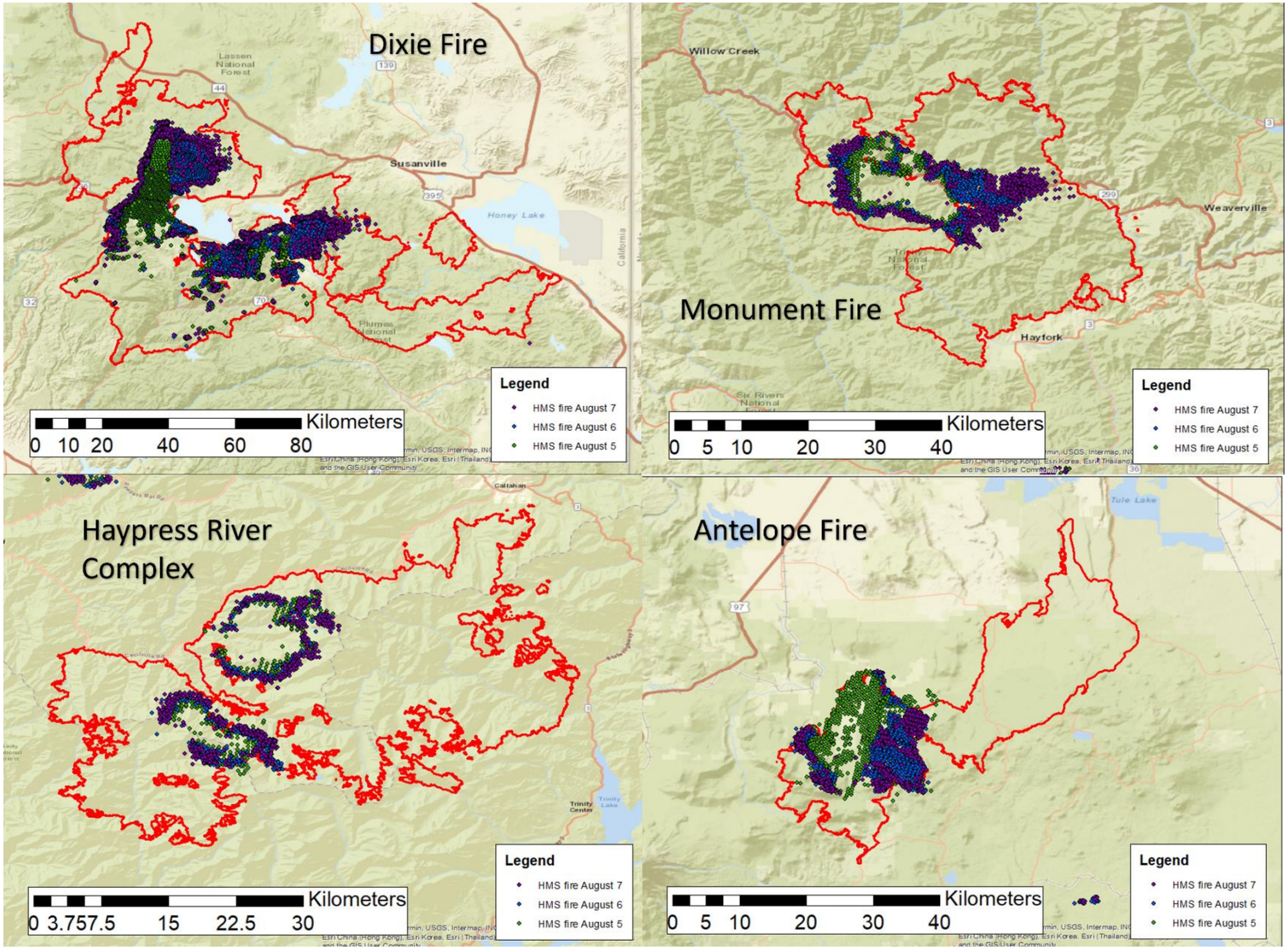

Figure 92. Final fire perimeters (red) and HMS fire detections for the Dixie, Monument, Haypress River Complex, and Antelope Fires during August 5-7, 2021.

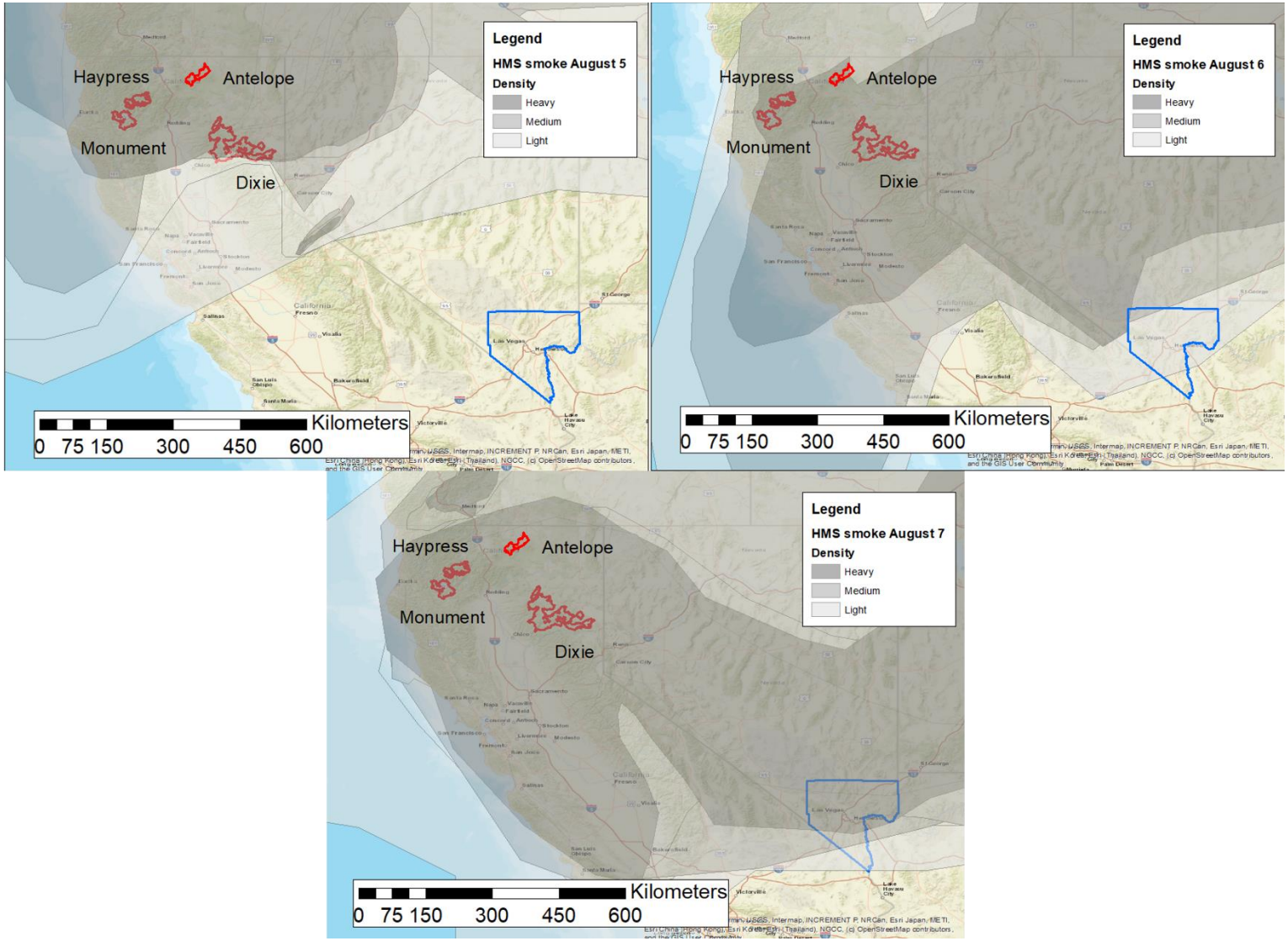

Figure 93. HMS smoke data for August 5-7, 2021, included with qualitative smoke density. Fire perimeters from the major fires contributing to the exclusion date are shown in red and the Clark County, NV, boundary is shown in blue.

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.

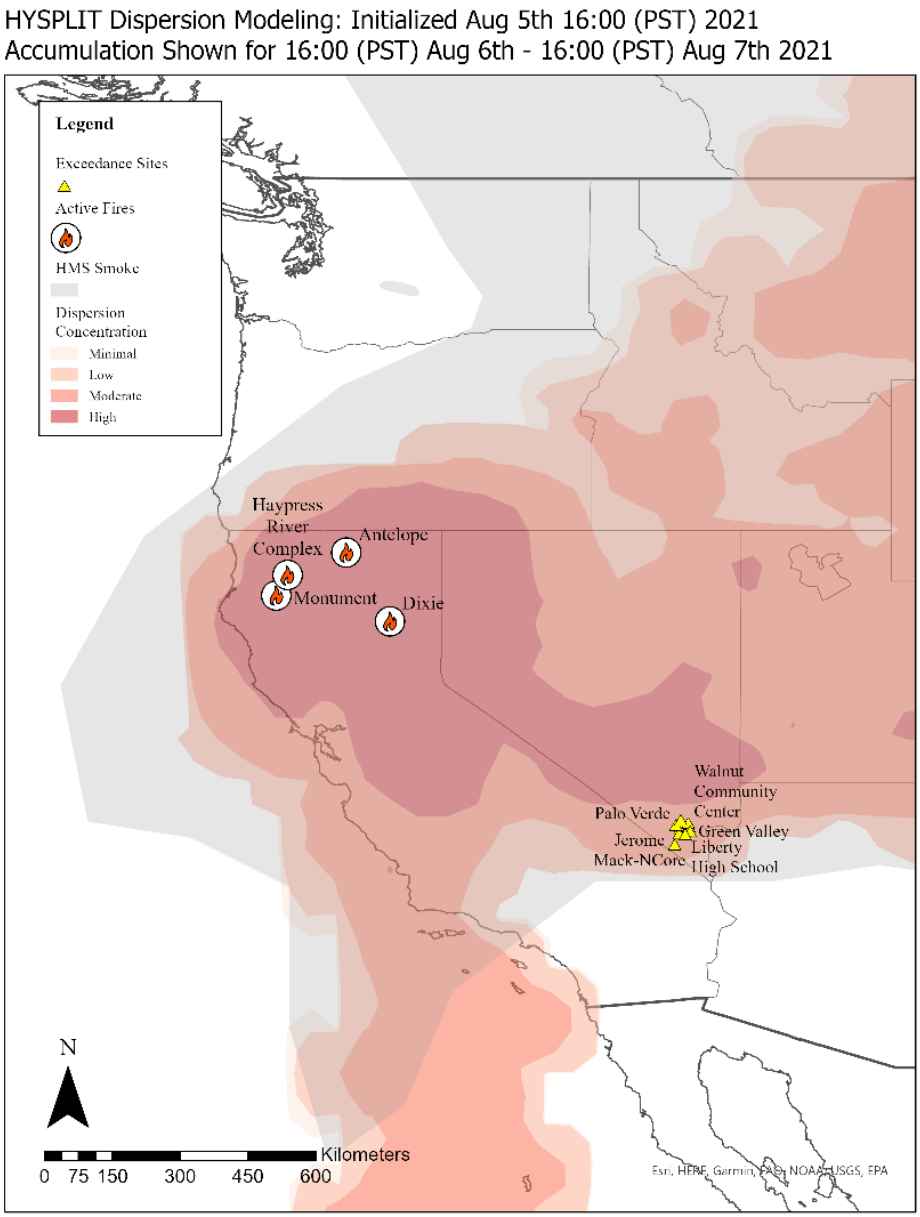

Figure 94. HYSPLIT dispersion modeling for four large fires (labeled as "Active Fires") throughout the western U.S. GDAS 1.0° meteorological data was used, and dispersion was initiated on August 5, 2021, at 16:00 PST to model the regional smoke observed in satellite and HMS products. HMS smoke is shown 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.

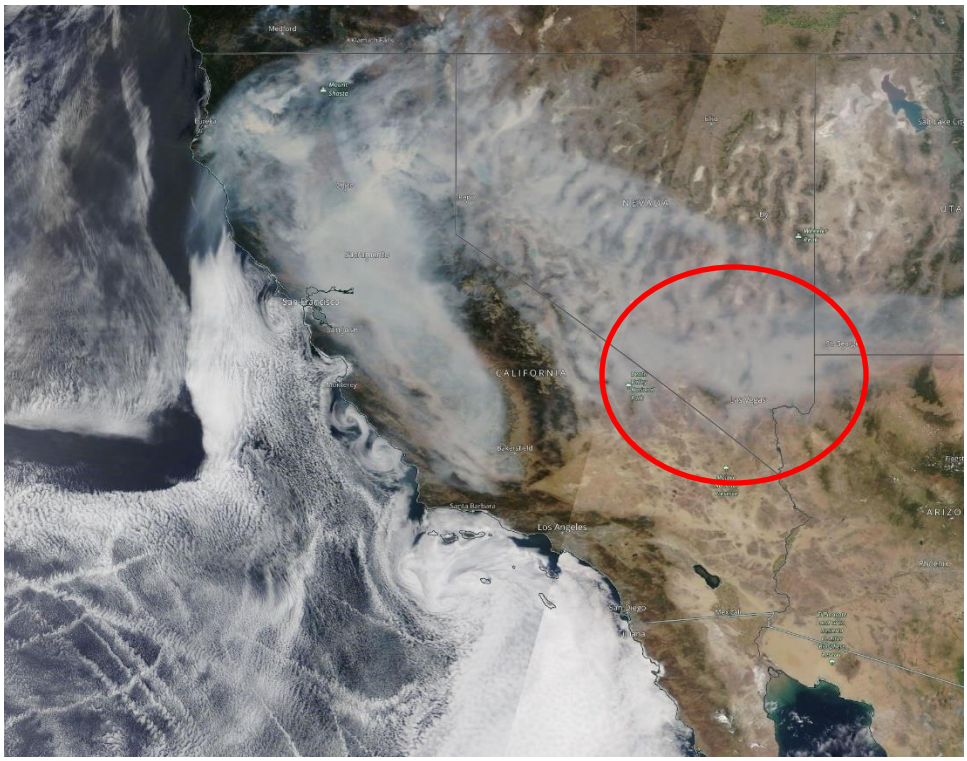

Figure 95. MODIS Terra satellite image valid on August 7, 2021. Smoke from California wildfires is visible across central and southern Nevada. This smoke contributed to poor air quality and reduced visibility in Clark County. The red circle shows the area of smoke over Clark County.

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.

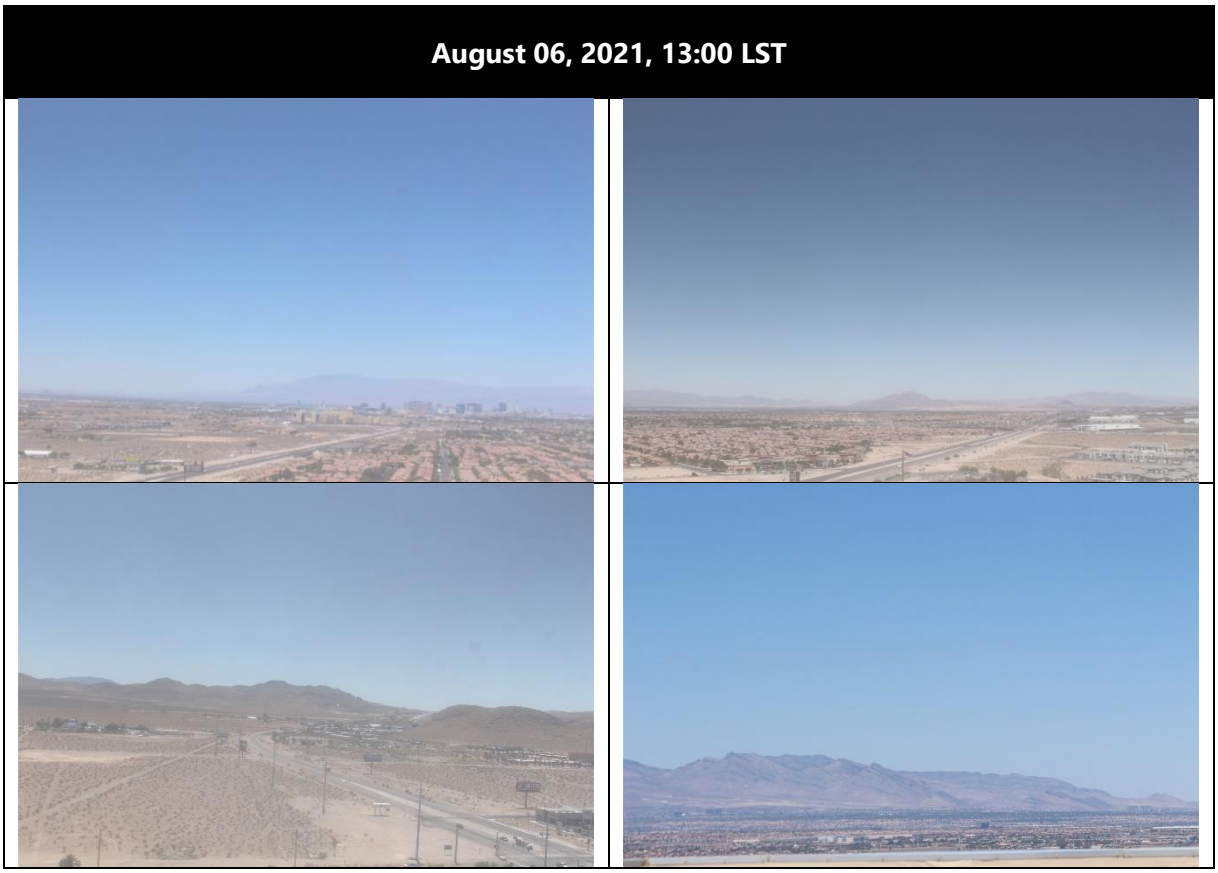

Figure 96. Camera images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions, taken from the M Resort Hotel in Clark County, NV, on August 6, 2021, at 13:00 LST.

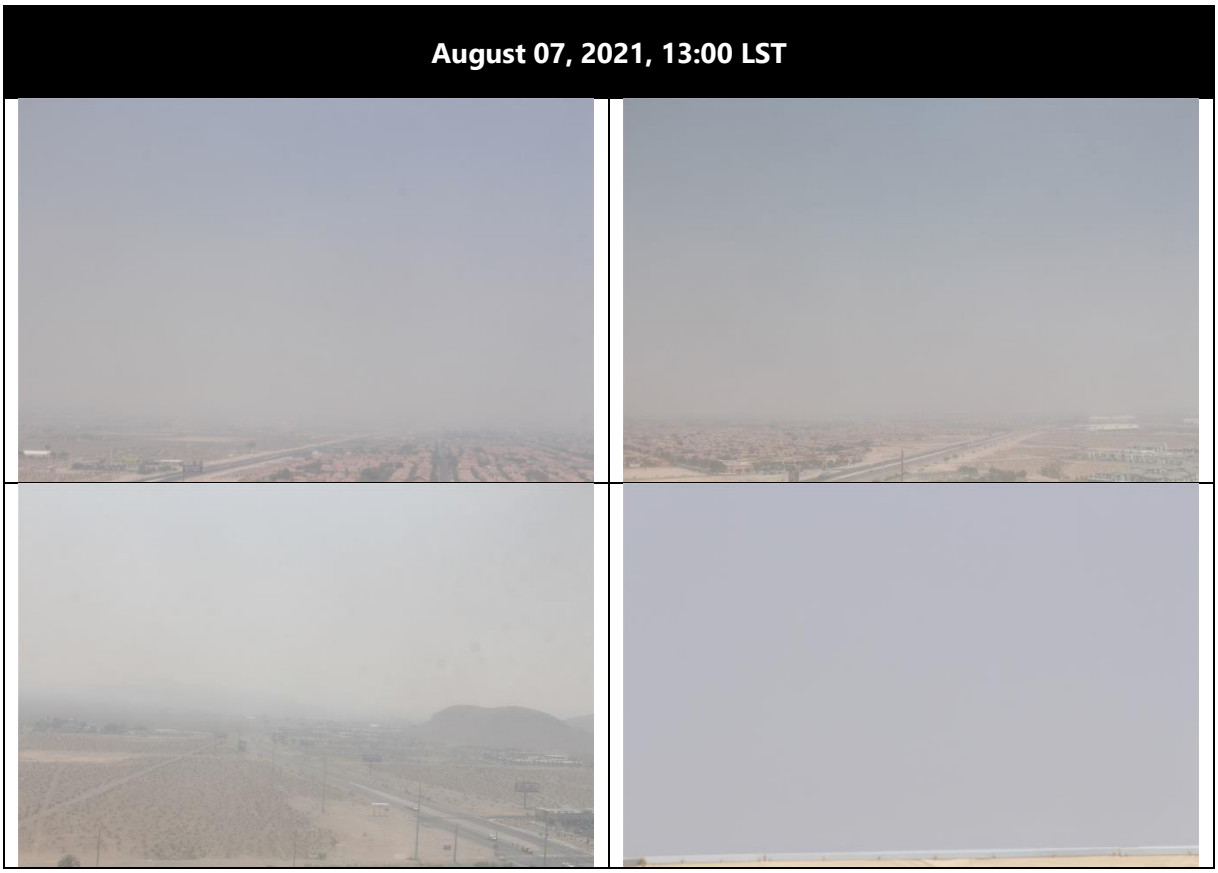

Figure 97. Camera images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions taken from the M Resort Hotel in Clark County, NV, on August 7, 2021, at 13:00 LST.

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**).

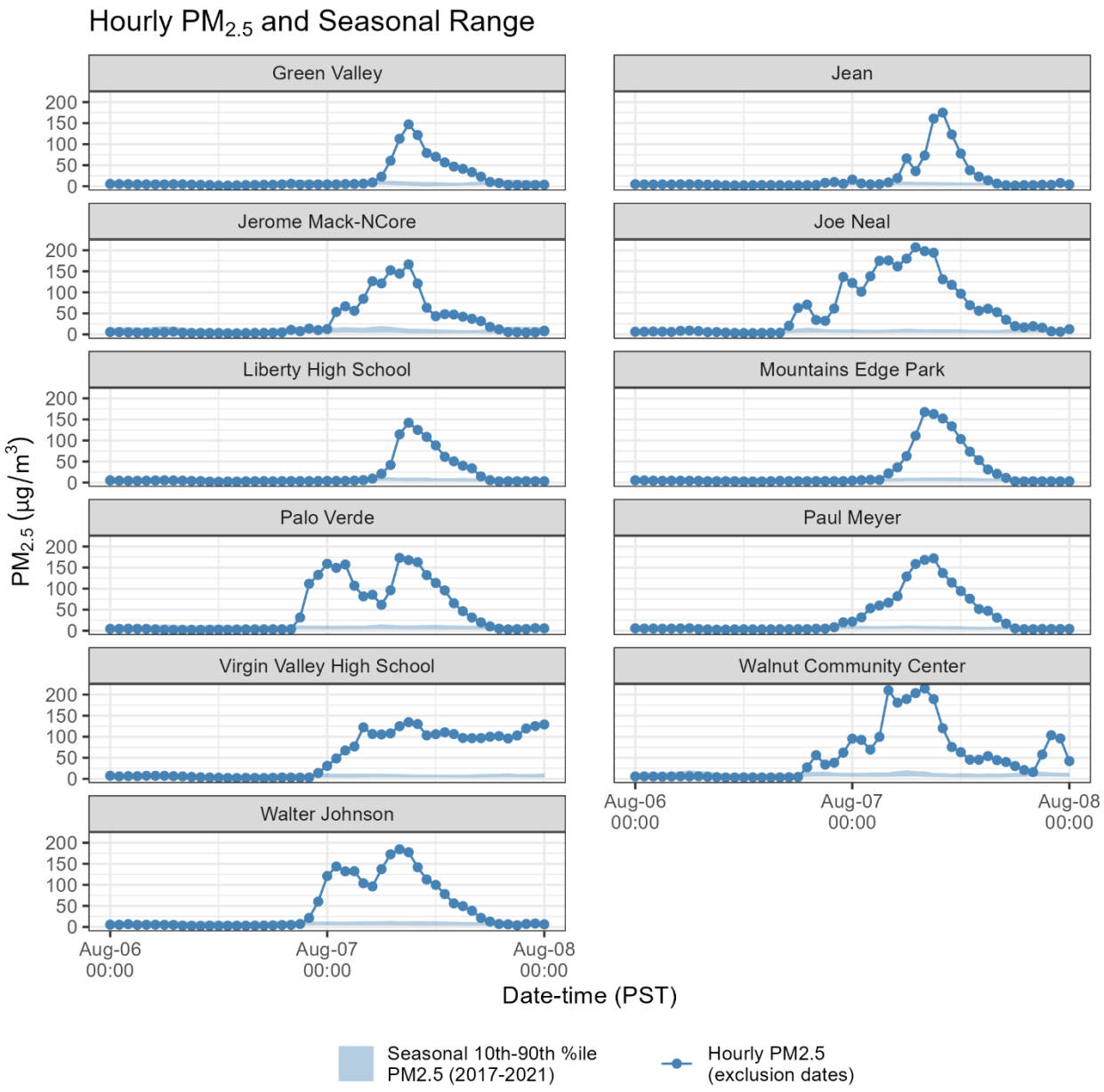

Figure 98. Hourly $PM_{2.5}$ measurements overlaid on the 10th-90th percentile diurnal concentration at affected sites that measure $PM_{2.5}$. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

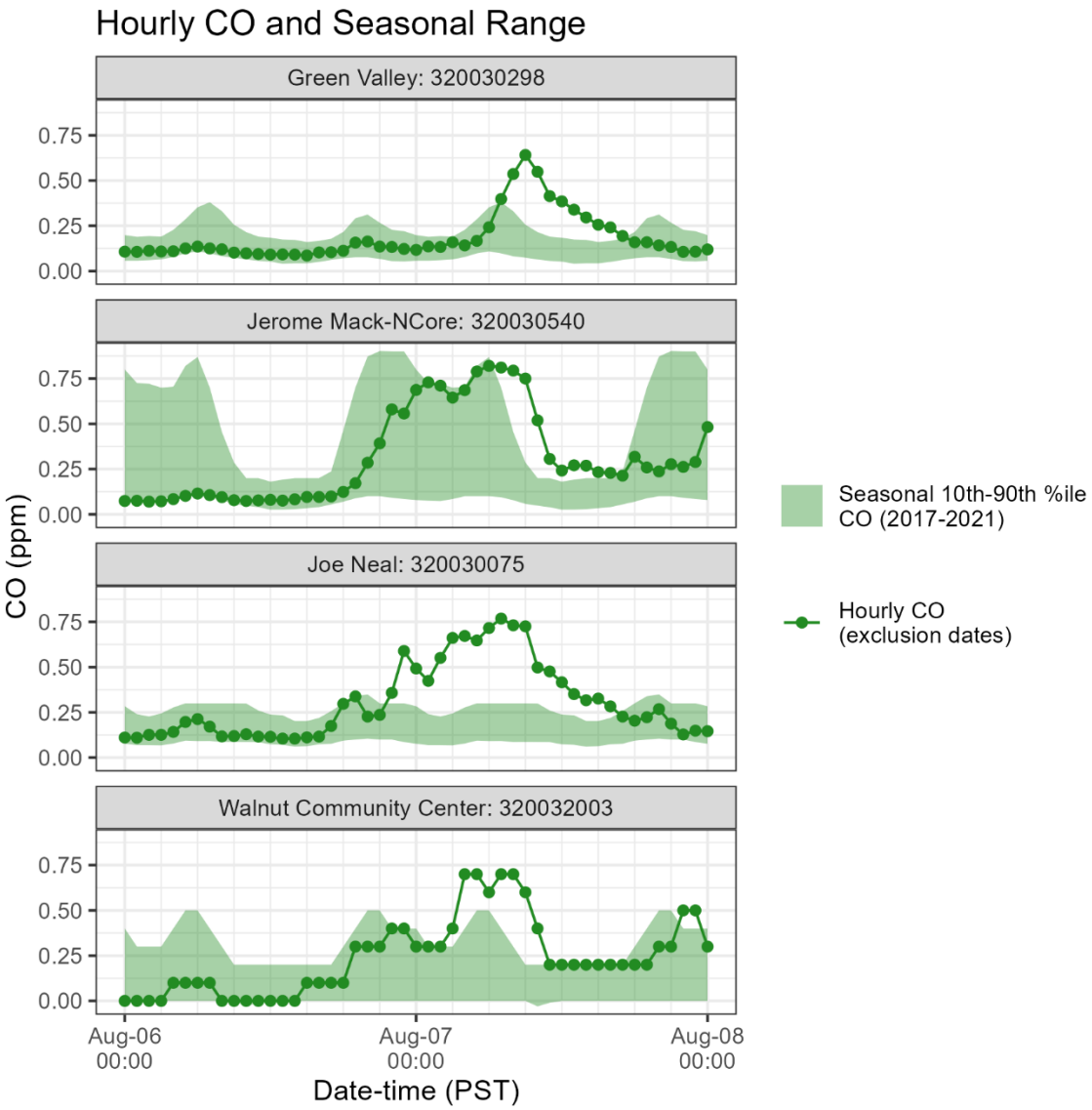

Figure 99. Hourly CO measurements overlaid on the 10th-90th percentile diurnal concentration at affected sites that measure CO. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

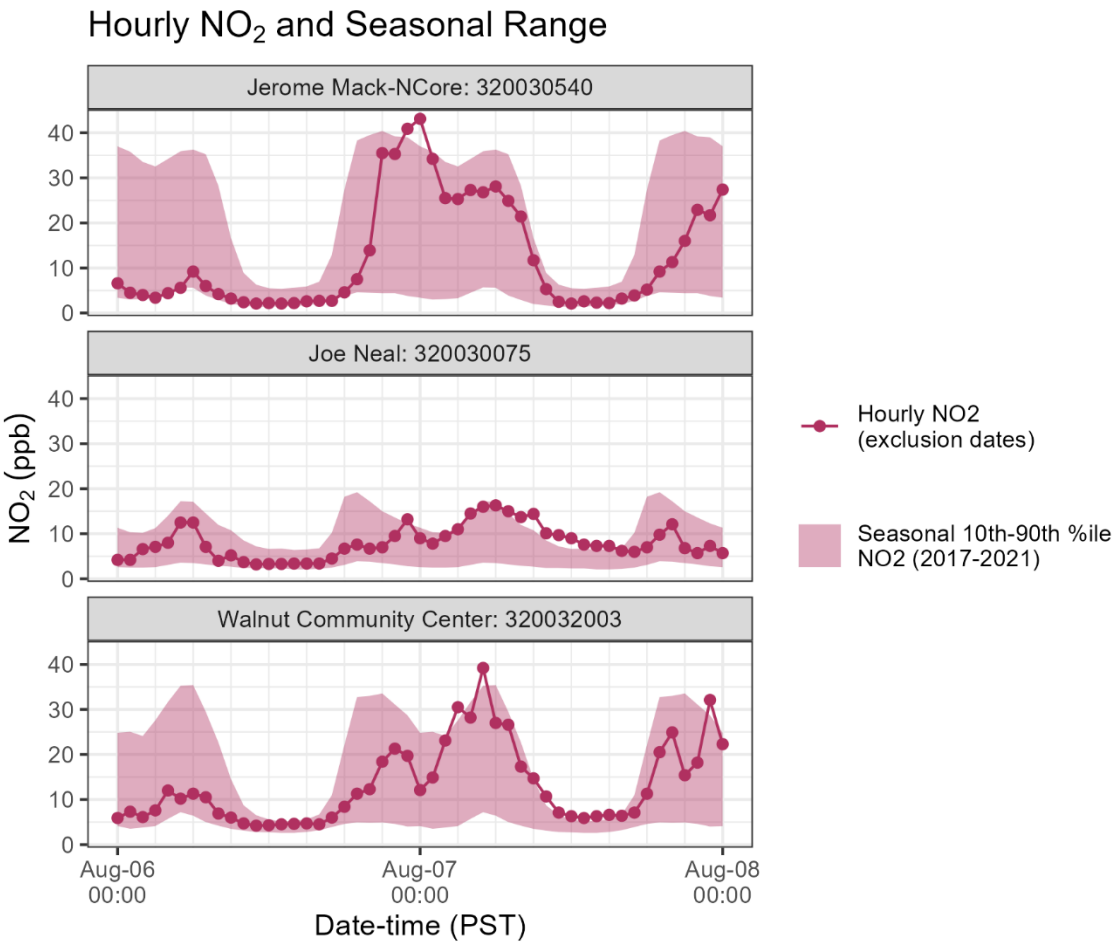

Figure 100. Hourly NO_2 measurements overlaid on the 10th-90th percentile diurnal concentration at affected sites that measure NO_2. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

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.

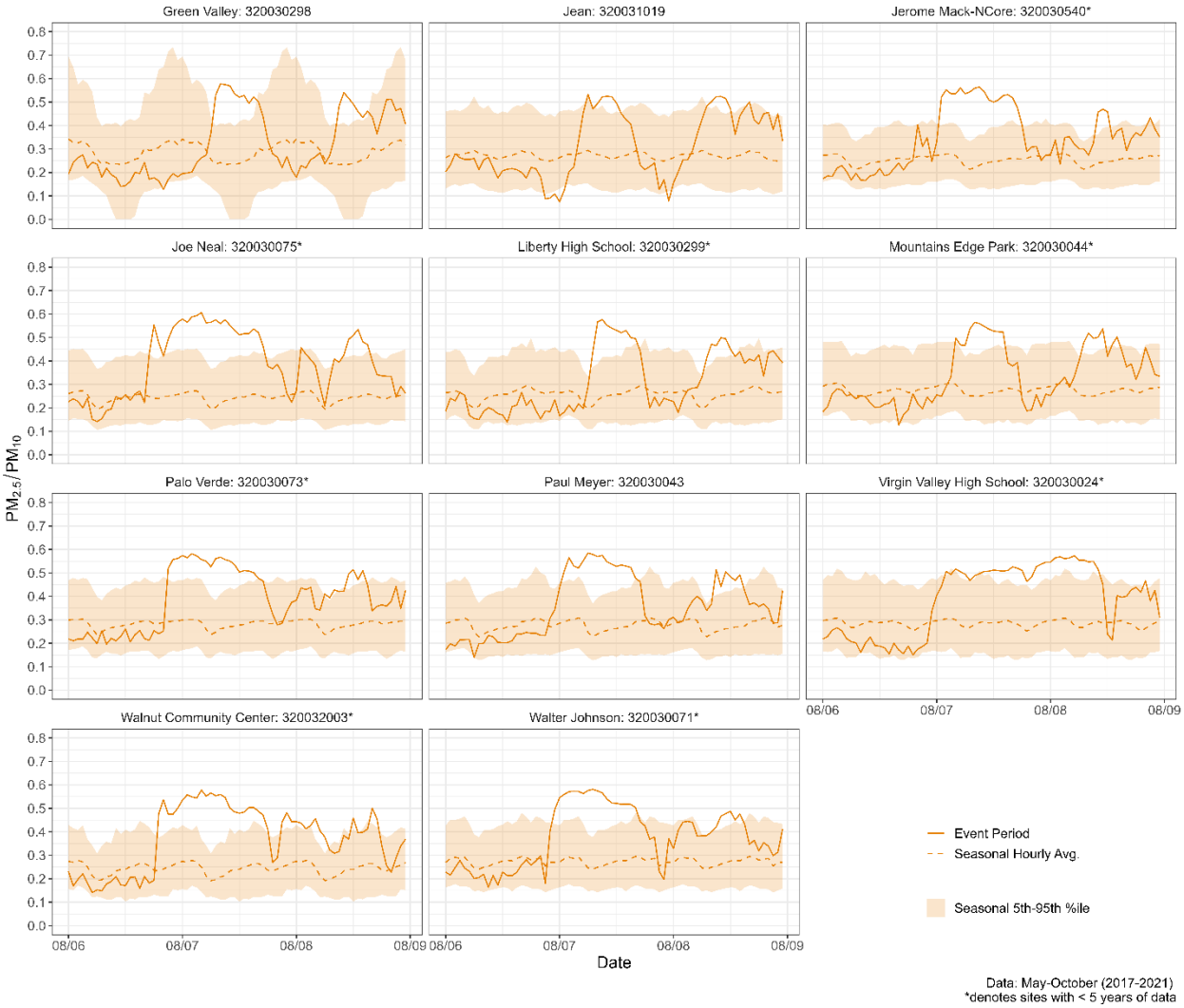

Figure 101. Ratio of $PM_{2.5}$-to-PM_{10} concentrations at all affected sites during the August 7 event period. The 5-yr average $PM_{2.5}$-to-PM_{10} diurnal ratio is displayed as a dotted line, and the 5th-95th percentile range is shown as a shaded ribbon. The 5th-95th percentile concentration is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

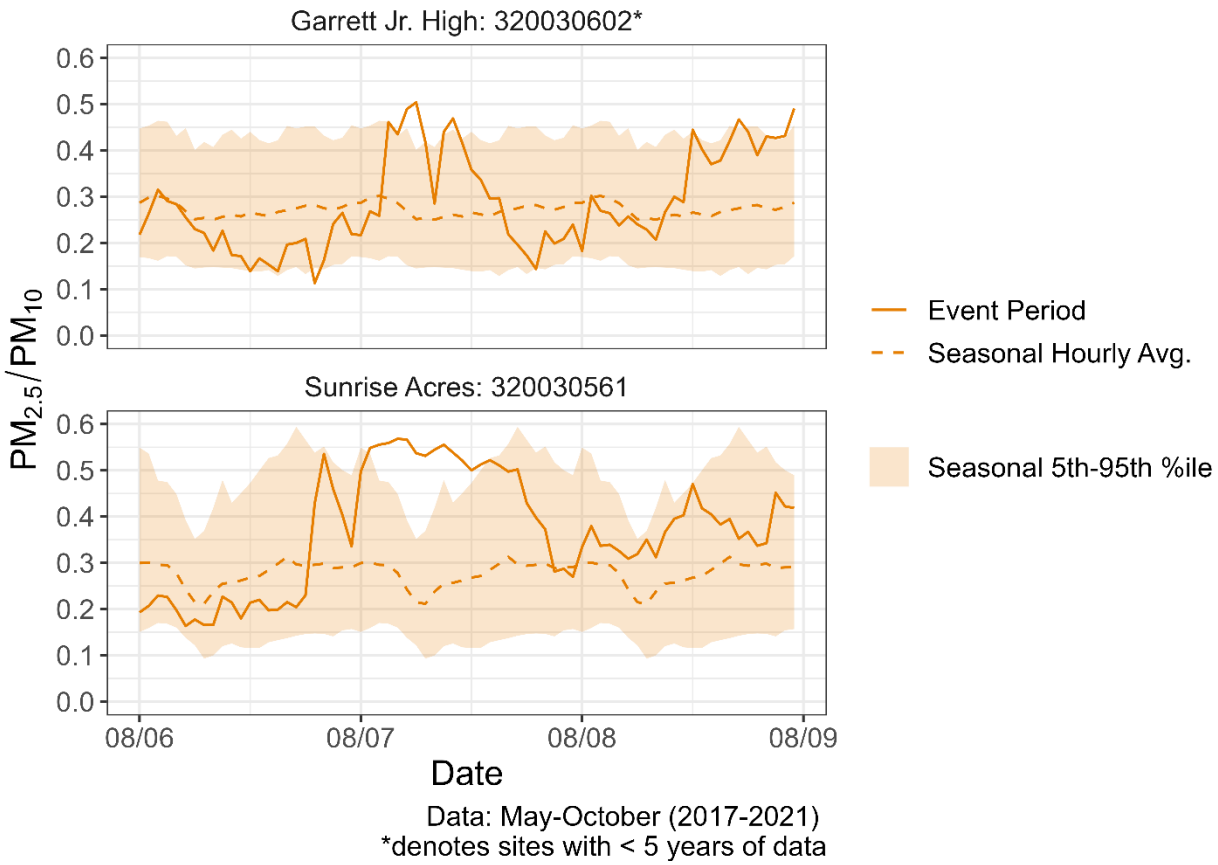

Figure 102. Ratio of $PM_{2.5}$-to-PM_{10} concentrations at all non-affected sites during the August 7 event period. The 5-yr average $PM_{2.5}$-to-PM_{10} diurnal ratio is displayed as a dotted line, and the 5th-95th percentile range is shown as a shaded ribbon. The 5th-95th percentile concentration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

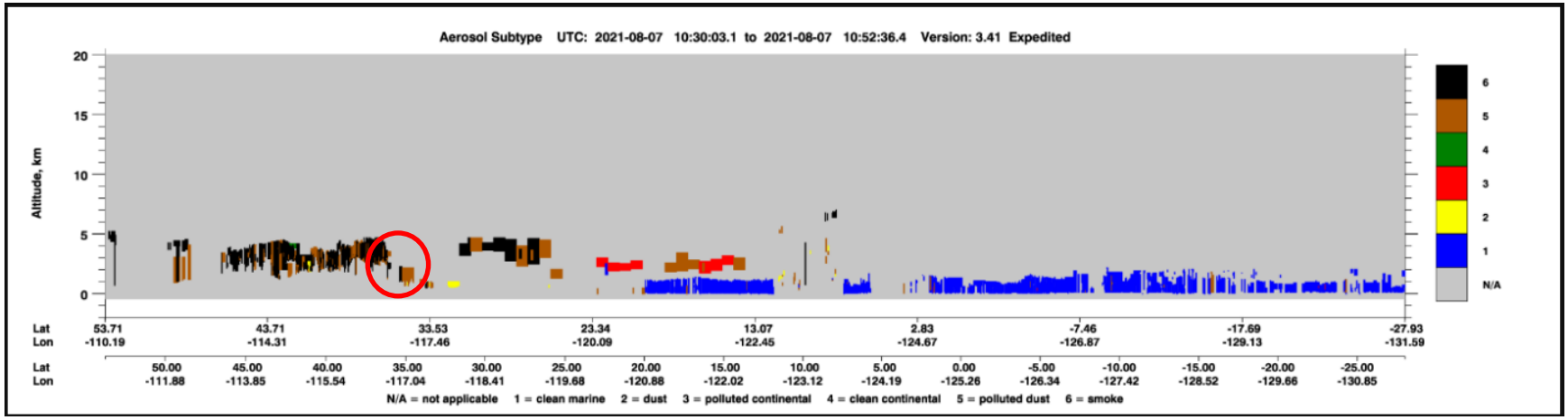

Figure 103. CALIPSO image on August 7, 2021. Black colors are defined as smoke and brown colors as polluted dust. The satellite detected a smoke layer near the Las Vegas region at an elevation of 1-4 km AGL. The red circle indicates Las Vegas (which is centered near 36.2, -115.2), with a smoke layer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

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.

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	Mountains Edge Park	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.

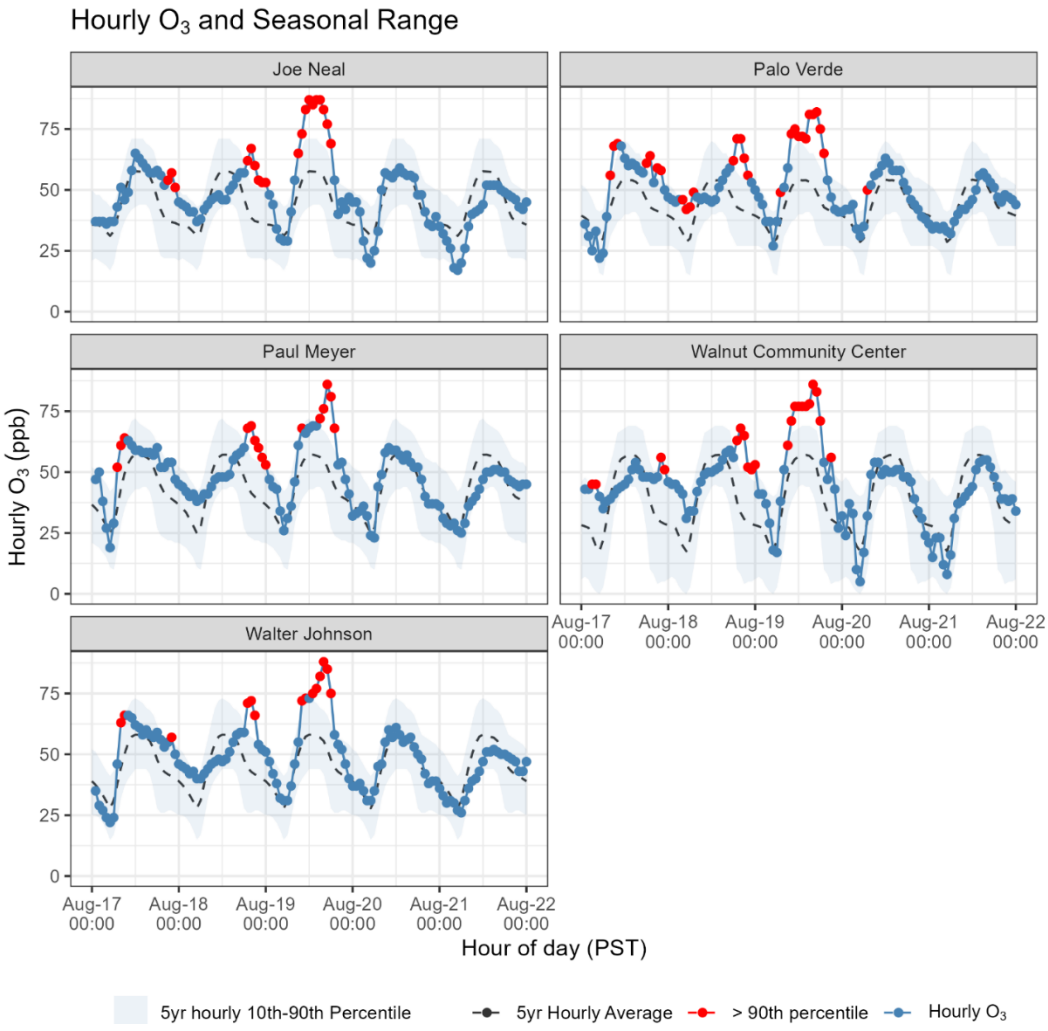

Figure 104. Hourly ozone concentrations (ppb) compared to 5-yr* ozone season (May 1-October 31) hourly means and 10th-90th percentiles. Note: data collected from the Walnut Community Center site is only available for June 1-October 31, 2021.

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]

[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.

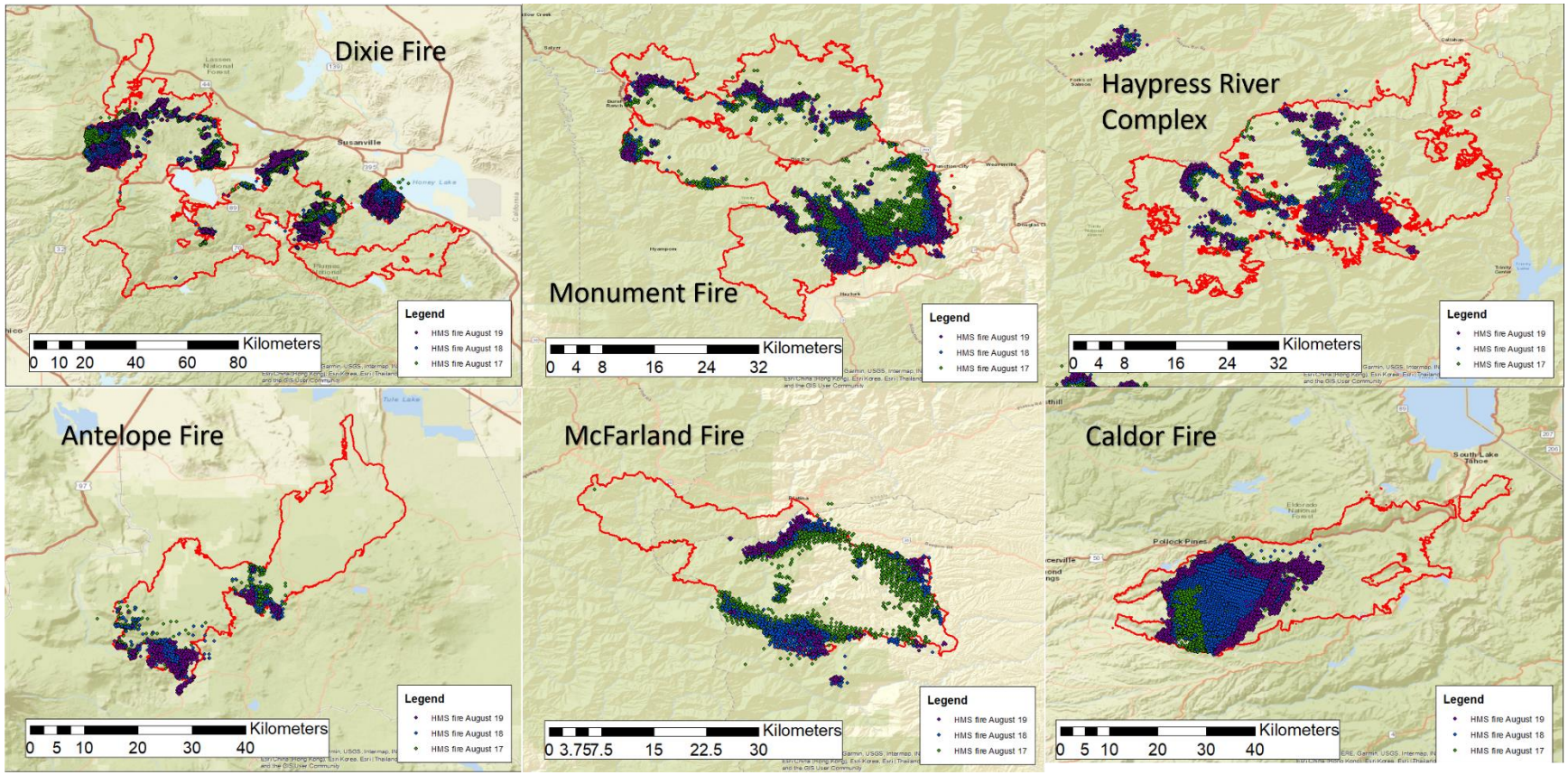

Figure 105. Final fire perimeters (red) and HMS fire detections for the Dixie, Monument, Haypress River Complex, Antelope, McFarland, and Caldor Fires during August 17-19, 2021.

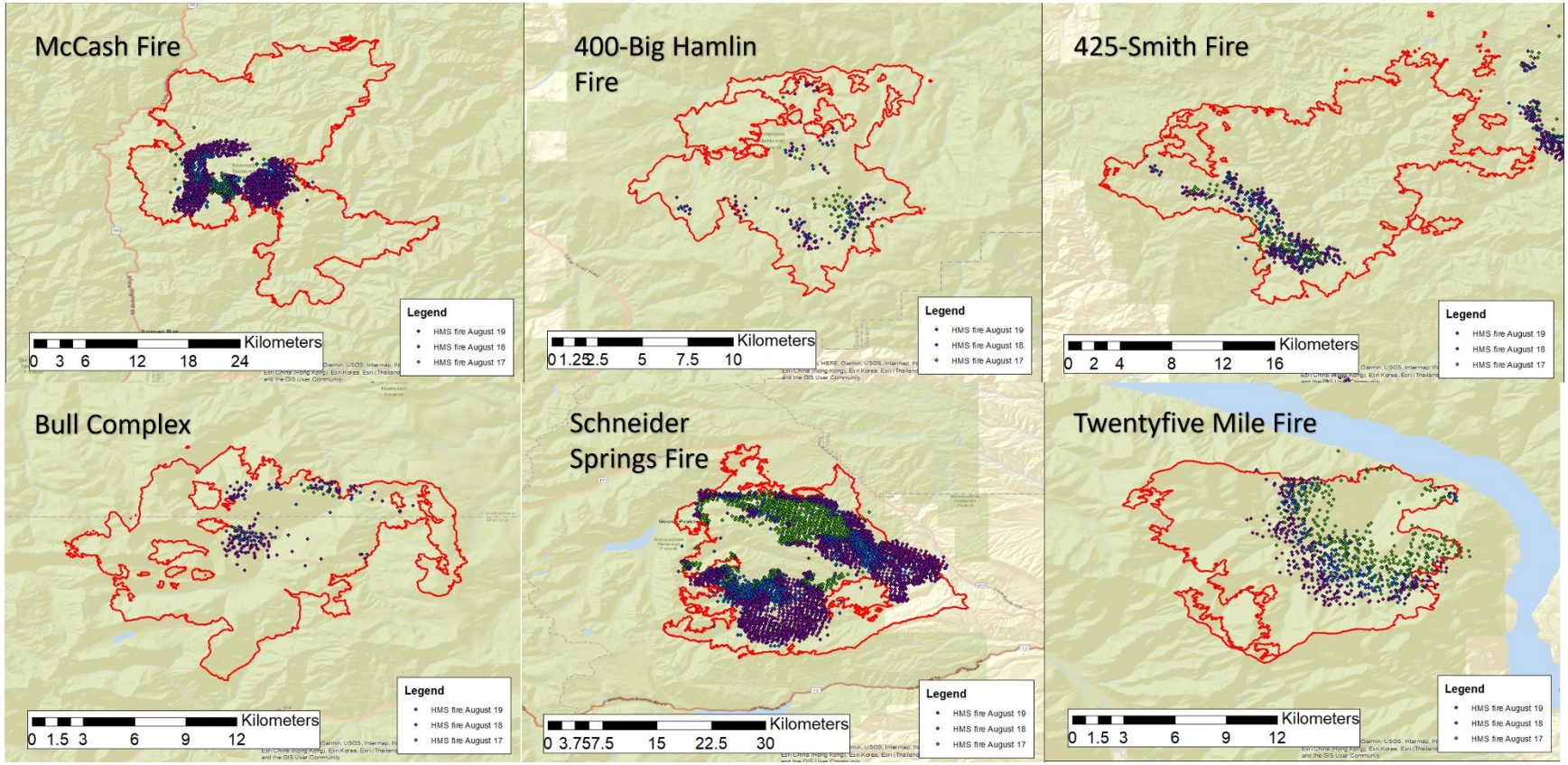

Figure 106. Final fire perimeters (red) and HMS fire detections for the McCash, Big Hamlin, Smith, Bull Complex, Schneider Springs, and Twentyfive Mile Fires during August 17-19, 2021.

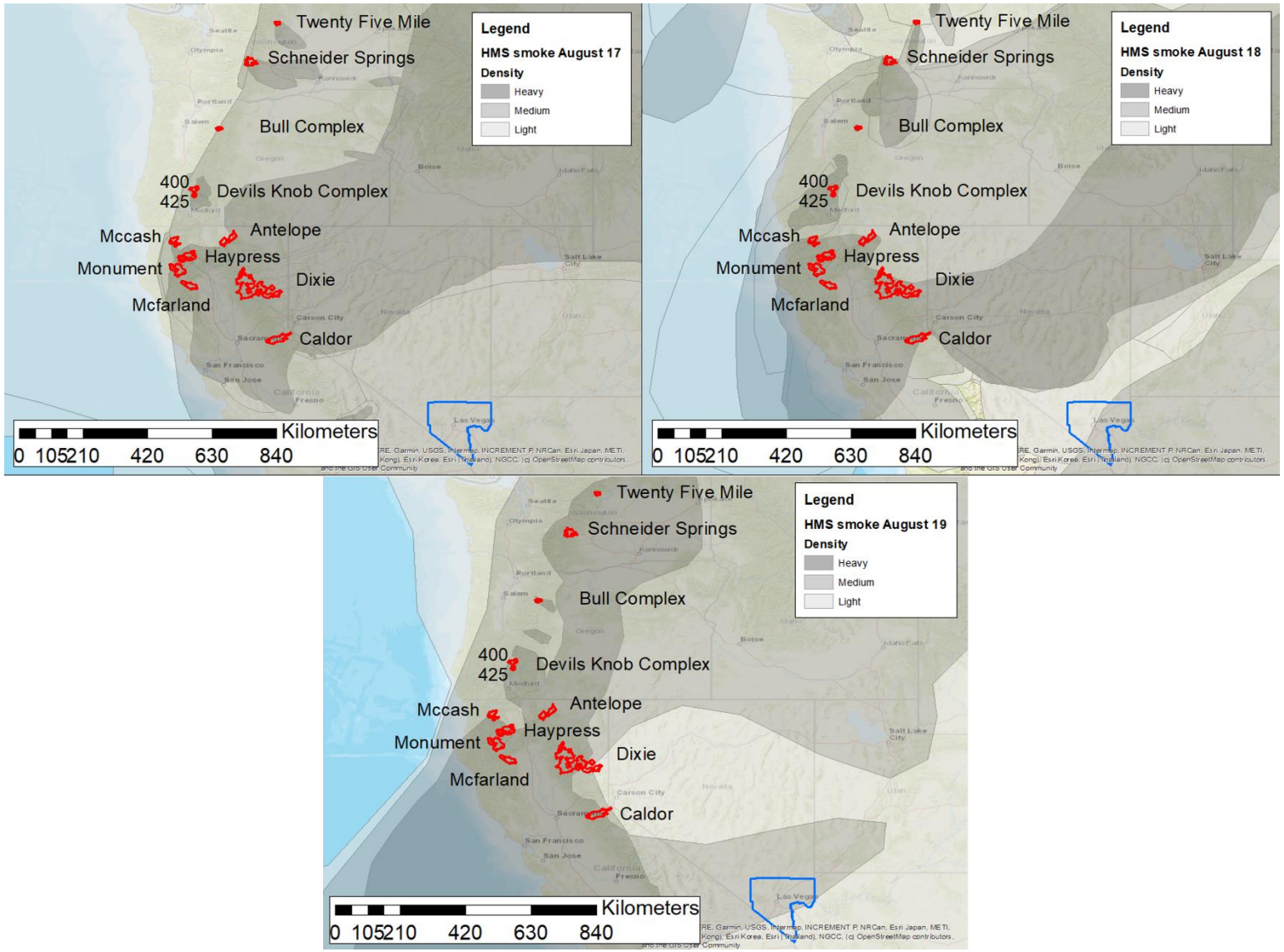

Figure 107. HMS smoke boundaries for August 17-19, 2021, is included with qualitative smoke density. Fire perimeters from the major fires contributing to the exclusion date are shown in red and the Clark County, NV, boundary is shown in blue.

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.

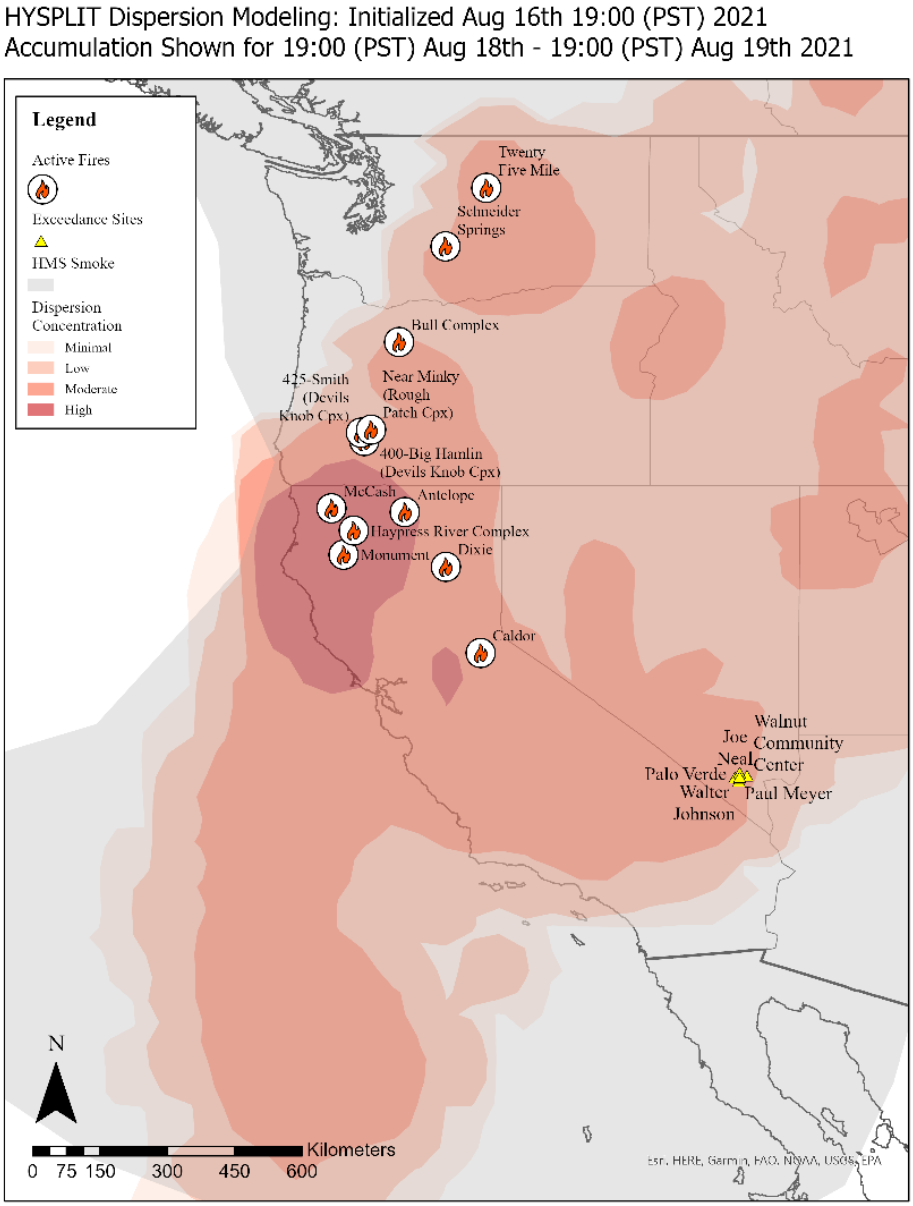

Figure 108. HYSPLIT dispersion modeling for 12 large fires (labeled as "Active Fires") throughout the western U.S. GDAS 1.0° meteorological data was used, and dispersion was initiated on August 16, 2021, at 19:00 PST to model the regional smoke observed in satellite and HMS products. HMS smoke is shown 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.

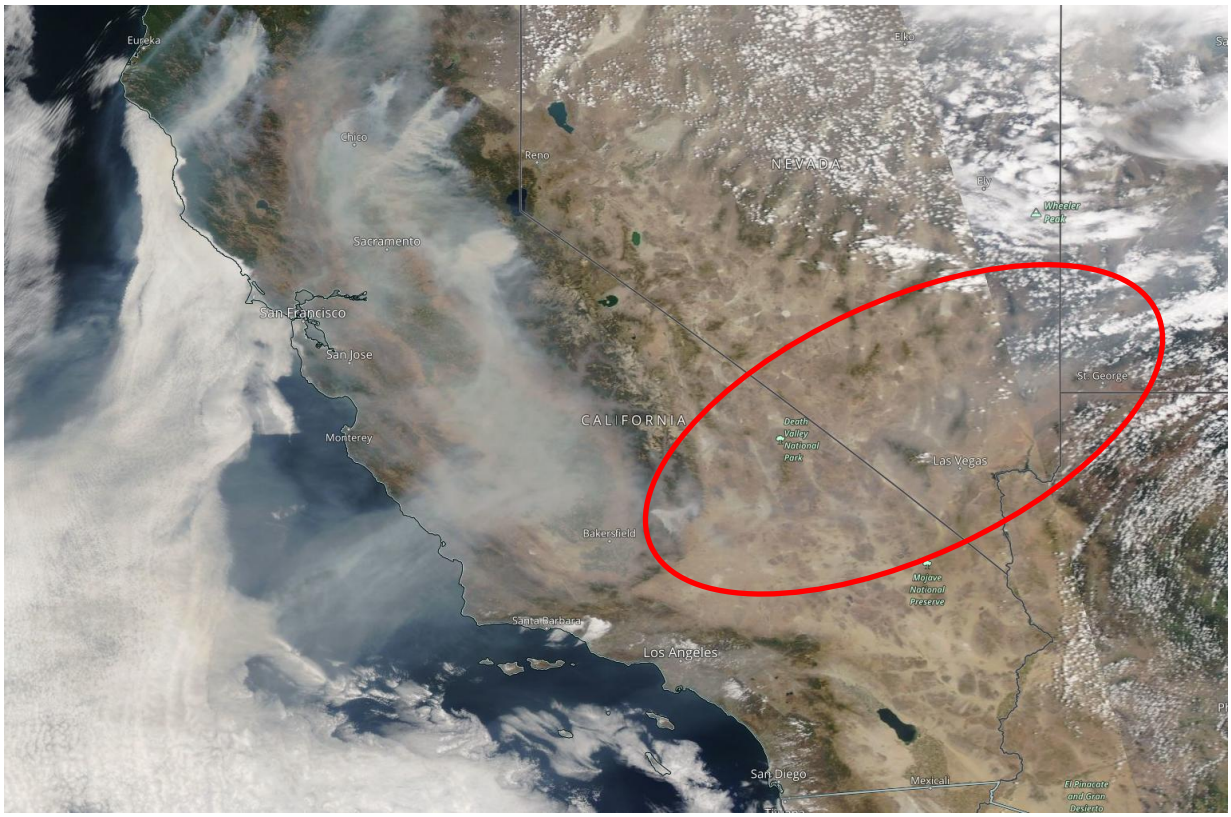

Figure 109. MODIS Aqua satellite image valid on August 19, 2021. Smoke from California wildfires is visible across central and southern Nevada. This smoke contributed to poor air quality and reduced visibility in Clark County. The red circle shows the area of smoke over Clark County.

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.

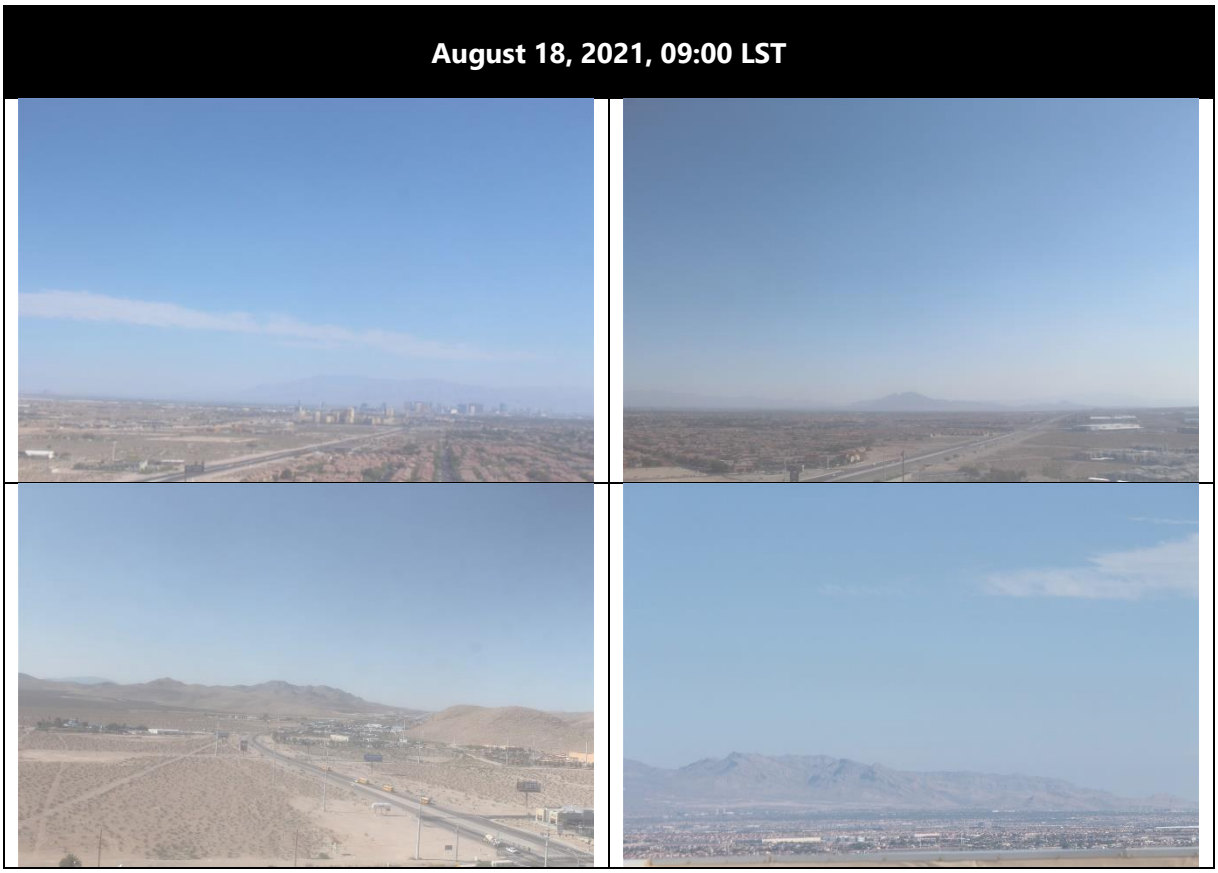

Figure 110. Camera images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions, taken from the M Resort Hotel in Clark County, NV, on August 18, 2021, at 09:00 LST.

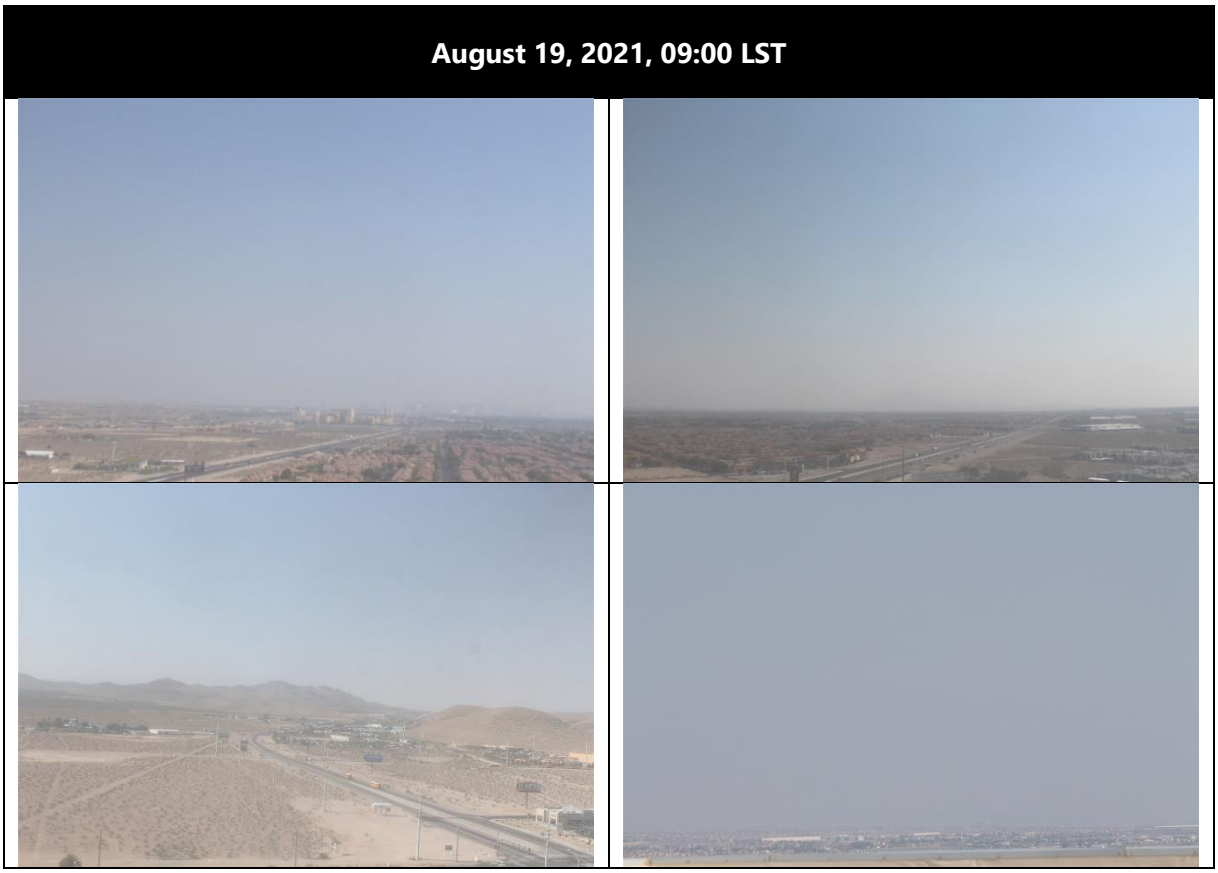

Figure 111. Camera images for north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions, taken from the M Resort Hotel in Clark County, NV, on August 19, 2021, at 09:00 LST.

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.

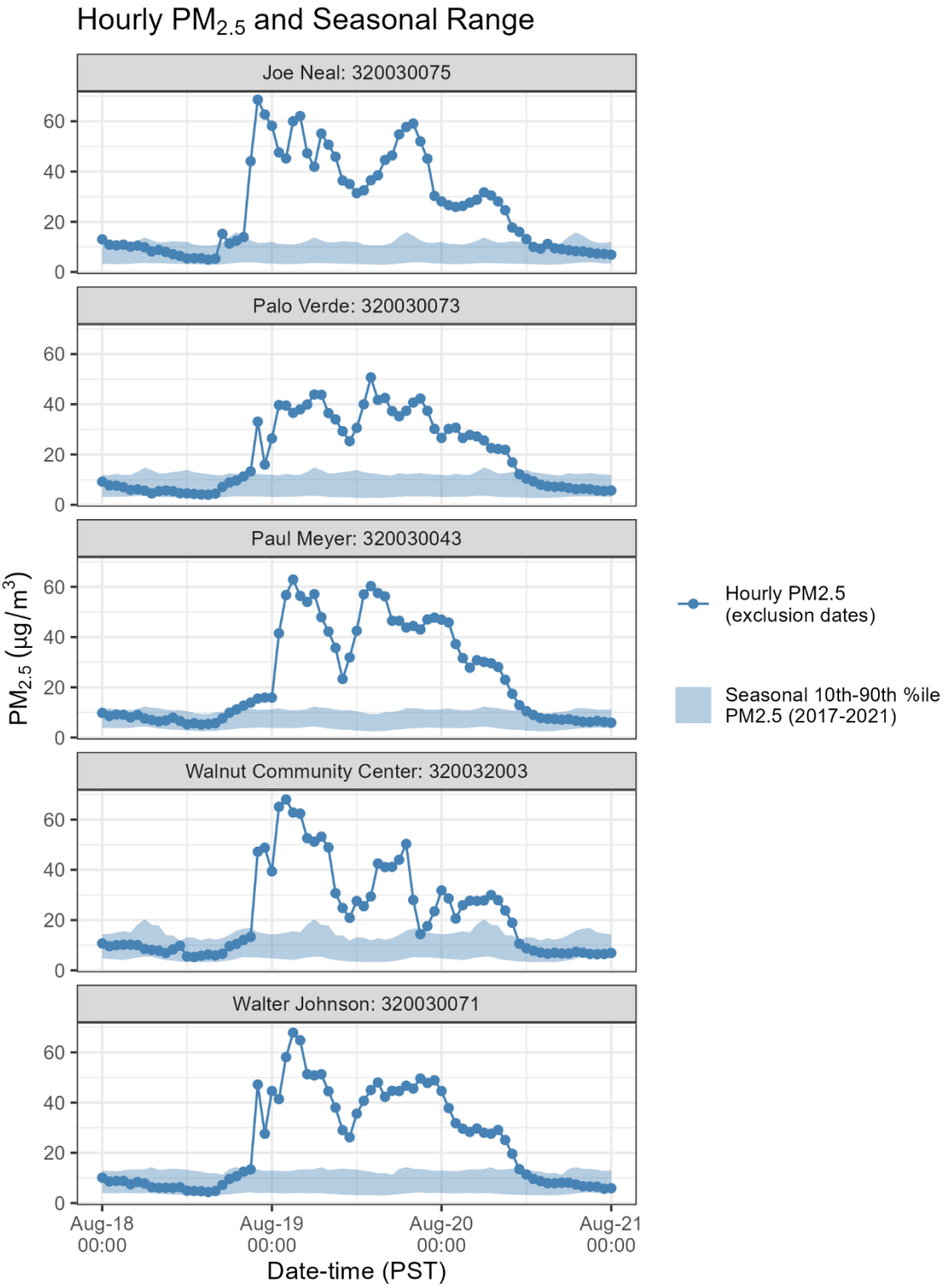

Figure 112. Hourly $PM_{2.5}$ measurements overlaid on the 10th-90th percentile diurnal concentration at affected sites that measure $PM_{2.5}$. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

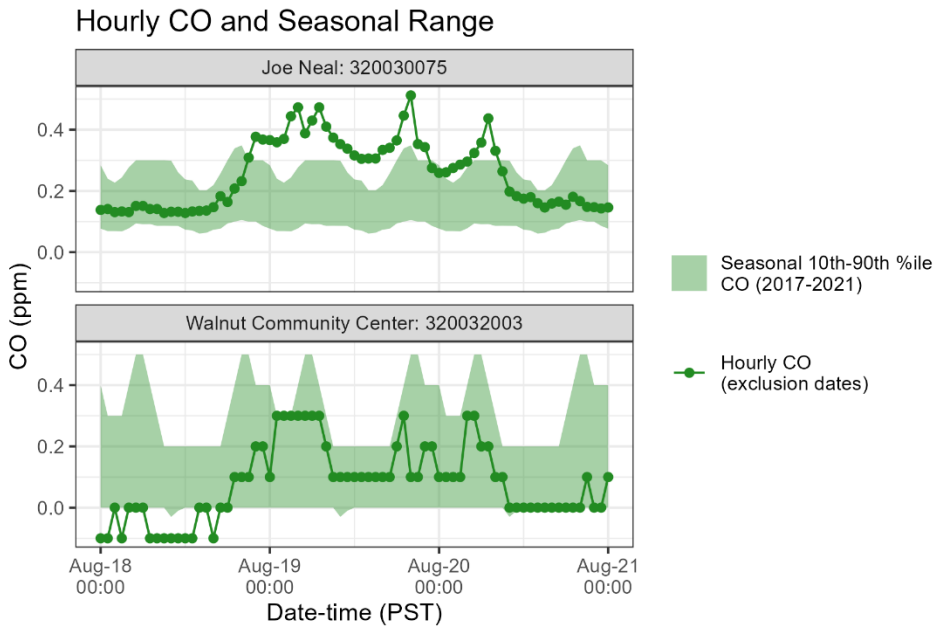

Figure 113. Hourly CO measurements overlaid on the 10th-90th percentile diurnal concentration at affected sites that measure CO. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

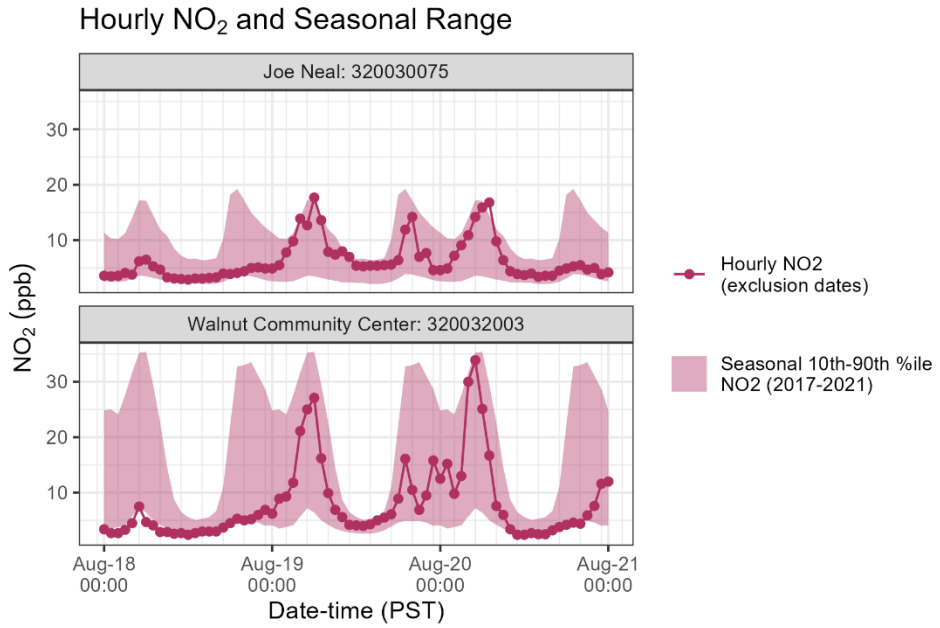

Figure 114. Hourly NO_2 measurements overlaid on the 10th-90th percentile diurnal concentration at affected sites that measure NO_2. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

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.

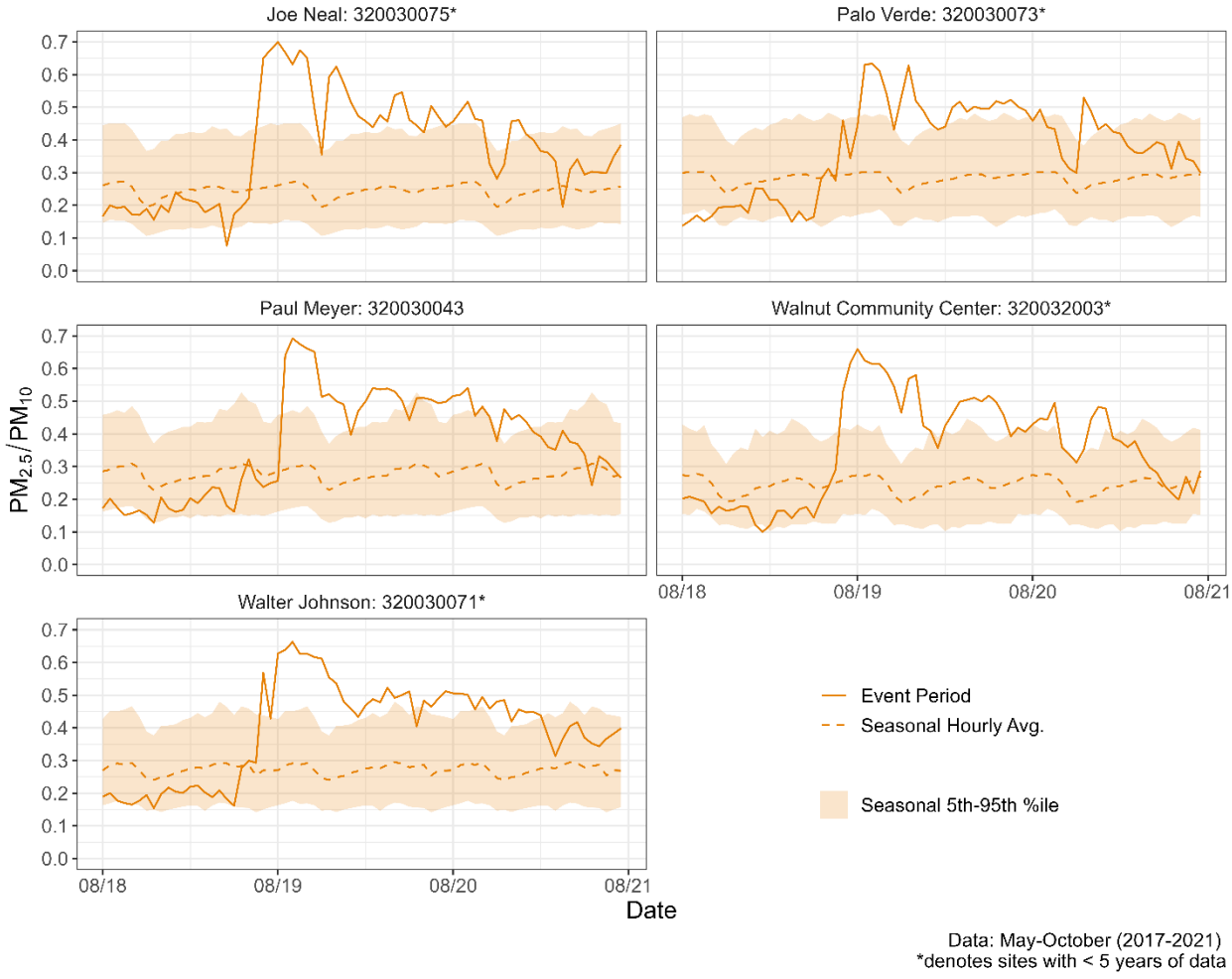

Figure 115. Ratio of $PM_{2.5}$-to-PM_{10} concentrations at the affected sites during the August 19 event period. The 5-yr average $PM_{2.5}$-to-PM_{10} diurnal ratio is displayed as a dotted line, and the 5th-95th percentile range is shown as a shaded ribbon. The 5th-95th percentile concentration is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

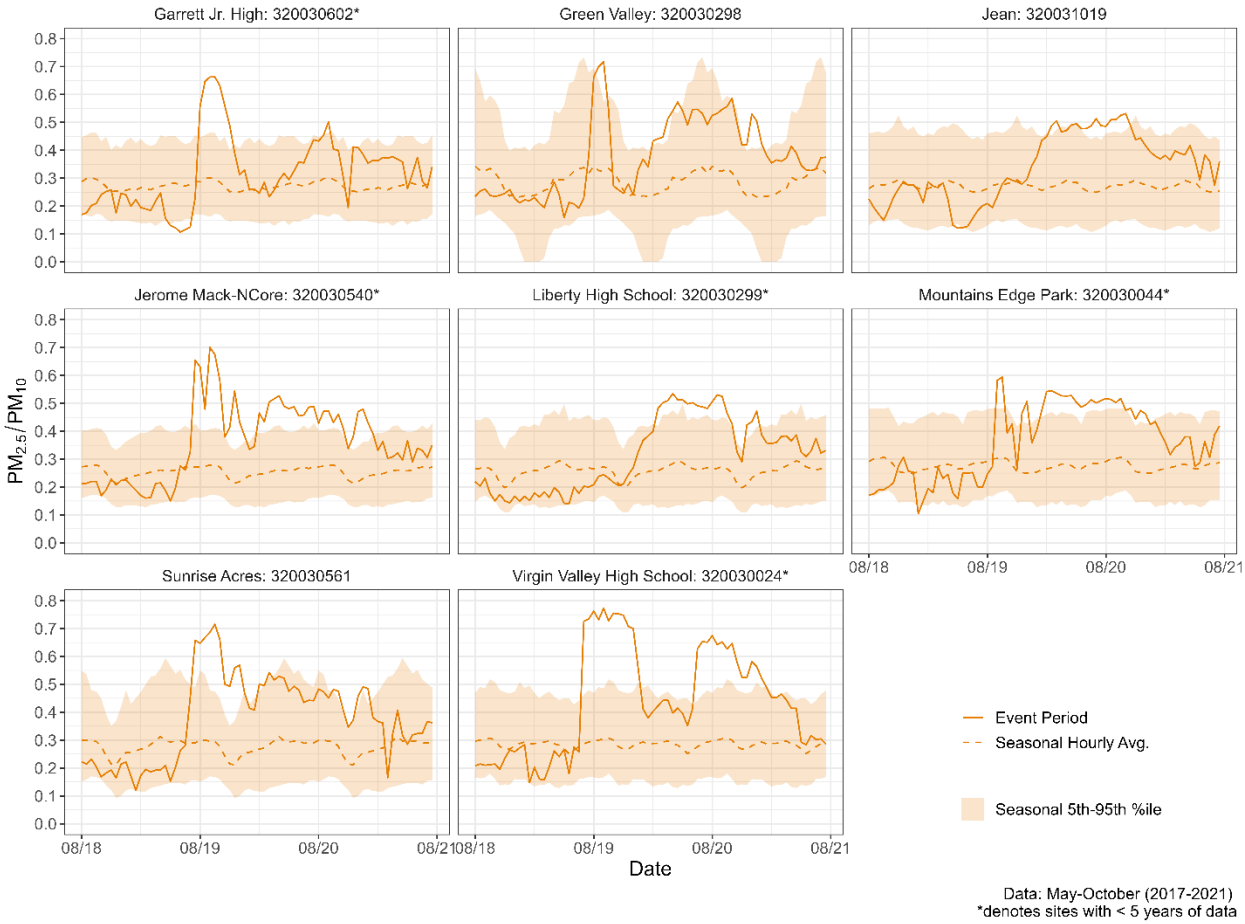

Figure 116. Ratio of $PM_{2.5}$-to-PM_{10} concentrations at the affected sites during the August 19 event period. The 5-yr average $PM_{2.5}$-to-PM_{10} diurnal ratio is displayed as a dotted line, and the 5th-95th percentile range is shown as a shaded ribbon. The 5th-95th percentile concentration is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

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.

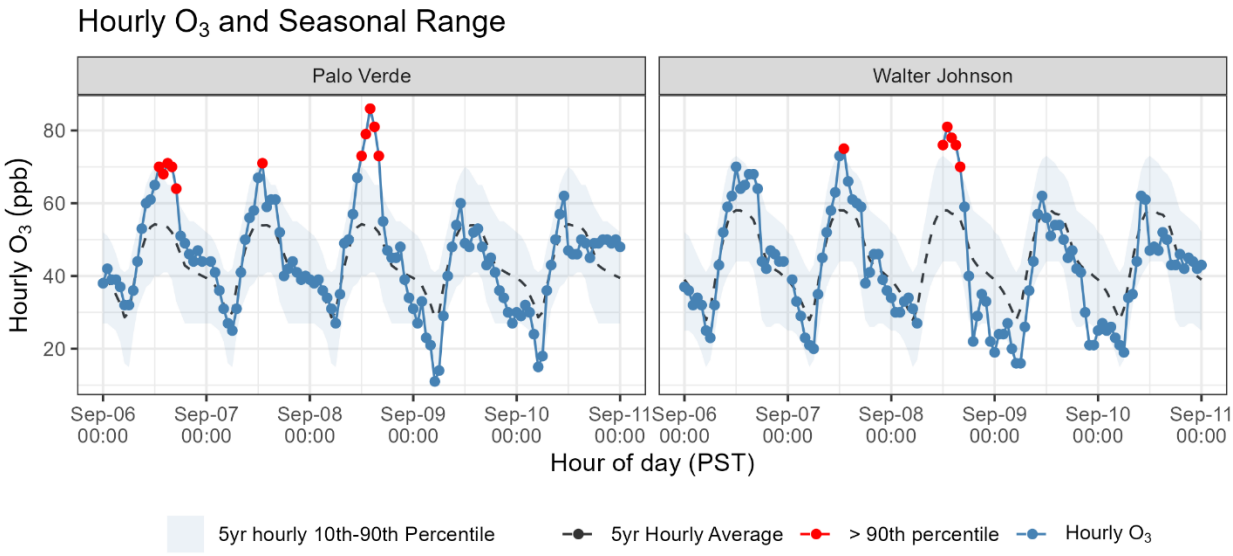

Figure 117. Hourly ozone concentrations (ppb) compared to 5-yr ozone season (May 1-October 31, 2017-2021) hourly means and 10th-90th percentiles.

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]

[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.

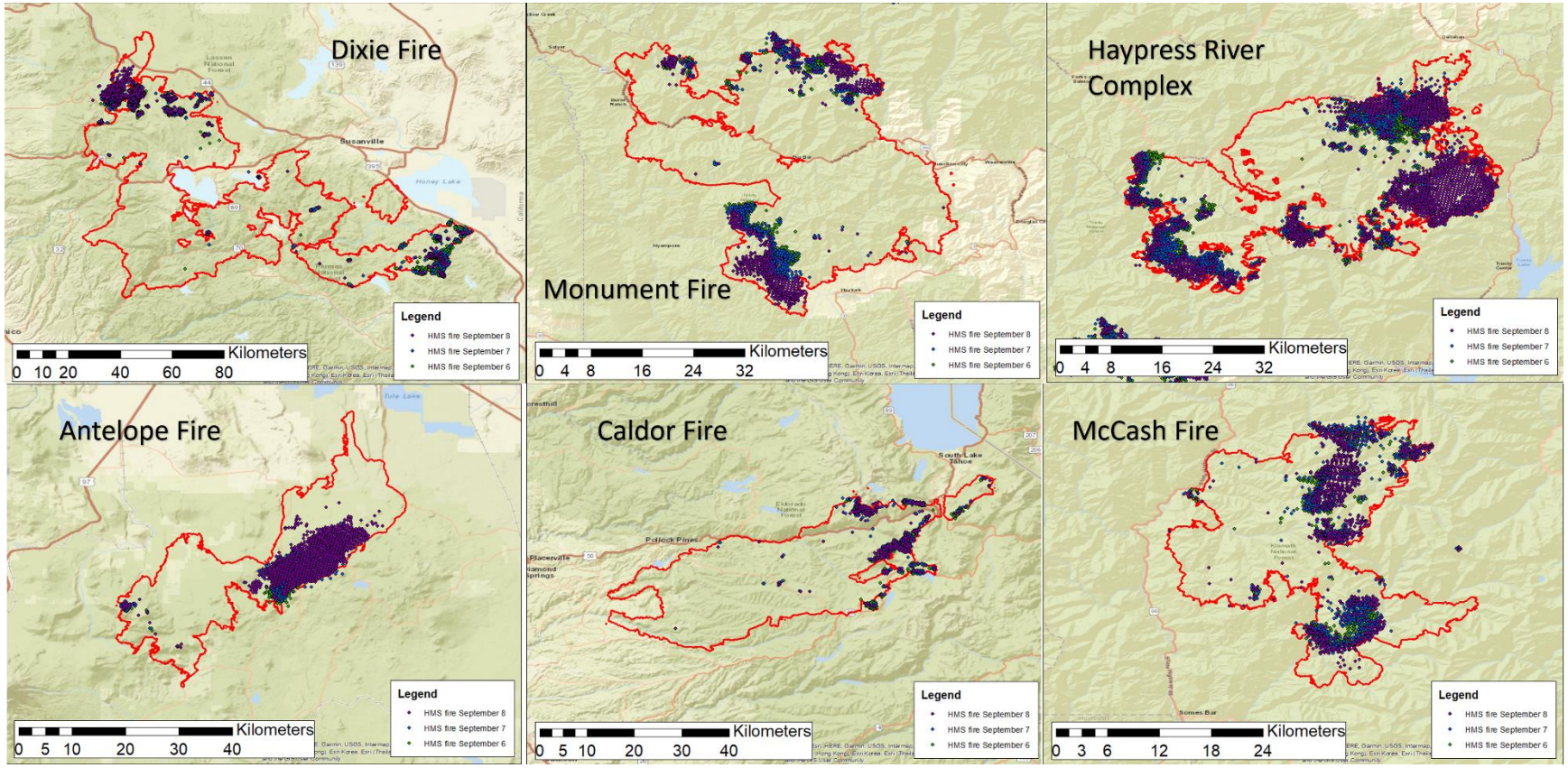

Figure 118. Final fire perimeters (red) and HMS fire detections for the Dixie, Monument, Haypress River Complex, Antelope, Caldor, and McCash Fires during September 6-8, 2021.

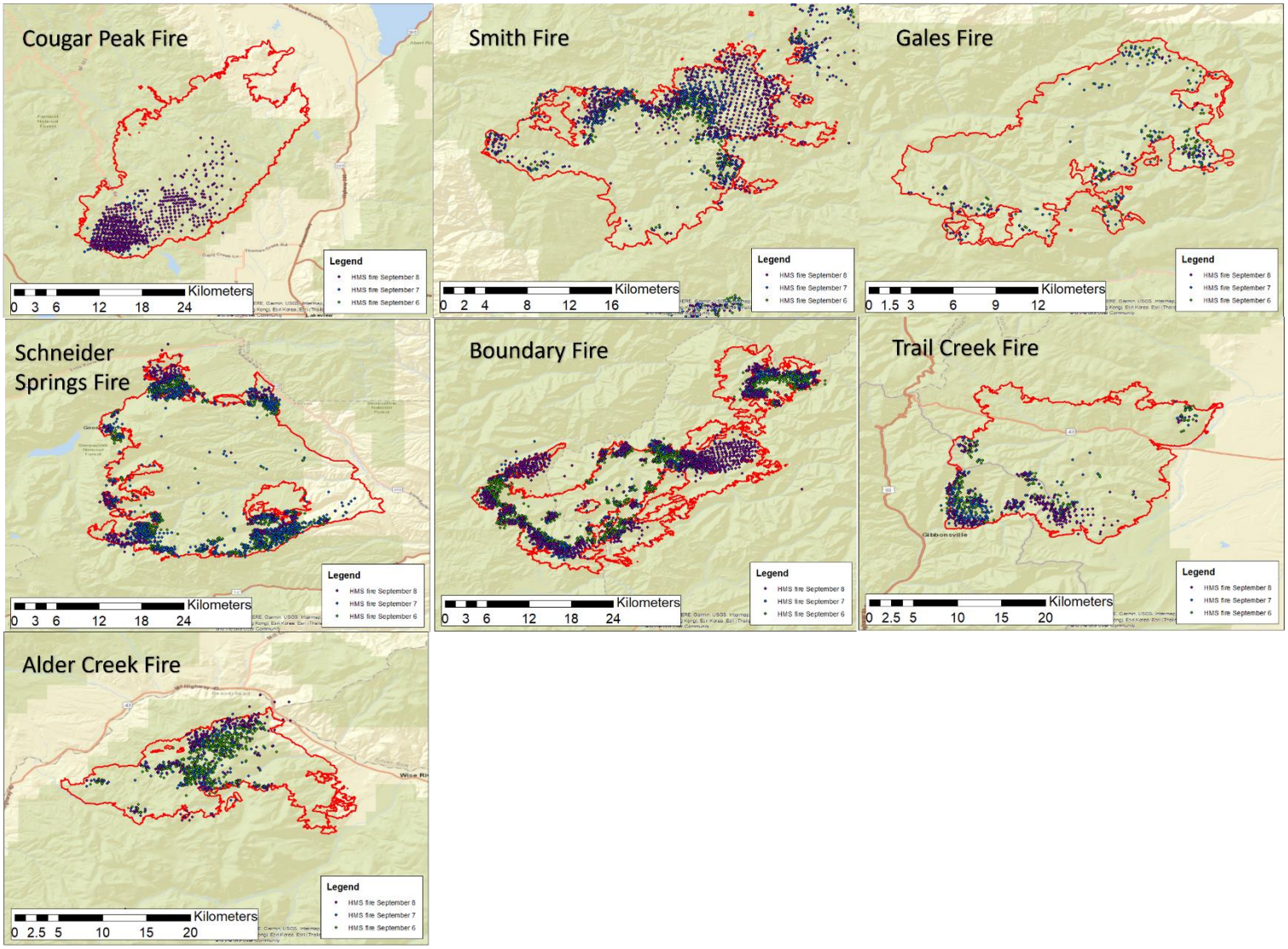

Figure 119. Final fire perimeters (red) and HMS fire detections for the Cougar Peak, Smith, Gales, Schneider Springs, Boundary, Trail Creek, and Alder Creek Fires during September 6-8, 2021.

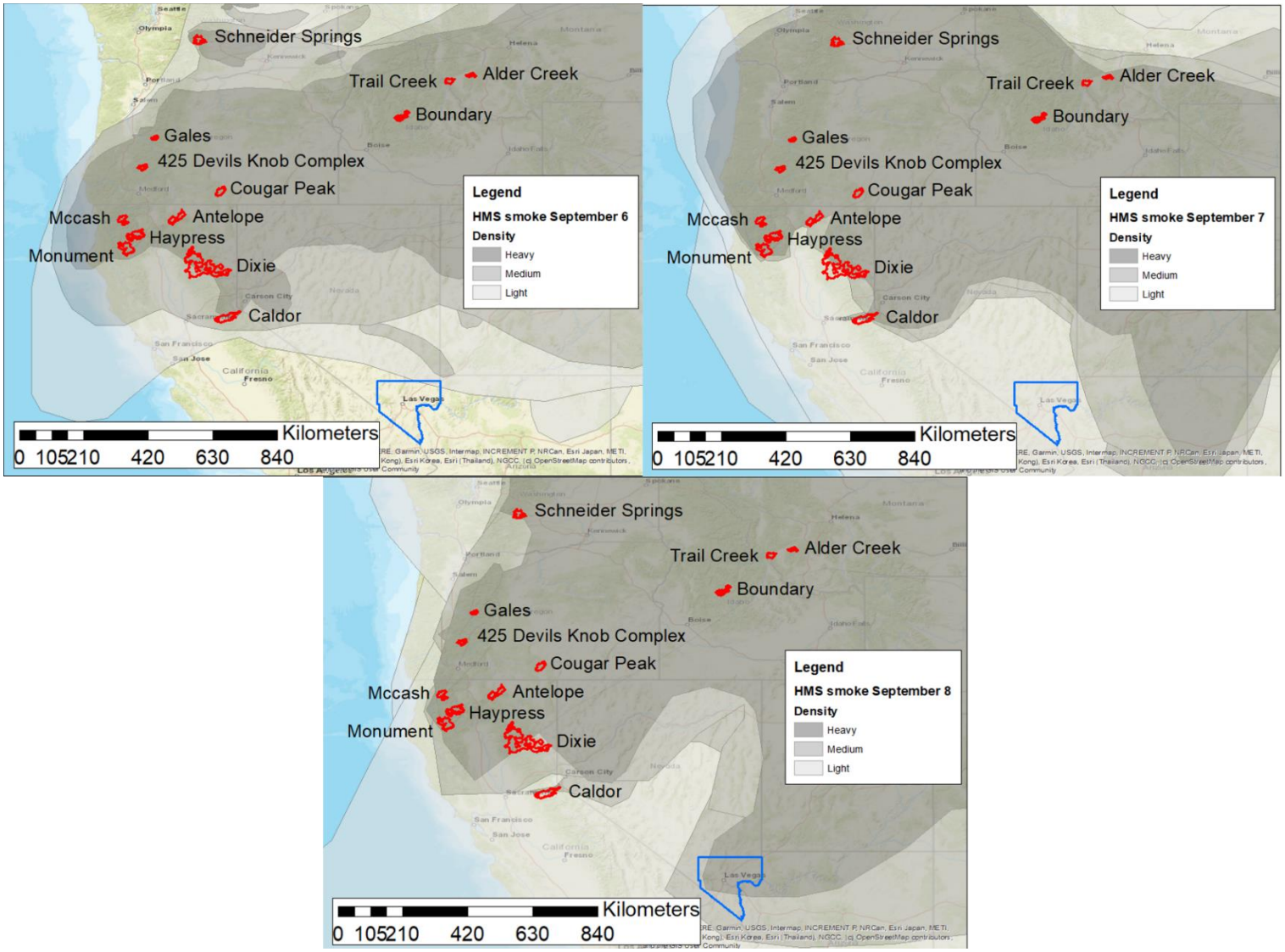

Figure 120. HMS smoke for September 6-8, 2021, is included with qualitative smoke density. Fire perimeters from the major fires contributing to the exclusion date are shown in red and the Clark County, NV, boundary is shown in blue.

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.

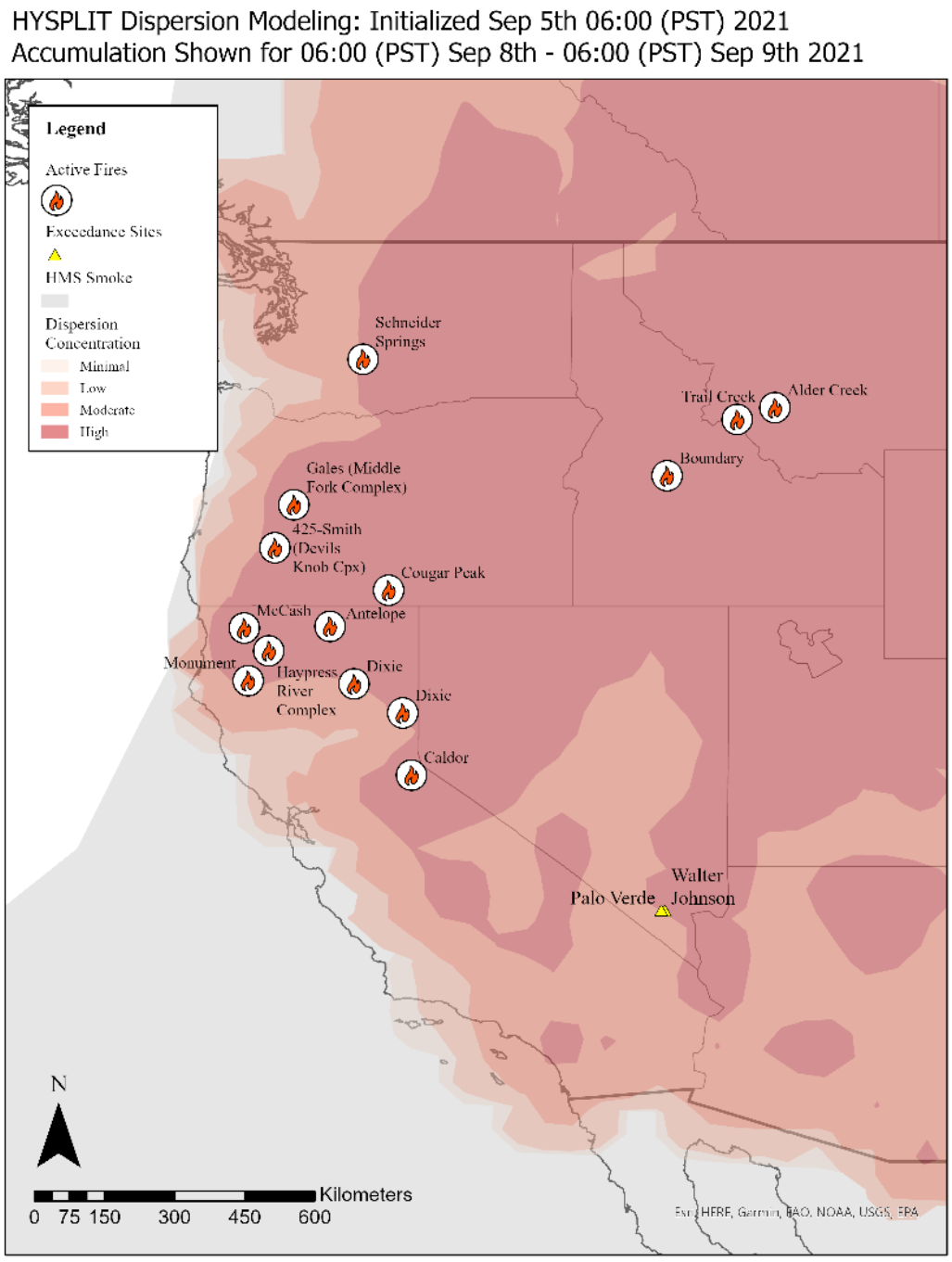

Figure 121. HYSPLIT dispersion modeling for 13 large fires (labeled as "Active Fires") throughout the western U.S. GDAS 1.0° meteorological data was used, and dispersion was initiated on September 5 at 06:00 PST to model the regional smoke observed in satellite and HMS products. HMS smoke is shown in 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.

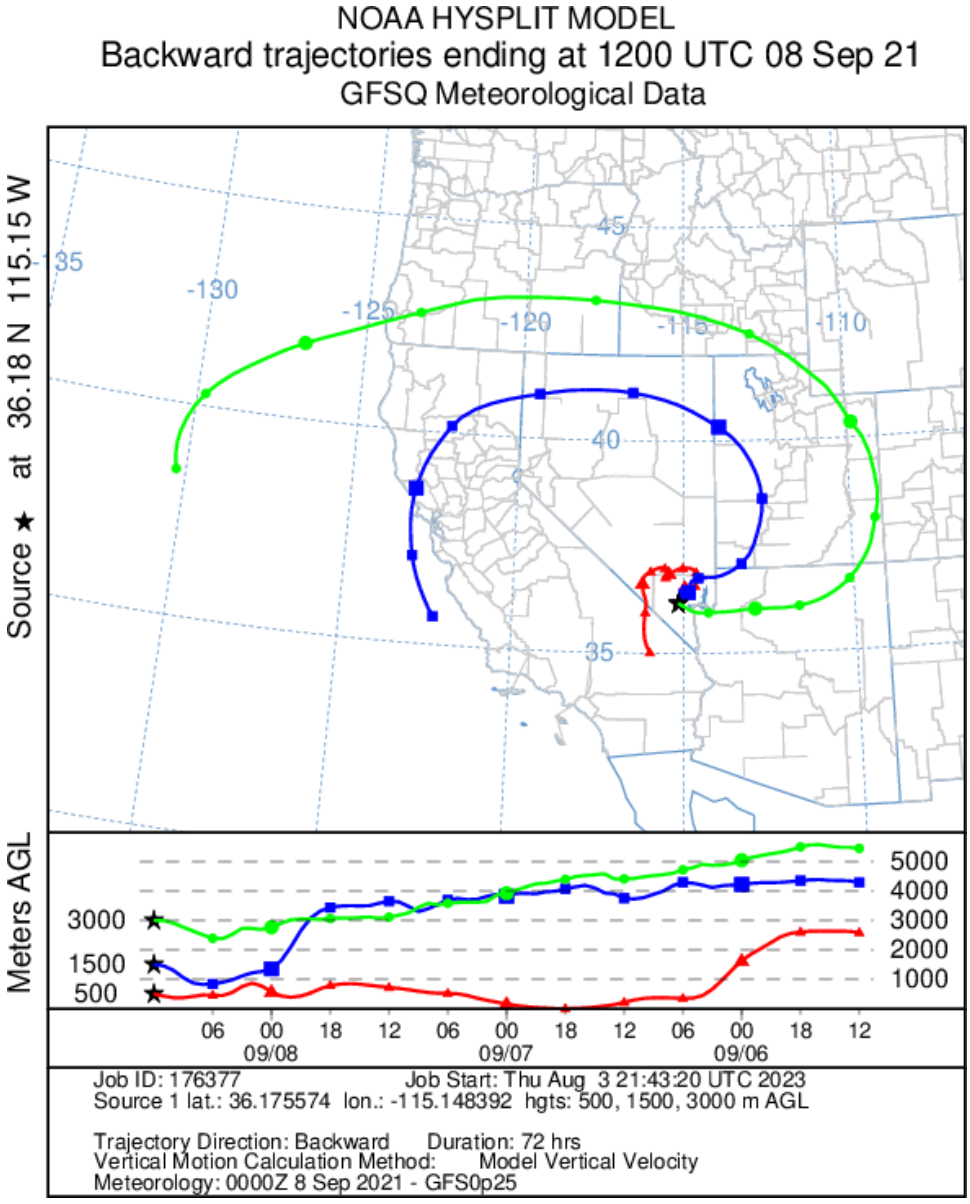

Figure 122. NOAA GFS HYSPLIT 72-hr back trajectory analysis ending at 12:00 UTC (04:00 PST) on September 8, 2021, shows smoke from fires in northern California and Oregon was likely transported into Clark County, NV, contributing to atypical ozone levels.

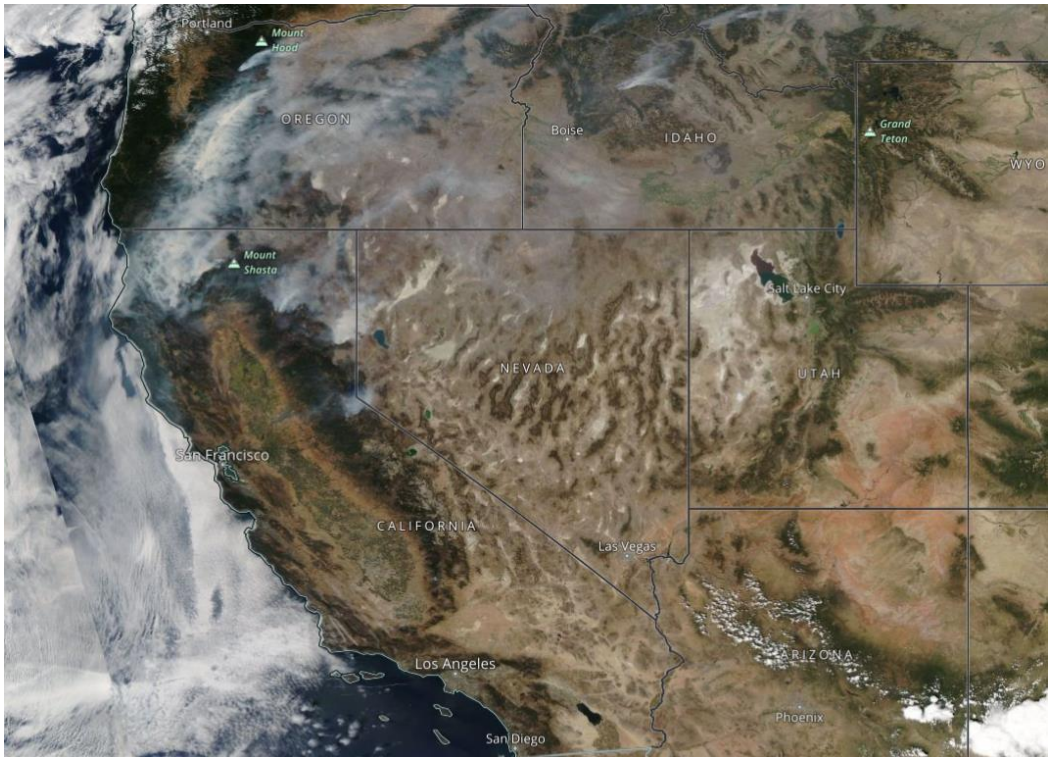

Figure 123. MODIS Aqua satellite image on September 5, 2021. Based on surface observations of haze and 72-hr back trajectory analysis on September 8, smoke from fires in northern California and Oregon impacted air quality in Clark County, NV.

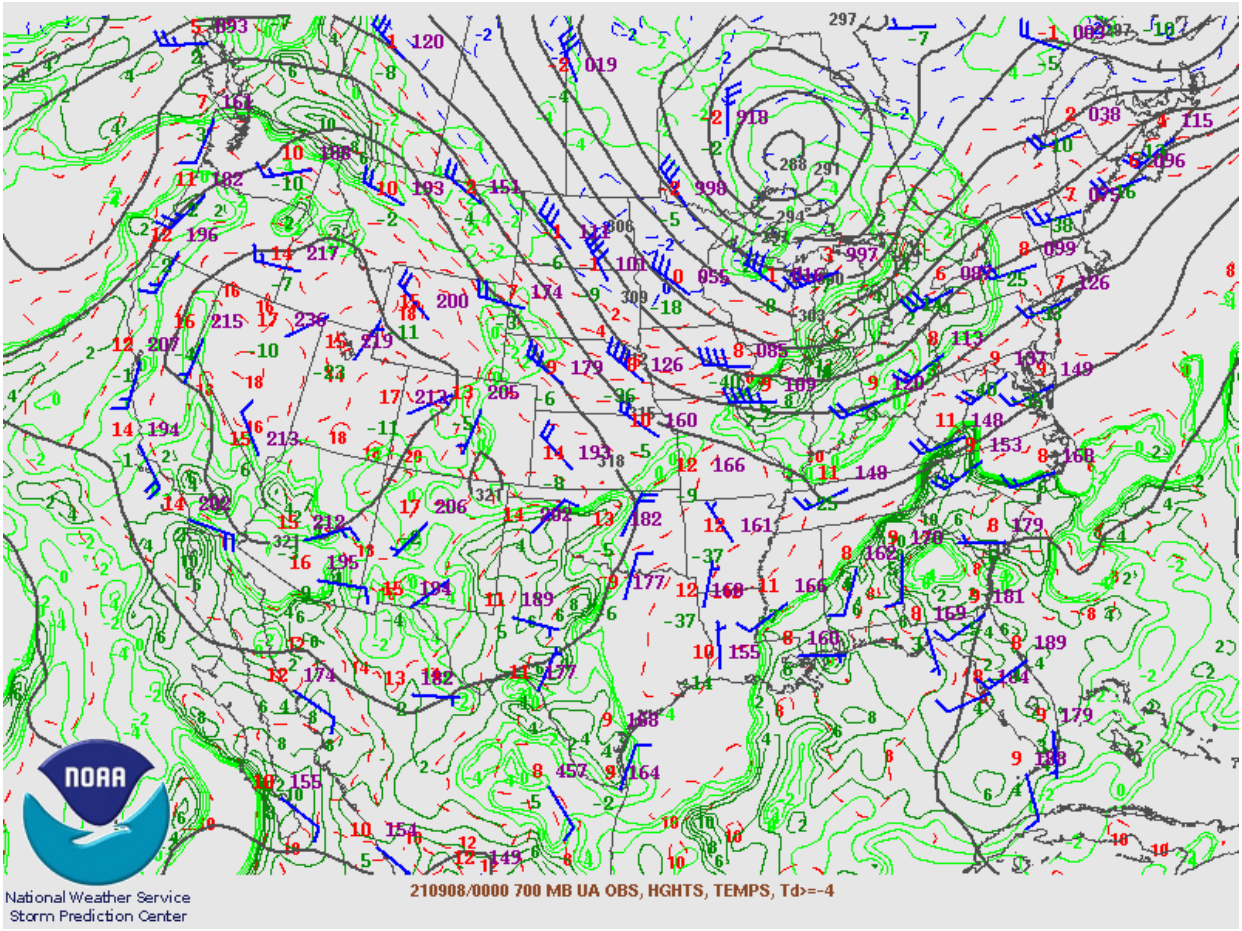

Figure 124. 700-mb map valid at 00:00 UTC on September 8, 2021 (16:00 PST on September 7, 2021). High pressure aloft over central and eastern Nevada allowed wildfire smoke to be transported into Clark County, NV.

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.

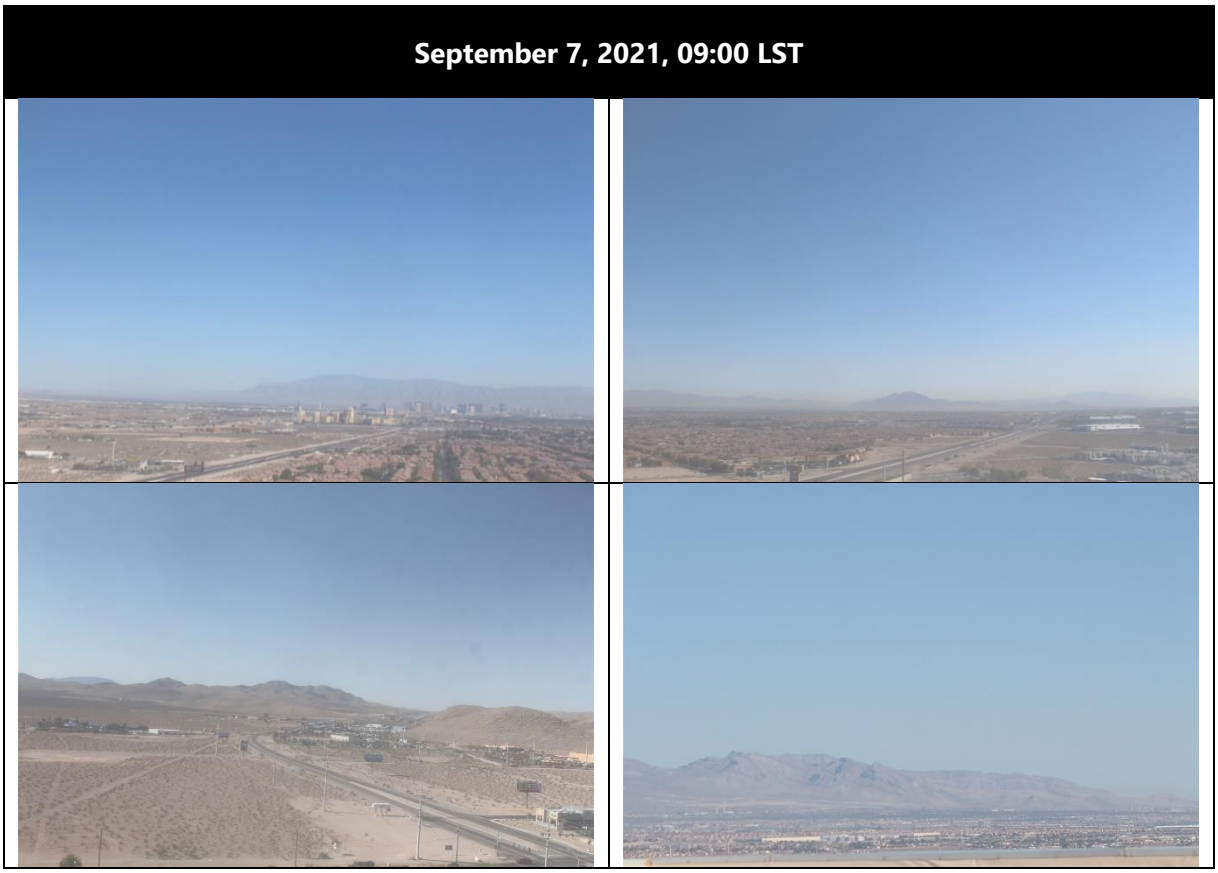

Figure 125. Camera images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions. taken from the M Resort Hotel in Clark County, NV, on September 7, 2021, at 09:00 LST.

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).

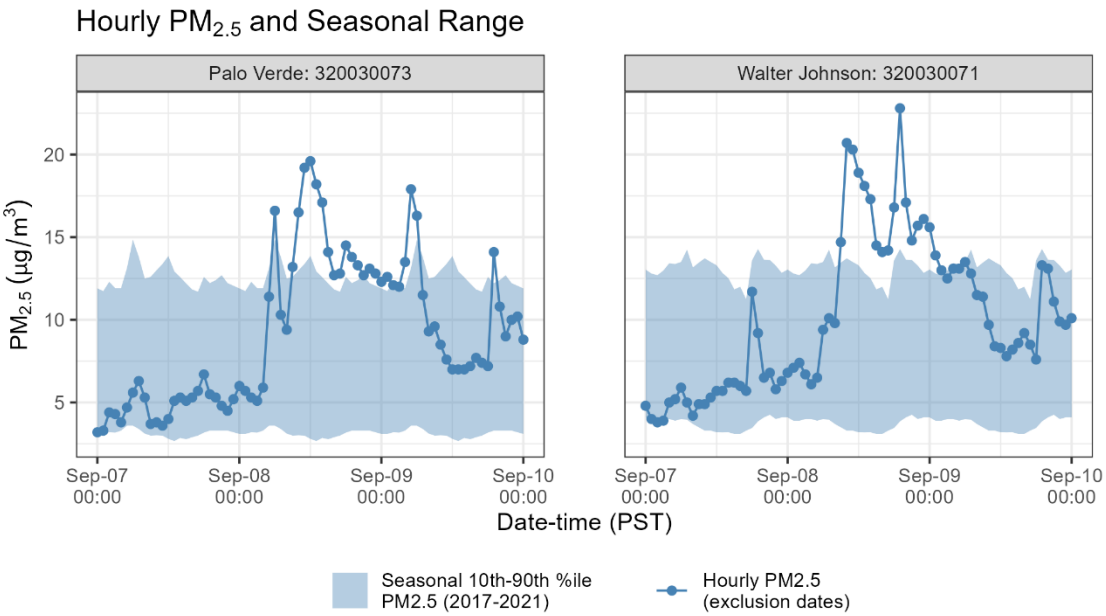

Figure 127. Hourly $PM_{2.5}$ measurements overlaid on the 10th-90th percentile diurnal concentration at a subset of event-affected measurement sites that measure $PM_{2.5}$ concentrations. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

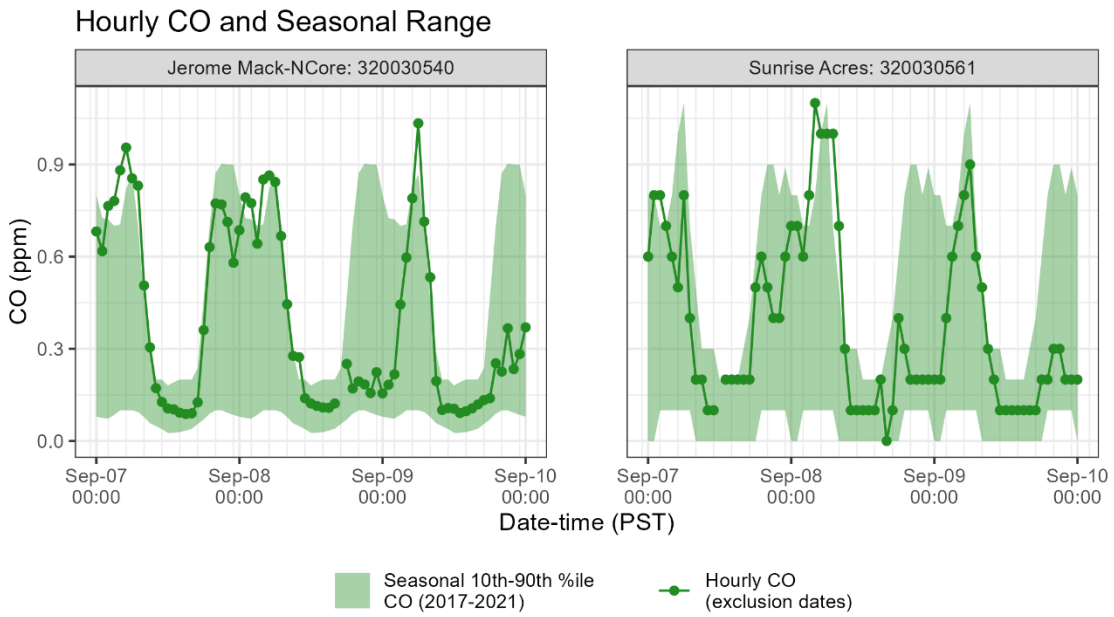

Figure 128. Hourly CO measurements overlaid on the 10th-90th percentile diurnal concentration at Clark County sites that measure CO. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

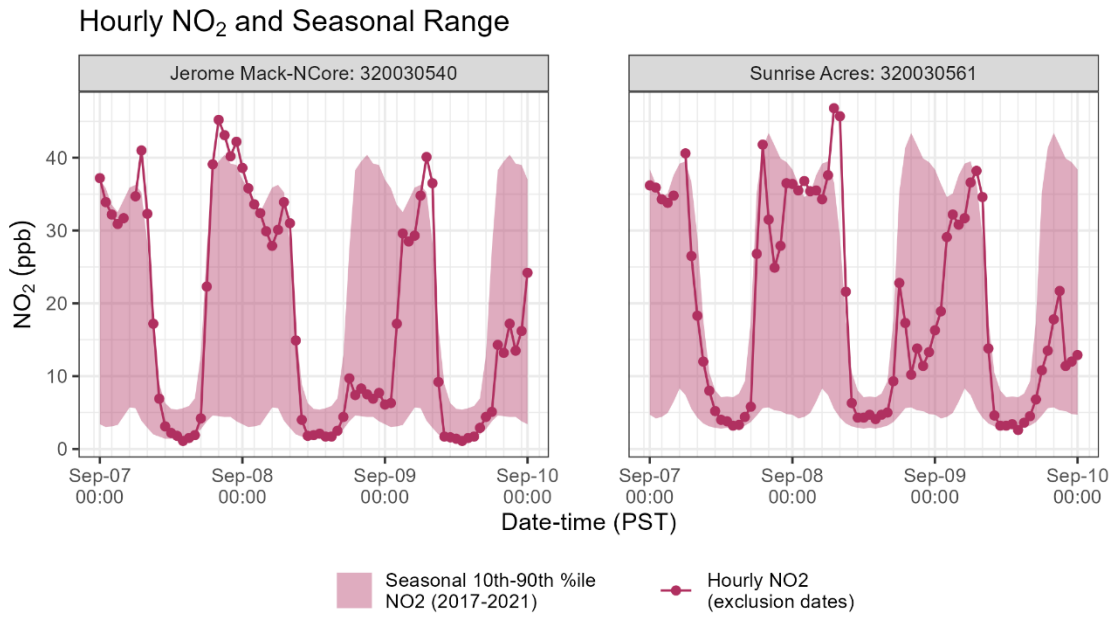

Figure 129. Hourly NO_2 measurements overlaid on the 10th-90th percentile diurnal concentration at Clark County sites that measure NO_2. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2021.

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.

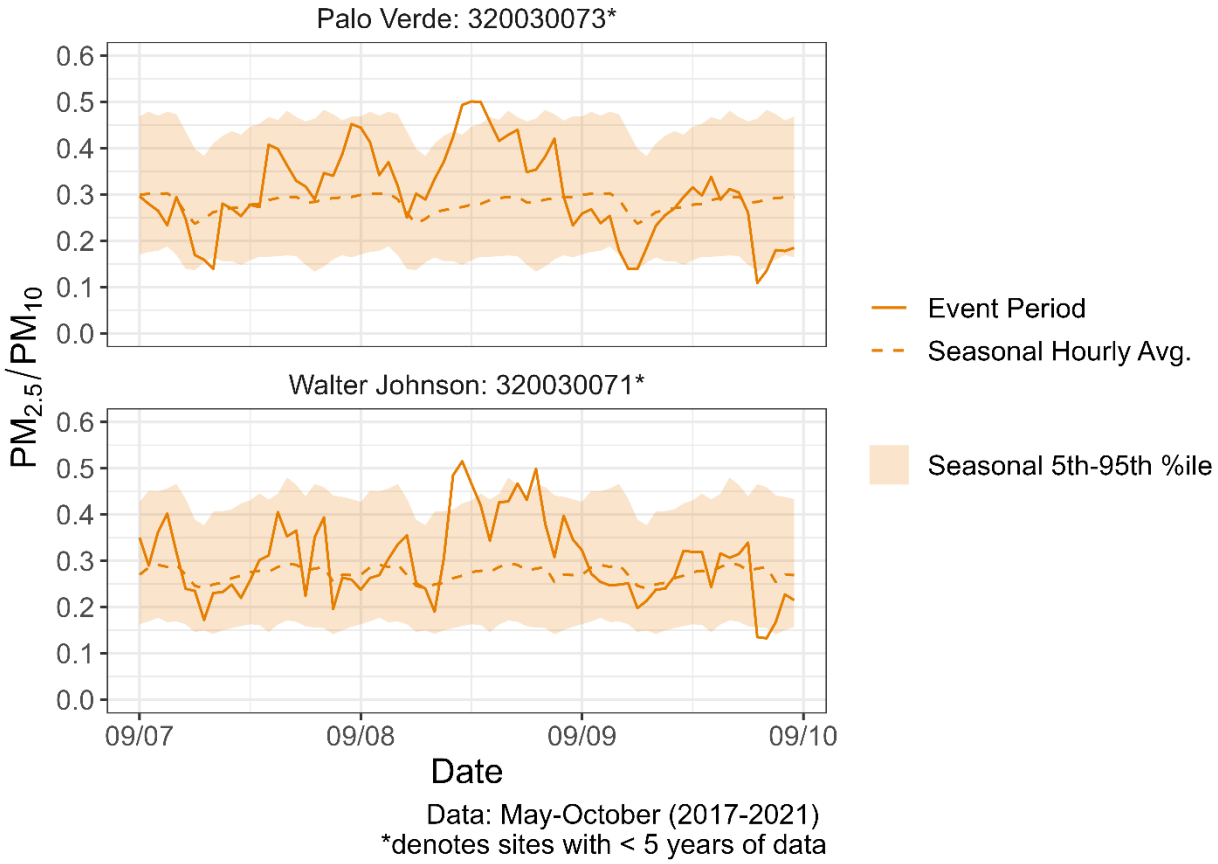

Figure 130. Ratio of $PM_{2.5}$-to-PM_{10} concentrations at the Palo Verde (top) and Walter Johnson (bottom) sites before and during the September 9 event period. The 5-yr average $PM_{2.5}$-to-PM_{10} diurnal ratio is displayed as a dotted line, and the 5th-95th percentile range is shown as a shaded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

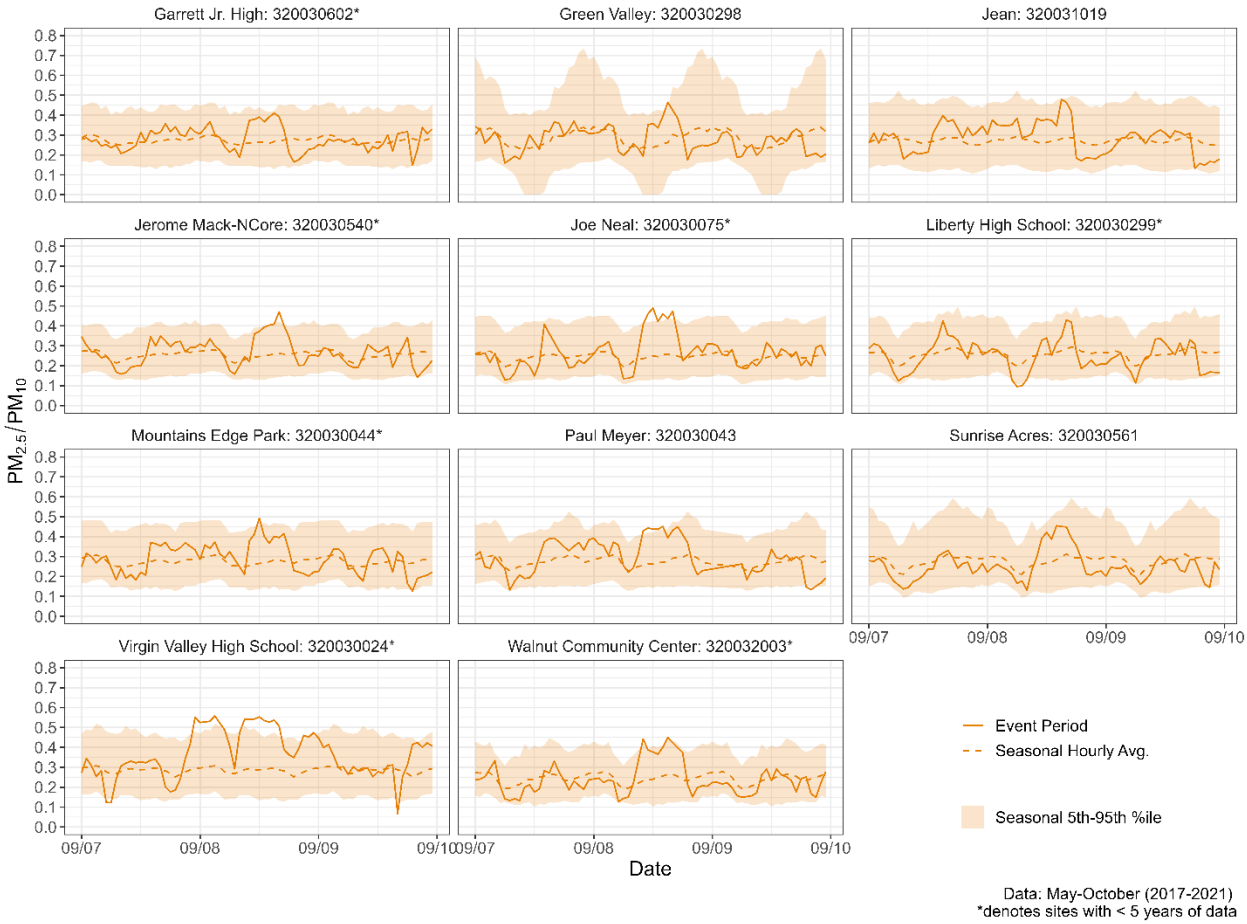

Figure 131. Ratio of $PM_{2.5}$-to-PM_{10} concentrations at the non-affected sites before and during the September 9 event period. The 5-yr average $PM_{2.5}$-to-PM_{10} diurnal ratio is displayed as a dotted line, and the 5th-95th percentile range is shown as a shaded ribbon. The 5th-95th percentile 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.

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.

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.

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	*(2)* Joe Neal and Paul Meyer	Regional Smoke
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, Mountains Edge Park, Palo Verde, Paul Meyer, and Walter Johnson	Regional Smoke
September 1-2, 2022	97th – 98th	*(1)* Paul Meyer	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.

5.1 June 16, 2022

5.1.1 Event Summary

An ozone event took place on June 16, 2022, in Clark County, Nevada, where the maximum daily 8-hr average (MDA8) ozone concentration was greater than 70 ppb 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 an MDA8 value of 72 ppb; it is outside of the Las Vegas Valley and not significant for the design value assessments, however, is indicative of a wide-spread regional ozone event. All sites within the Las Vegas Valley experienced MDA8 values on June 16 between 64 and 70 ppb, with an average MDA8 of 68 ppb. Regional wildfire smoke from eight fires within the U.S. and a fire in Baja, 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, HMS smoke detection, enhanced ground-level acetaldehyde concentrations, and back trajectory analysis. This combination of evidence suggests that this is an unrepresentative event for base and future design value ozone assessments.

Time series graphs showing 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 are shown in **Figure 132**. After the typical diurnal peak near 12:00 PST, hourly ozone concentrations remained enhanced during the typical diurnal minimum, exceeding the 90th percentile between 14:00 to 20:00 PST and not returning to typical concentrations overnight. This enhancement of ozone concentrations later in the day than usual impacted the MDA8 concentrations by keeping ozone concentrations high and increasing the maximum 8-hr average value. The MDA8 value for each exceedance site was between 11:00 to 18:00 PST at each exceedance site.

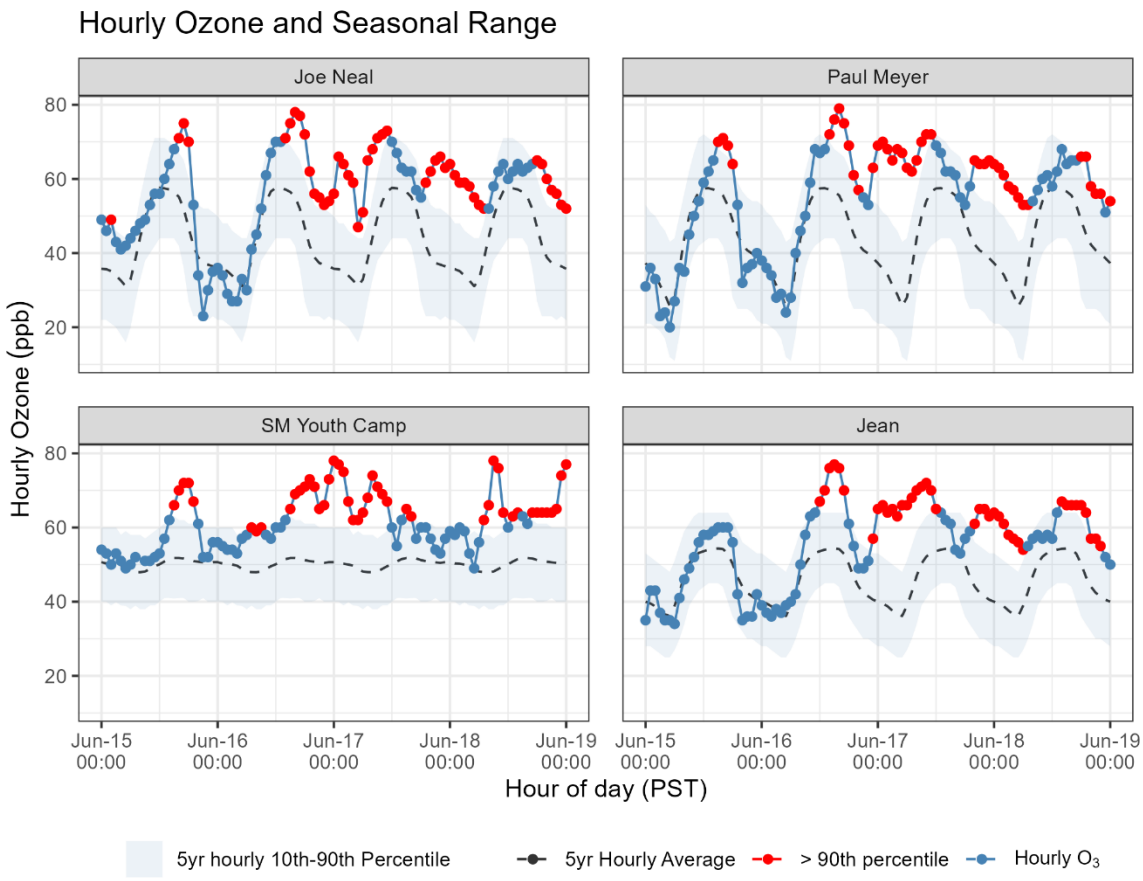

Figure 132. Hourly ozone concentrations (ppb) across June 15-19, 2022, compared to 5-yr ozone season (May 1-October 31) hourly means and 10th-90th percentiles. Note: data collection at the SM Youth Camp did not begin until 2019.

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 and Jean sites, also included in Figure 132, are located far from the city center and thus give 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, 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 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 HMS maps that display the progression of smoke across the United States between June 14 and June 17, 2022, including the event date of June 16. On June 14, distinct eastward transport of smoke from fires in Arizona and New Mexico is visible. Beginning on June 15, this

eastward transport stagnates and smoke spreads westward and drifts over Clark County, as shown between the June 16 and 17 HMS images. 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. Additionally, a fire in north-central Baja Mexico is shown on the maps for June 14 and 15; the smoke from this fire was then mixed into the overall regional smoke on later dates. There is a clear progression of smoke into Las Vegas from the south and east between June 16 and June 17, coinciding with the unusually high ozone concentrations in the late afternoon and evening on June 16 at both urban and background sites in the Las Vegas area.

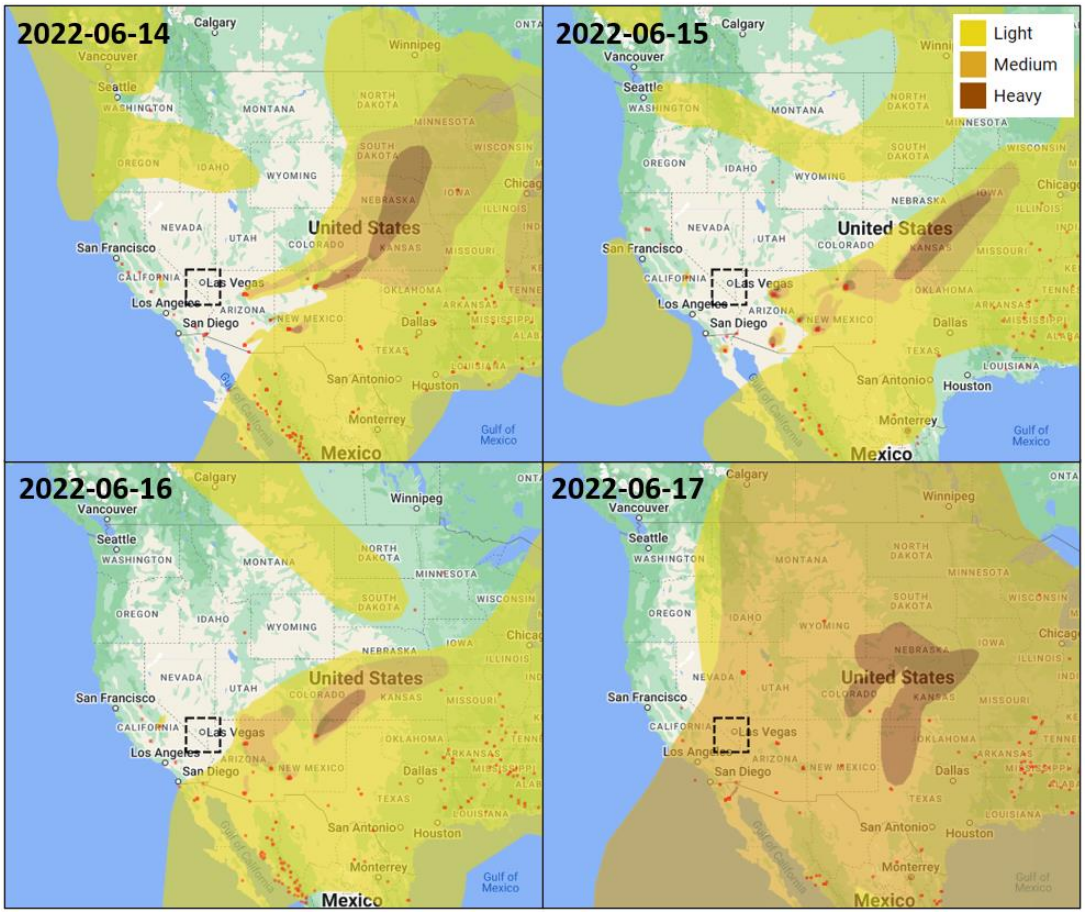

Figure 133. HMS smoke maps for June 14-17, 2022, showing smoke transport and qualitative smoke density. Clark County, NV, is enclosed by a dashed, black box on each map.

Numerous wildfires in Arizona, New Mexico, and Baja Mexico 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. Eight major wildfires in the U.S. with significant emissions that contributed to the regional smoke were identified: the Hermits Peak, Calf Canyon, Black, Tonto Canyon, Contreras, Haywire,

Pipeline, and Fish Fires. Another fire in north-central Baja Mexico was identified as a likely contributor of wildfire smoke to the area. We were unable to find details on this fire, but have provided general information based on HMS smoke and fire records.

Table 30 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 InciWeb and Wikipedia. For the Baja fire in Mexico, we estimated the start and containment dates, as well as the first size based on HMS fire hotspot data. For fires in the U.S., perimeters for each fire in relation to Clark County are shown in Figure 134. A zoomed in view of each fire is shown in Figure 135.

Table 30. Wildfires affecting Clark County on the exclusion day of June 16, 2022. The fire name, state location, total acreage, acres burned on or before the exclusion day, and the start and containment dates are included. 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
Hermits Peak	New Mexico	341,735	336,638 (June 16)[27]	April 6	Aug. 21
Calf Canyon	New Mexico	341,735	336,638 (June 16)[27]	April 9	Aug. 21
Black	New Mexico	325,136	320,971 (June 16)[28]	May 14	Nov. 18
Tonto Canyon	Arizona	9,264	8,884 (June 15)[29]	June 12	June 22
Contreras	Arizona	29,482	11,489 (June 15)[30]	June 11	July 4
Haywire	Arizona	5,575	5,372 (June 16)[31]	June 13	July 4
Pipeline	Arizona	26,532	24,815 (June 16)[32]	June 12	July 4
Fish	Arizona	3,704	1,900 (June 16)[33]	June 10	July 13
Baja Fire	*Baja, MX*	*1,000*	*7,000 (June 17)*	*June 11*	*June 21*

[27] https://en.wikipedia.org/wiki/Calf_Canyon/Hermits_Peak_Fire
[28] https://en.wikipedia.org/wiki/Black_Fire_(2022)
[29] https://inciweb.nwcg.gov/incident-maps-gallery/azcnf-tonto-canyon-fire
[30] https://inciweb.nwcg.gov/incident-maps-gallery/azppa-contreras-fire
[31] https://inciweb.nwcg.gov/incident-information/azcof-haywire-fire
[32] https://inciweb.nwcg.gov/incident-information/azcof-pipeline-fire
[33] https://inciweb.nwcg.gov/incident-publication/azasf-fish-fire/apachesitgreaves-national-forests-continue-responding-to-the-fish-fire

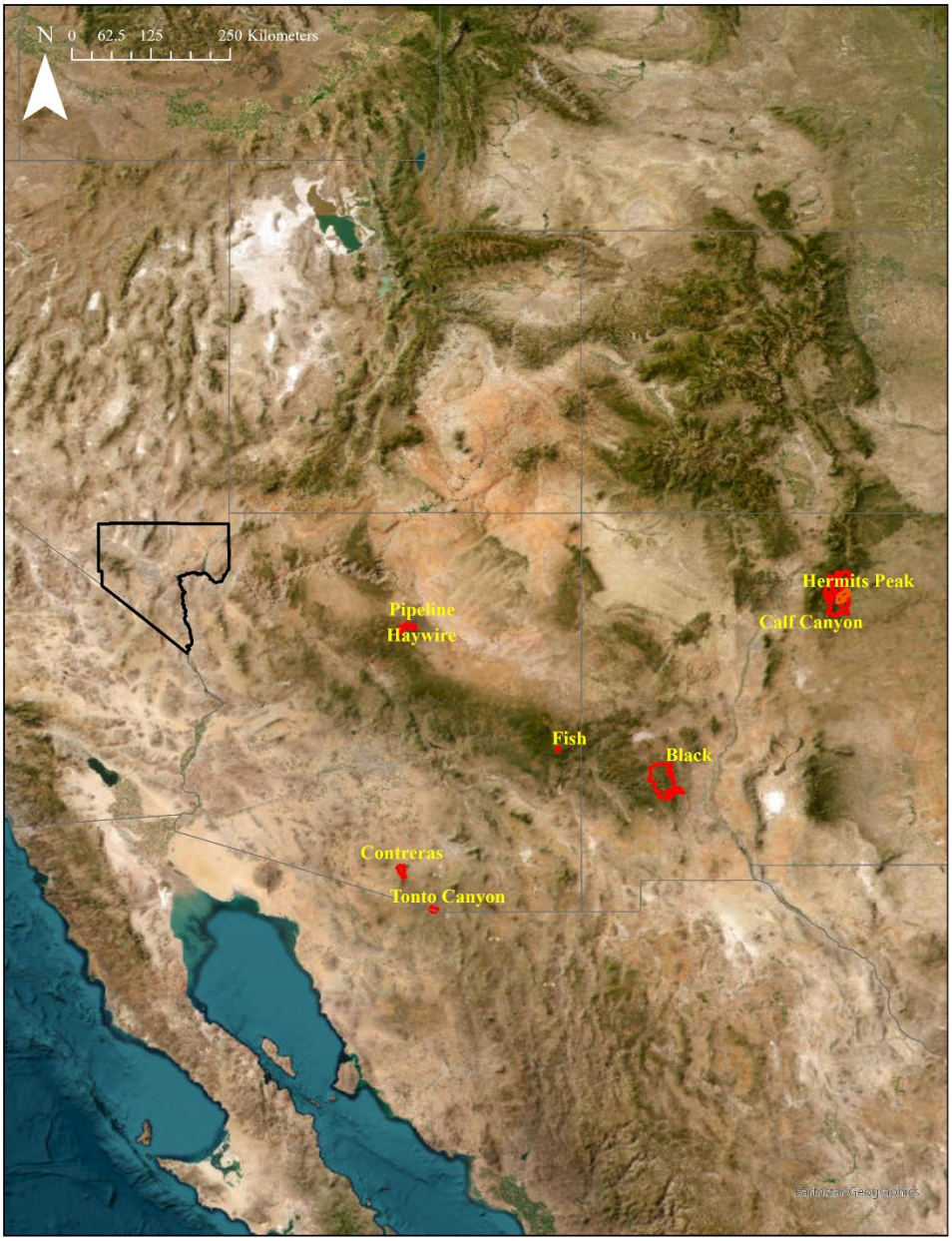

Figure 134. Final fire perimeters (red) for the eight active fire regions in the U.S. during the June 16, 2022, exclusion date in relation to Clark County (black perimeter).

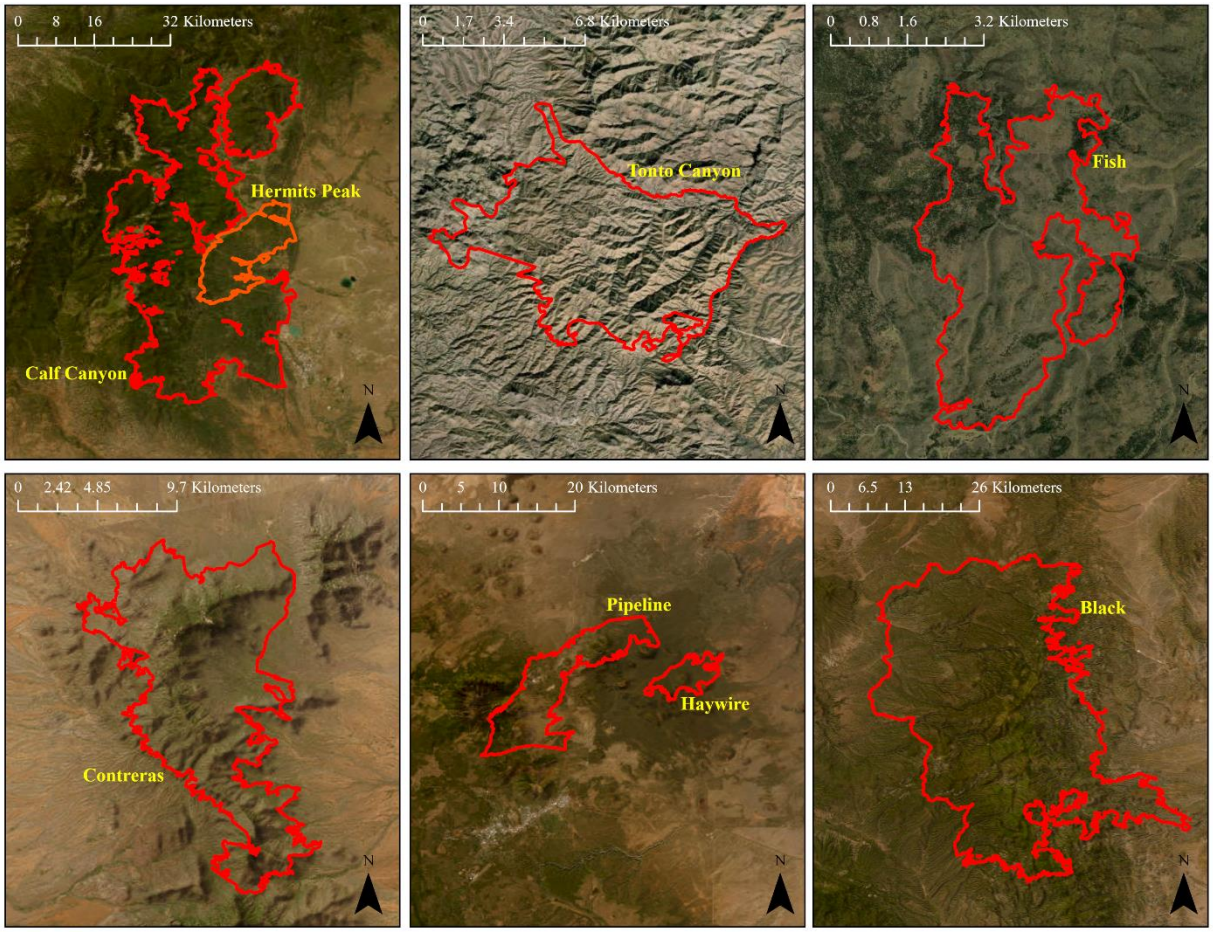

Figure 135. Final fire perimeters (red) for the eight active fire regions in the U.S. during the June 16, 2022, exclusion date.

5.1.3 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 5.1.2), we first determined 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 smoke mixing to the surface. We then used this information to model smoke via the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model and compare the results with independent data sources, including HMS and High-Resolution Rapid Refresh (HRRR) model data.

The planetary boundary layer (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 two skew-T diagrams in Figure 136 show the vertical profile of the atmosphere 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 removal of the near-surface temperature inversion from the 04:00 PST

sounding to the 16:00 PST sounding on June 16, and the large mixing layer above the surface after the near-surface inversion had dissipated. The early morning near-surface temperature inversion, observed by the 04:00 PST sounding, likely prevented air aloft from mixing down into the lower troposphere. During the afternoon (16:00 PST) sounding, the temperature inversion was no longer active, allowing the air to be mixed down into the lower troposphere, as indicated by the temperature line following near the dry adiabatic lapse rate lines. This indicates that the lower PBL was well-mixed up to approximately 3,100 m above ground level (agl), at the same time ozone concentrations were remaining unusually high and smoke was likely being transported into the area. The North American Mesoscale Forecast System (NAM)-modeled PBL heights over Clark County on June 17 at 00:00 UTC (June 16 at 16:00 PST) roughly corresponds to the PBL heights shown by the sounding of the same time (Figure 137), providing independent verification. The NAM-modeled data map in Figure 137 shows PBL heights above 2 km in altitude in 1 km increments, with color contours starting at 1 km.

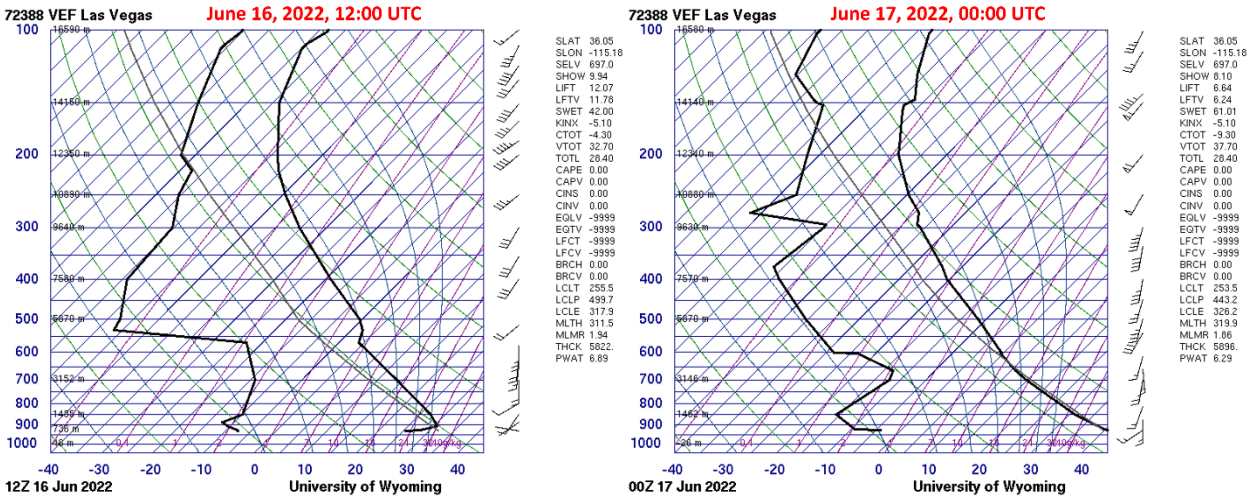

Figure 136. Skew-T soundings launched from the Las Vegas National Weather Service office on June 16, 2022, at 12:00 UTC (04:00 PST) (left), and June 17 at 00:00 UTC (June 16 at 16:00 PST) (right).

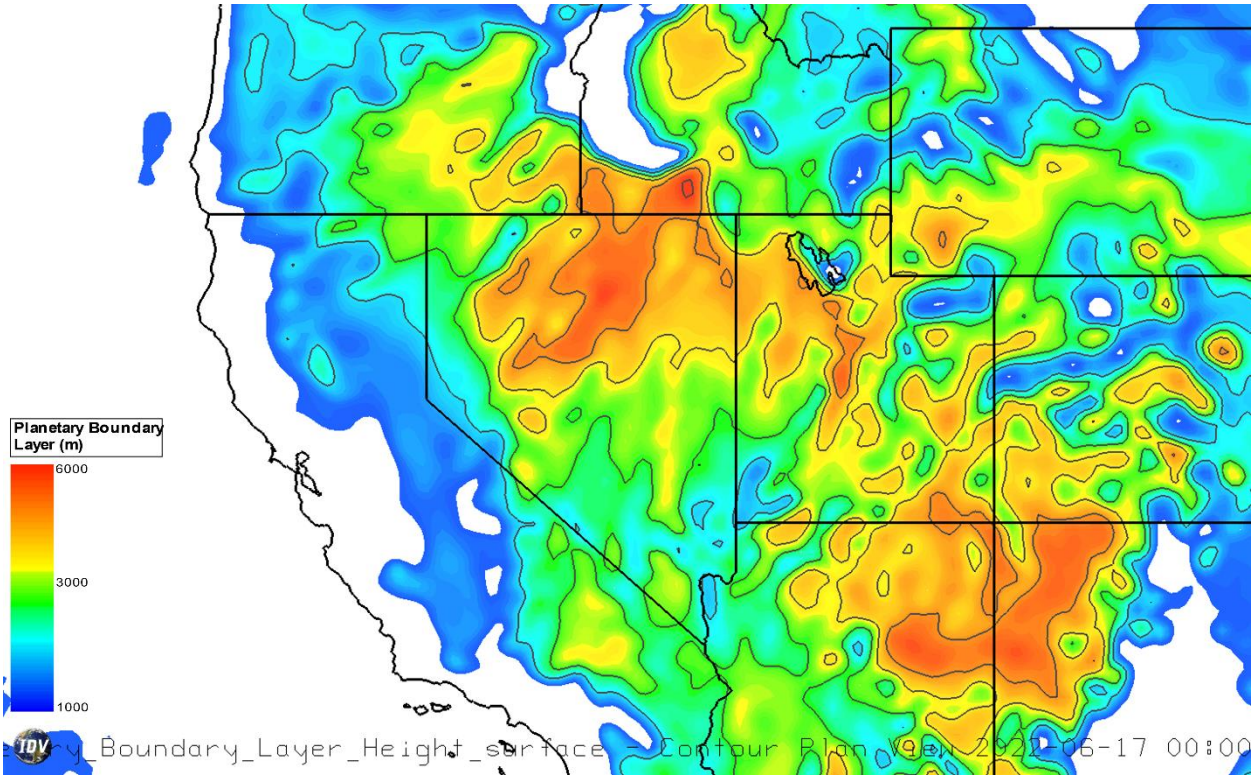

Figure 137. PBL height contour map based on the NAM model for June 17, 2022, at 00:00 UTC (June 16 at 16:00 PST). The gray lines denote PBL heights above 2 km in altitude in 1 km increments. Color contours begin at 1 km.

HYSPLIT dispersion modeling was performed from June 13 through June 16, 2022. Dispersion was initiated for June 13 at 19:00 PST from the eight identified active fires in the U.S. impacting the exclusion date and modeled through the exclusion date to simulate the smoke patterns seen in satellite imagery and HMS smoke data. We were not able to model smoke dispersion from the Baja fire in Mexico due to a lack of daily fire information (i.e., fire perimeters). Global Data Assimilation System (GDAS) data at 1.0° horizontal resolution was used for meteorological input. Output from the dispersion modeling has been integrated for 8-hr intervals over the period starting at 19:00 PST on June 15 and ending at 19:00 PST on June 16, including the afternoon and evening of June 16, when ozone concentrations were abnormally high and smoke intruded into the area. Smoke accumulation throughout the boundary layer at 0-3,700 m for this period is shown in **Figure 138**.

The HYSPLIT dispersion modeling shows that smoke from multiple fires in the U.S. produced a dense layer of smoke that blanketed the region east of Clark County, NV. The modeling results are consistent with the HMS smoke plume (shown in gray in Figure 138); HMS is an independent smoke identification database.

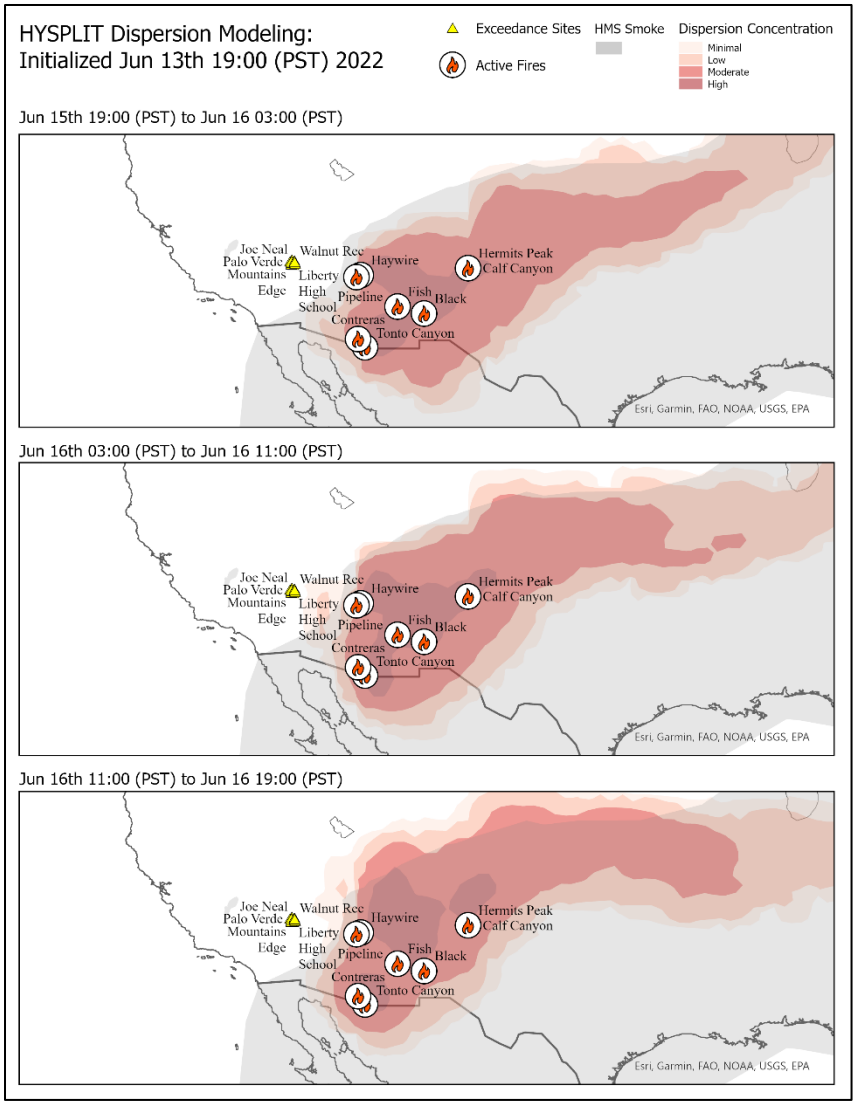

Figure 138. HYSPLIT dispersion modeling for seven large fires (labeled as "Active Fires") in New Mexico and Arizona on or before the exclusion date of July 16, 2022. GDAS 1.0° meteorological data was used, and dispersion was initiated on June 13, 2022, at 19:00 PST to model the regional smoke observed 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 0-3,700 m for 8-hr periods between 19:00 PST on June 15 through 19:00 PST on June 16, 2022.

While the smoke plume was not directly over Clark County in the late afternoon on June 16, back trajectories shown in Figure 139 indicate that air was advected from the southwest and from the area of regional smoke in the afternoon on June 16, 2022. These HYSPLIT back trajectories were initialized on June 16 at 16:00 PST (00:00 UTC); i.e., during the middle of the MDA8 ozone period. Lower level (500 and 1,000 m) back trajectories show surface level transport from the direction of the regional smoke. Upper level (2,500 m) back trajectories show longer ranger transport from the Baja, Mexico fire direction. The upper-level trajectory would still be within a well-mixed boundary layer in Clark

County according to PBL height estimates. Back trajectories and dispersion modeling indicate that although the main plume remained to the east of Clark County, smokey air was likely advected into the region in the afternoon on June 16 from both the Arizona/New Mexico fires and the Baja fire in Mexico, which impacted ozone concentrations and kept them high outside of the typical diurnal profile. These results are consistent with the previous HMS evidence that shows the overall smoke plume was moving westward toward Clark County between June 16 and 17. Additionally, based on the boundary layer analysis, we suggest that smoke entering the area would have been well mixed with the surface.

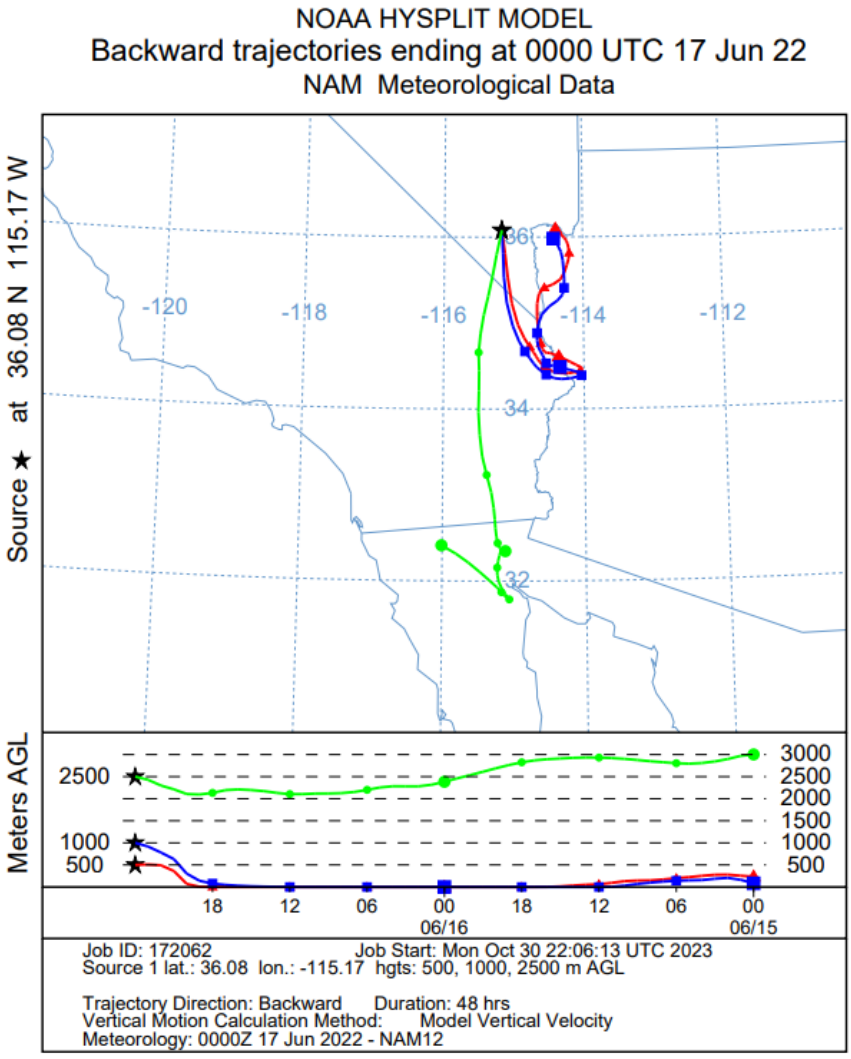

Figure 139. HYSPLIT back trajectory analysis initiated on June 16, 2022, at 16:00 PST (00:00 UTC) showing air advection into Clark County in the afternoon using NAM 12 km meteorological data. Back trajectory heights were modeled at 500, 1,000, and 2,500 m to show near-surface and synoptic flow.

Confirmation of this analysis is shown by the HRRR forecasts in Figure 140. The HRRR data is shown for June 16, 2022, at 11:00 and 15:00 PST. The HRRR data shows heavy levels of smoke being emitted from the New Mexico, Arizona, and Baja Mexico fires that were mixed into a regional plume of smoke. The plume of smoke over southern California can be traced back to the Baja fire in Mexico, which is shown to be directly impacting Clark County on June 16 during the MDA8 ozone period. The back trajectories shown previously also indicate nearly direct transport from the Baja fire area in Mexico to Clark County, similar to the HRRR results. Overall, the HRRR product shows low to medium levels of vertically integrated smoke from the fires in Baja, Mexico, Arizona, and New Mexico over the Clark County region in the afternoon on June 16.

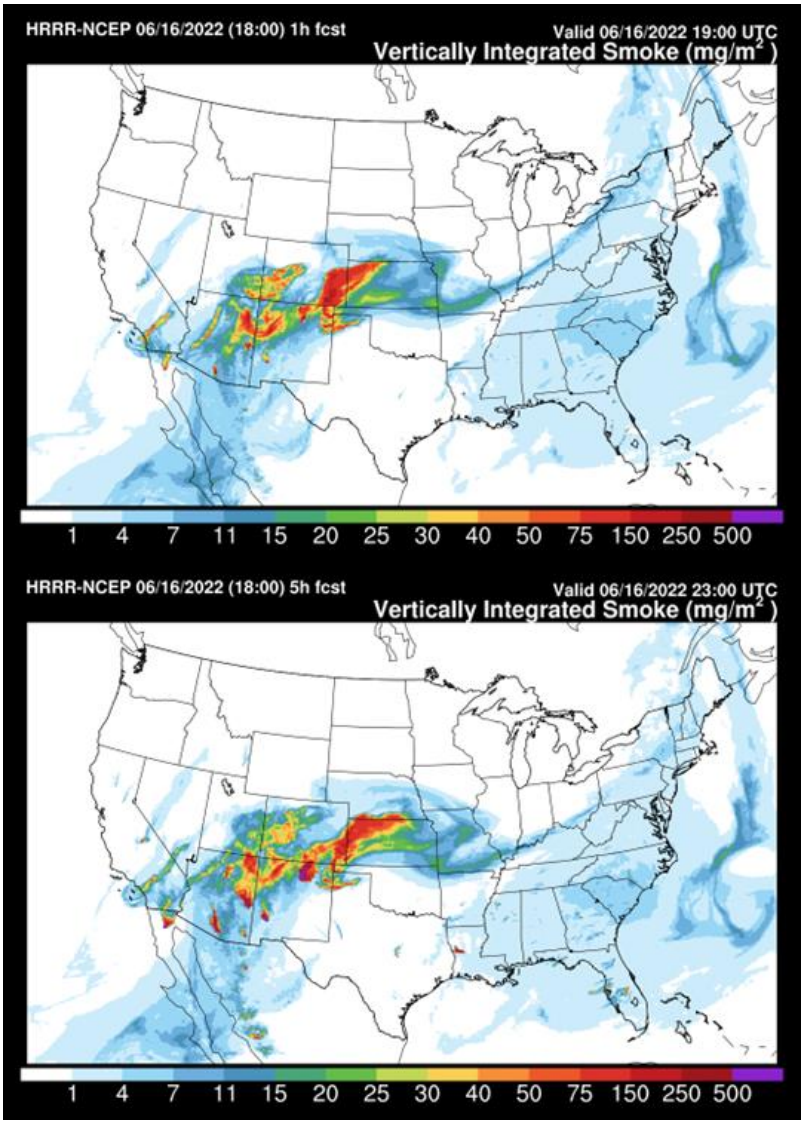

Figure 140. HRRR vertically integrated smoke forecast for June 16, 2022, at 11:00 PST and 15:00 PST.

5.1.4 Surface Impacts

Figure 141 and Figure 142 compare visibility conditions in the Las Vegas Valley before and during the exclusion date. Figure 141 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 142) do show more brown-tinted skies compared with June 15. This is consistent with a well-mixed boundary layer with smoke. Both Figure 141 and Figure 142 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 from the Arizona and New Mexico fires entered the Las Vegas area in the afternoon on June 16 and was well mixed in the column.

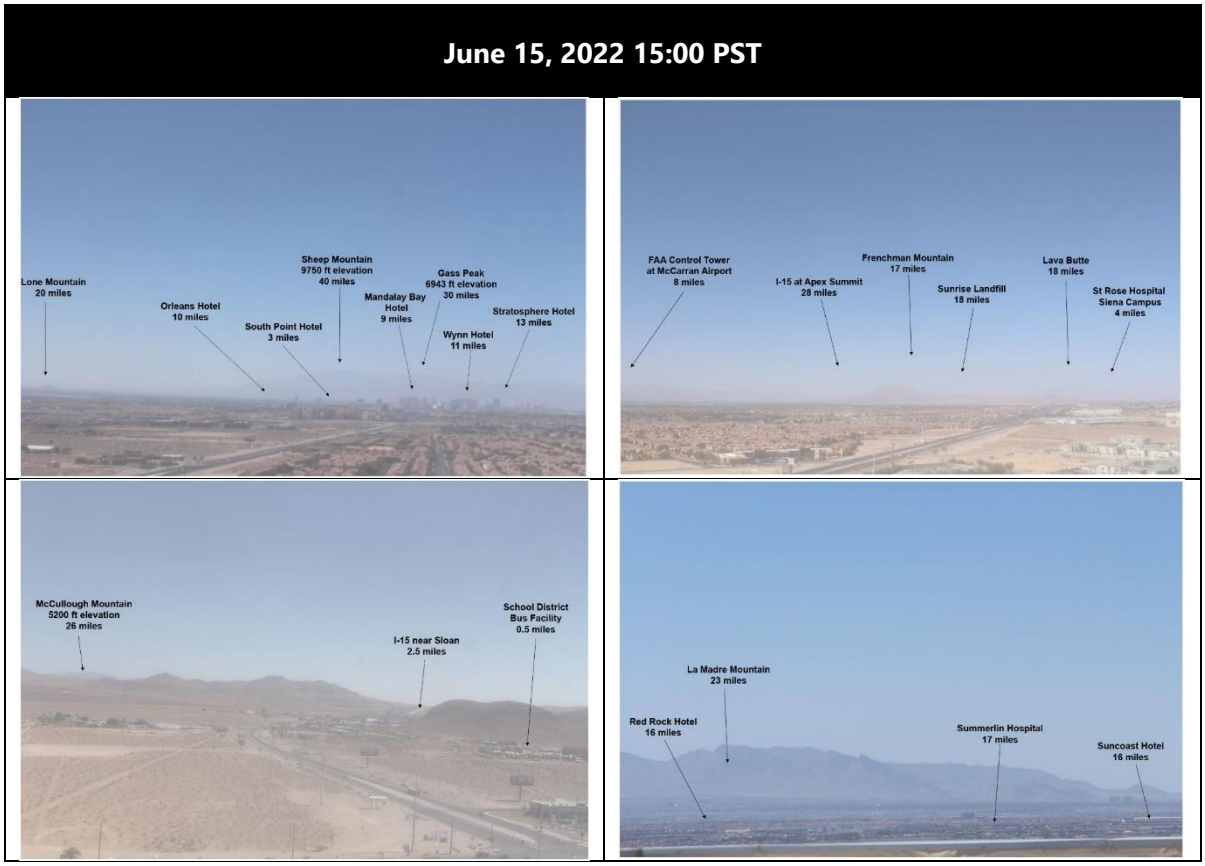

Figure 141. Camera images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions, taken from the M Resort Hotel in Clark County, NV, on June 15, 2022, at 15:00 PST.

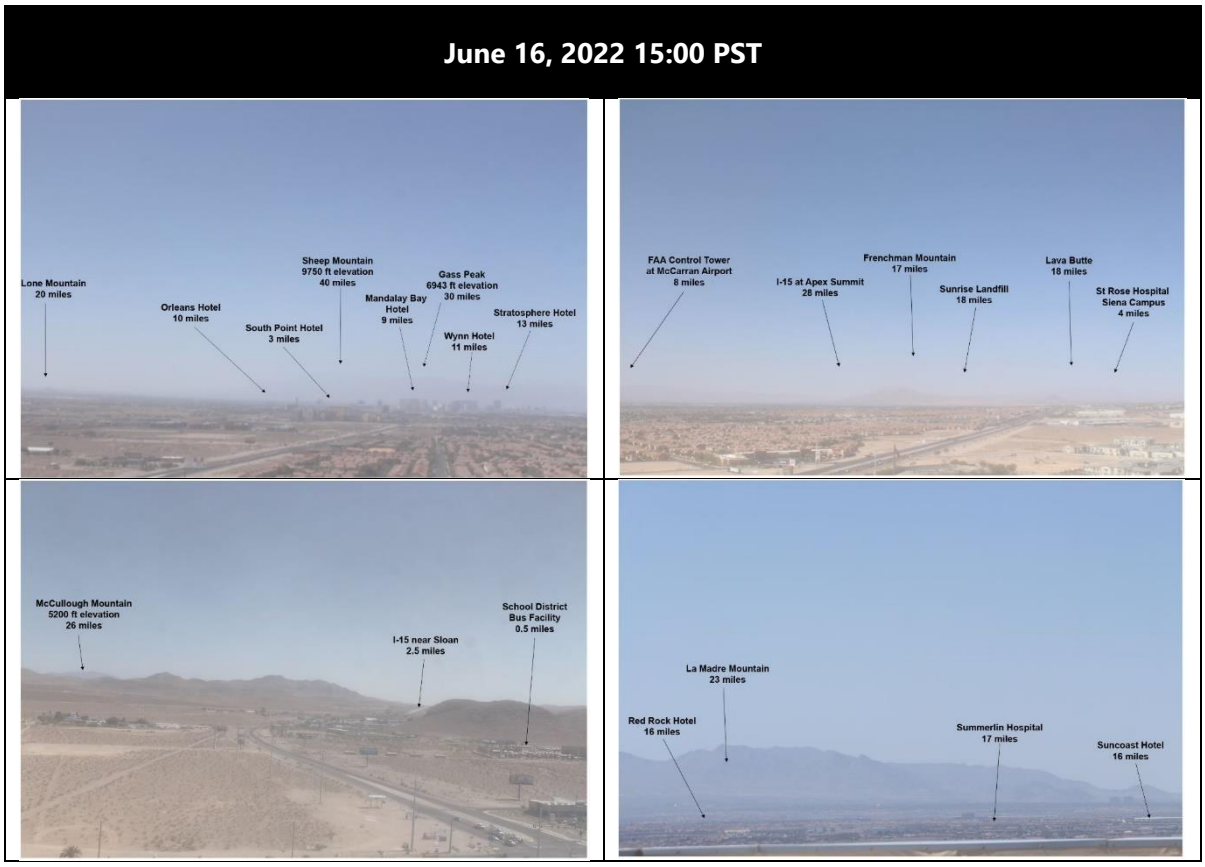

Figure 142. Camera images showing the north (top left), south (bottom left), northeast (top right), and northwest (bottom right) coordinal directions, taken from the M Resort Hotel in Clark County, NV, on June 16, 2022, at 15:00 LST.

Figure 143 through Figure 145 show the hourly $PM_{2.5}$, CO, and NO_2 concentrations for June 16, 2022. Figure 143Figure 98 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 around midnight on June 17, as shown by the quick rate of change in $PM_{2.5}$ concentrations around midnight at all sites. This suggests the main smoke plume was pushing westward and finally reached the area late on June 16 and into early June 17. $PM_{2.5}$ concentrations were not extremely high during this period because this regional smoke plume was likely significantly dispersed by the time it reached Clark County. While the main plume of smoke reached Clark County after the MDA8 ozone period on June 16, back trajectories show transport from the Baja, Mexico, Arizona, and New Mexico fire plumes before they were directly overhead in Clark County.

Hourly CO and NO_2 concentrations are shown in Figure 144 and Figure 145, 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.

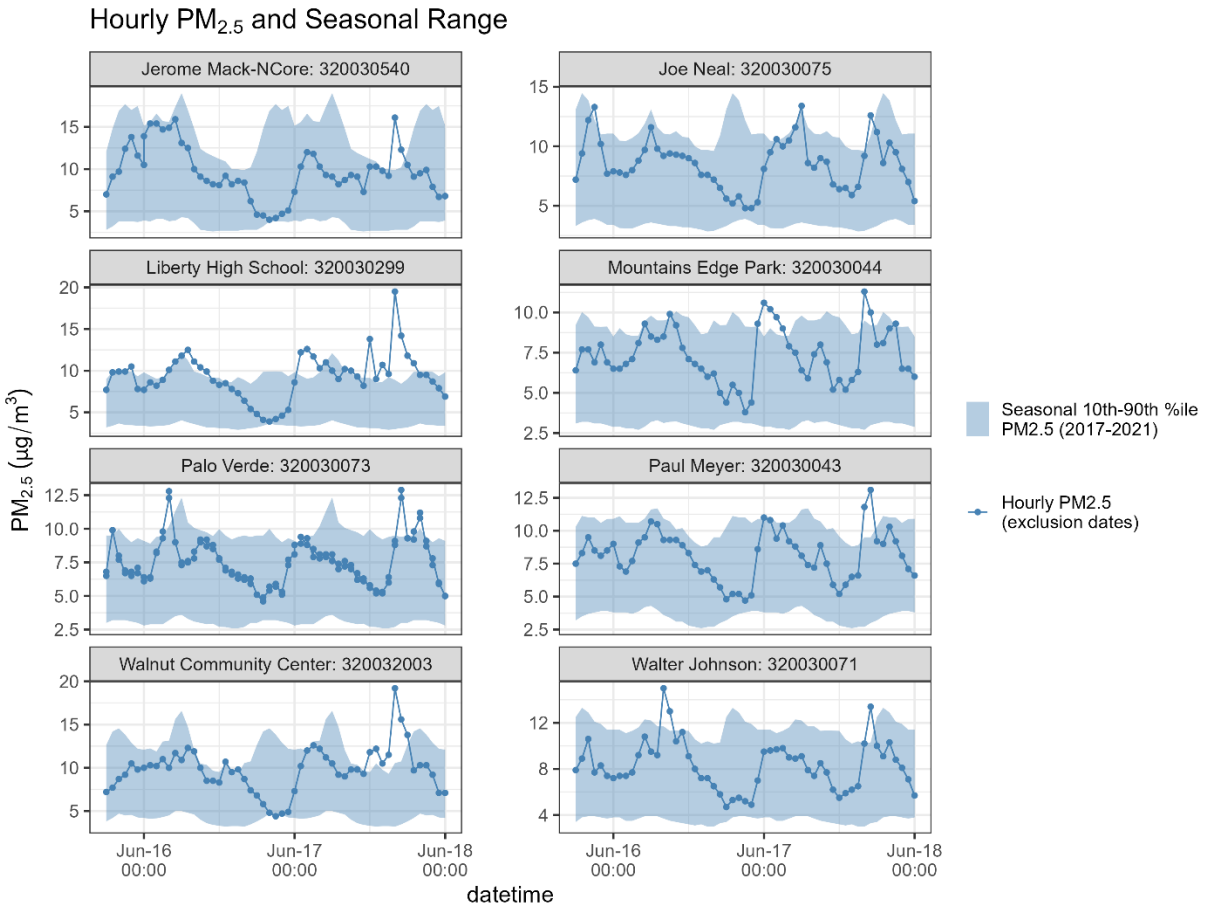

Figure 143. Hourly $PM_{2.5}$ measurements overlaid on the 10th-90th percentile diurnal concentration at the event-affected measurement sites and supporting sites that measure $PM_{2.5}$ concentrations. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2022.

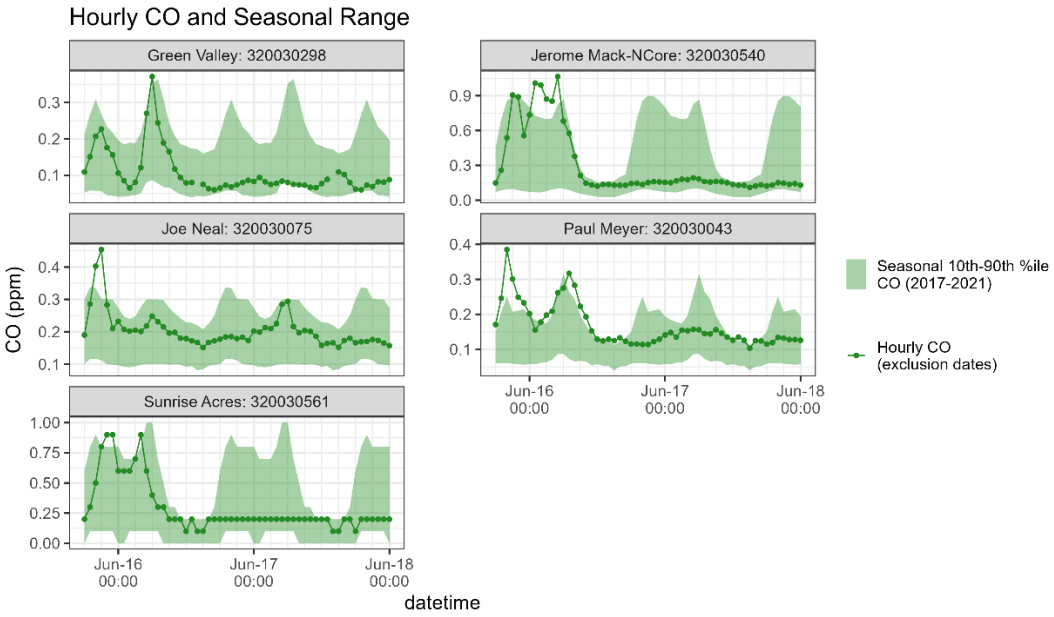

Figure 144. Hourly CO measurements overlaid on the 10th-90th percentile diurnal concentration at the event-affected sites and supporting sites that measure CO. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2022.

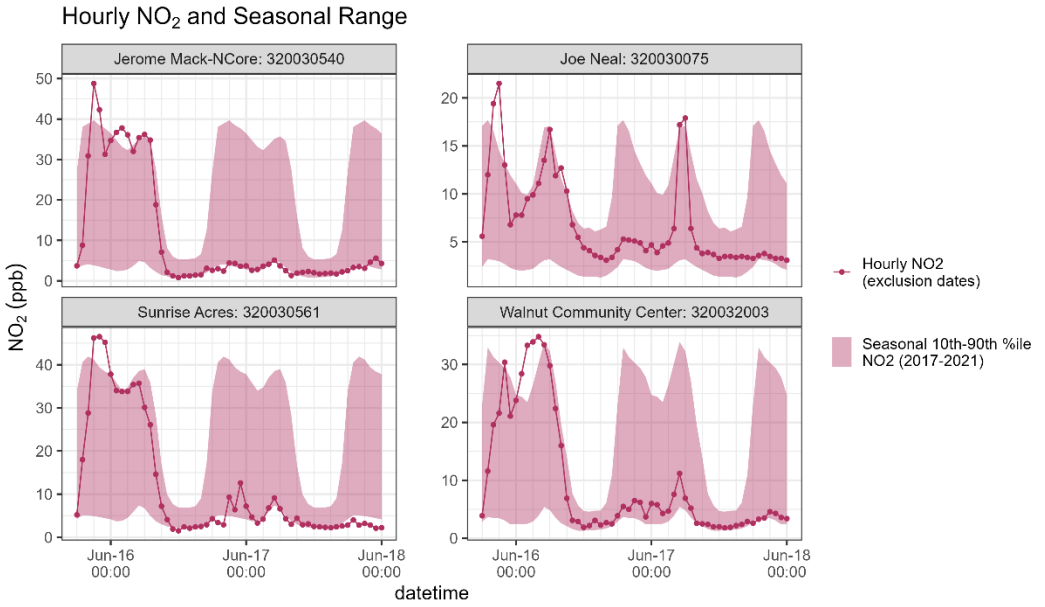

Figure 145. Hourly NO_2 measurements overlaid on the 10th-90th percentile diurnal concentration at the event-affected sites and supporting sites that measures NO_2. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2022.

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 146**. 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.[34,35,36] 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.

[34] 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.

[35] 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.

[36] 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.

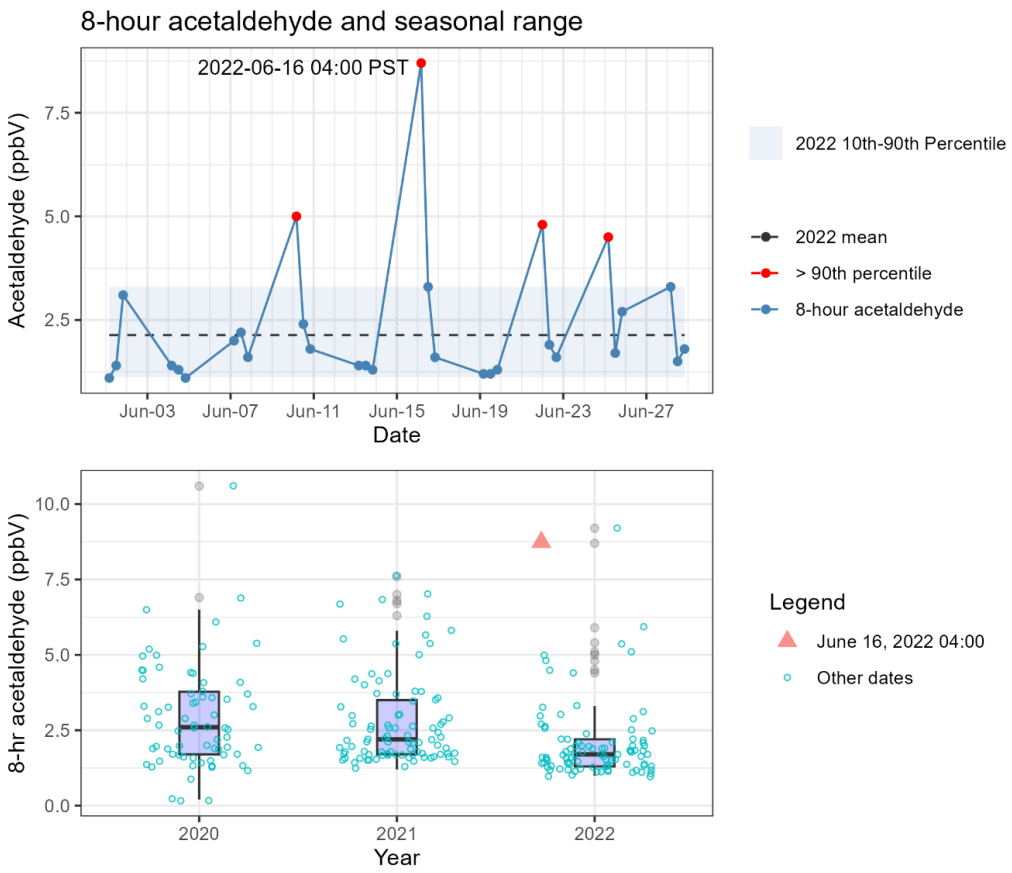

Figure 146. (Top) 8-hr acetaldehyde measurements before, on, and after the exclusion date overlaid on the 10th-90th percentile concentration in 2022. (Bottom) 8-hr acetaldehyde measurements grouped by year of measurement, where the box indicates the 25th-75th percentile of data, and the median is the solid line across the box. Individual datapoints have been overlaid across the boxplots.

5.1.5 Event Statistics

Table 31 summarizes the daily measurements of ozone, $PM_{2.5}$, CO, and NO_2 concentrations collected at the Joe Neal and Paul Meyer 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 both sites were above the 94.9th percentile. The 24-hr average $PM_{2.5}$ concentrations were above the 76th percentile at both 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 31. 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*		

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

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 32). 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 147 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.

Table 32. 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

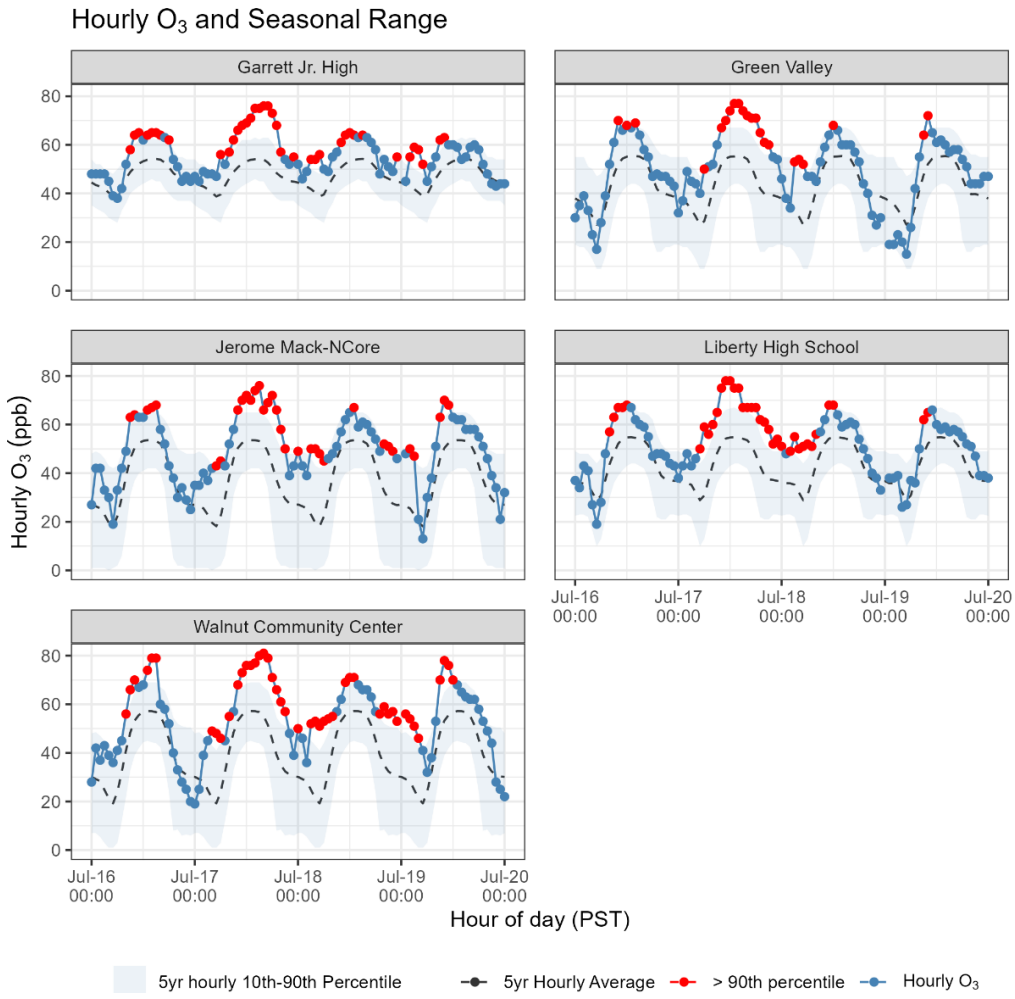

Figure 147. Hourly ozone concentrations (ppb) compared to 5-yr ozone season (May 1-October 31) hourly means and 10th-90th percentiles. Data collection did not begin until 2021 at Garrett Jr. High, Liberty High School, and Walnut Community Center, so data for these sites begins from the first available date in 2021.

5.2.2 Identification of Wildfires

Figure 148 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 149) 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.

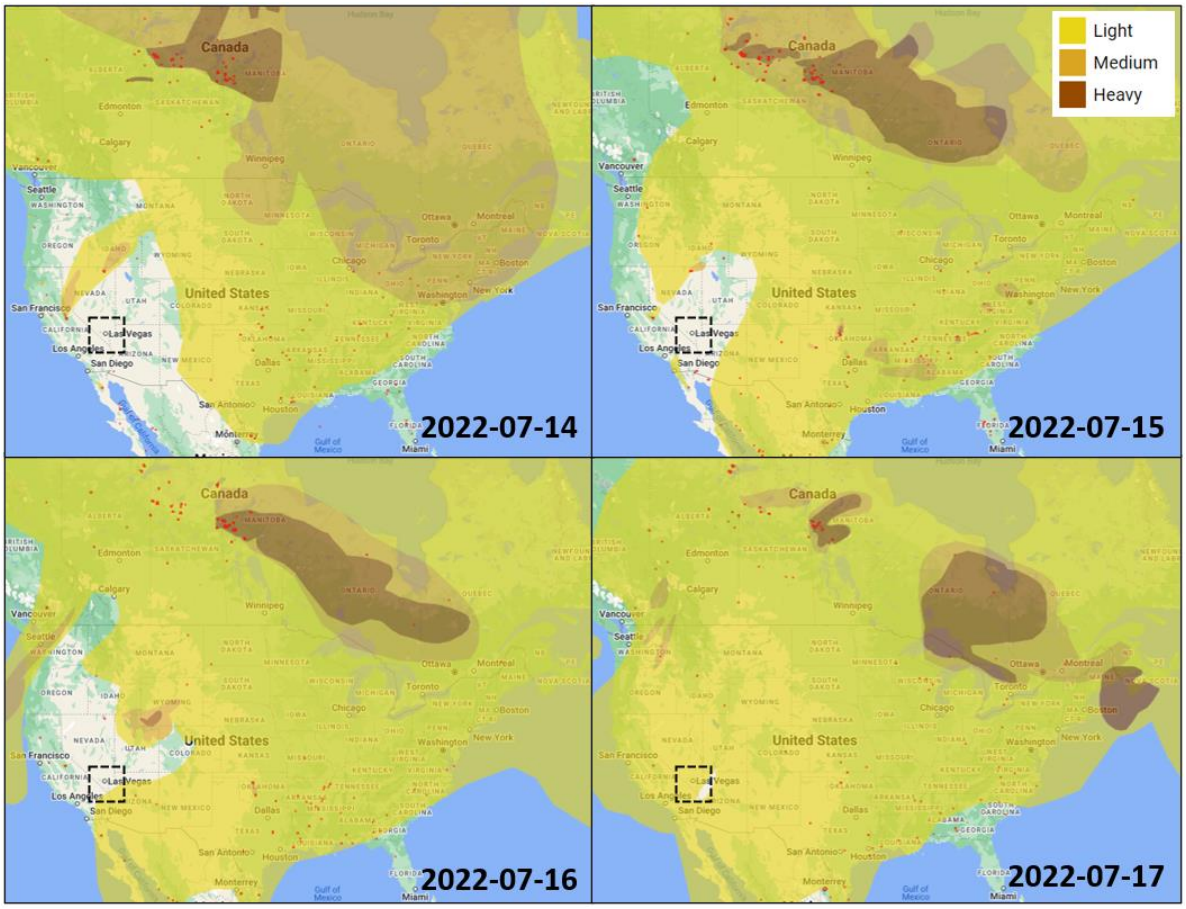

Figure 148. HMS smoke for July 14 - 17, 2022 is included with qualitative smoke density. Clark County, NV, is enclosed by black, dashed box.

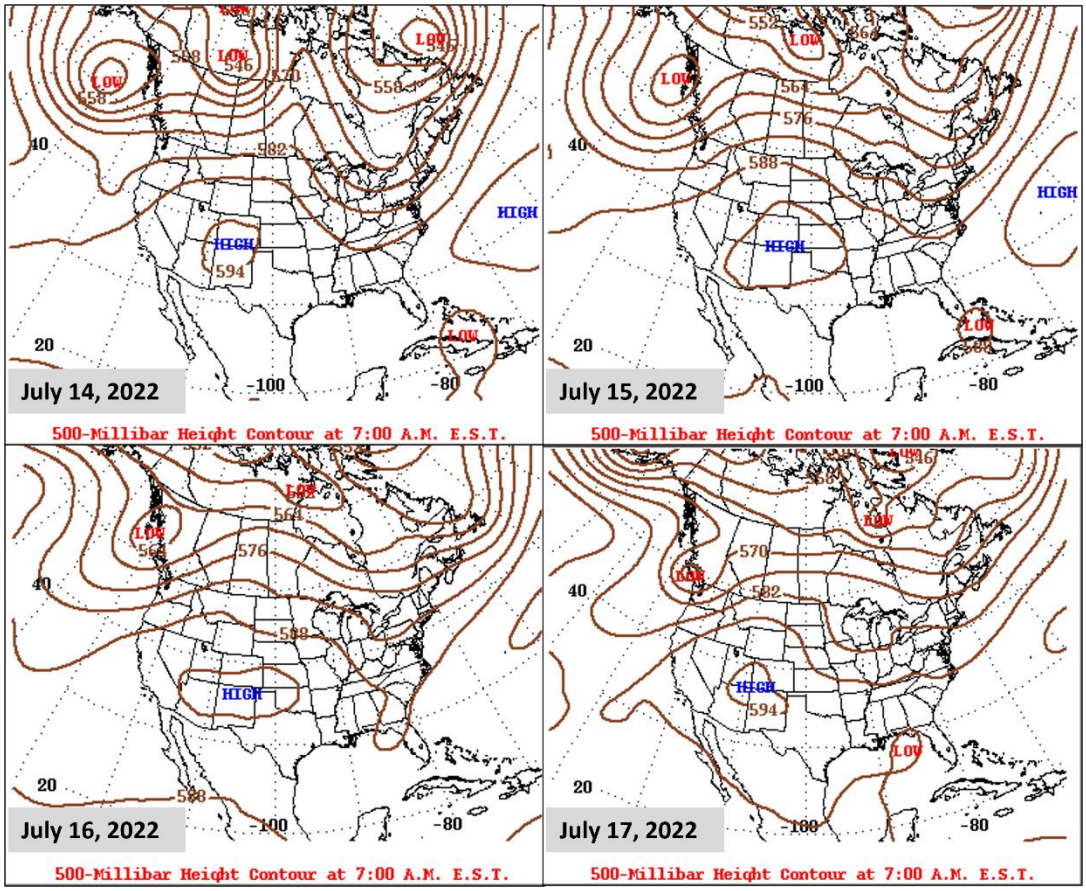

Figure 149. Daily 500-mb weather maps for July 14-17, 2022.

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 33, 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.[37] 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 150. A zoomed in view of each fire is shown in Figure 151.

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

Table 33. 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)[38]	Jul 13	Jul 23
Washburn	California	4,886	4,856 (Jul 17)[39]	Jul 7	Sep 30
Manitoba Complex	Manitoba-Canada	103,924[40]	--	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

[38] 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.

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

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

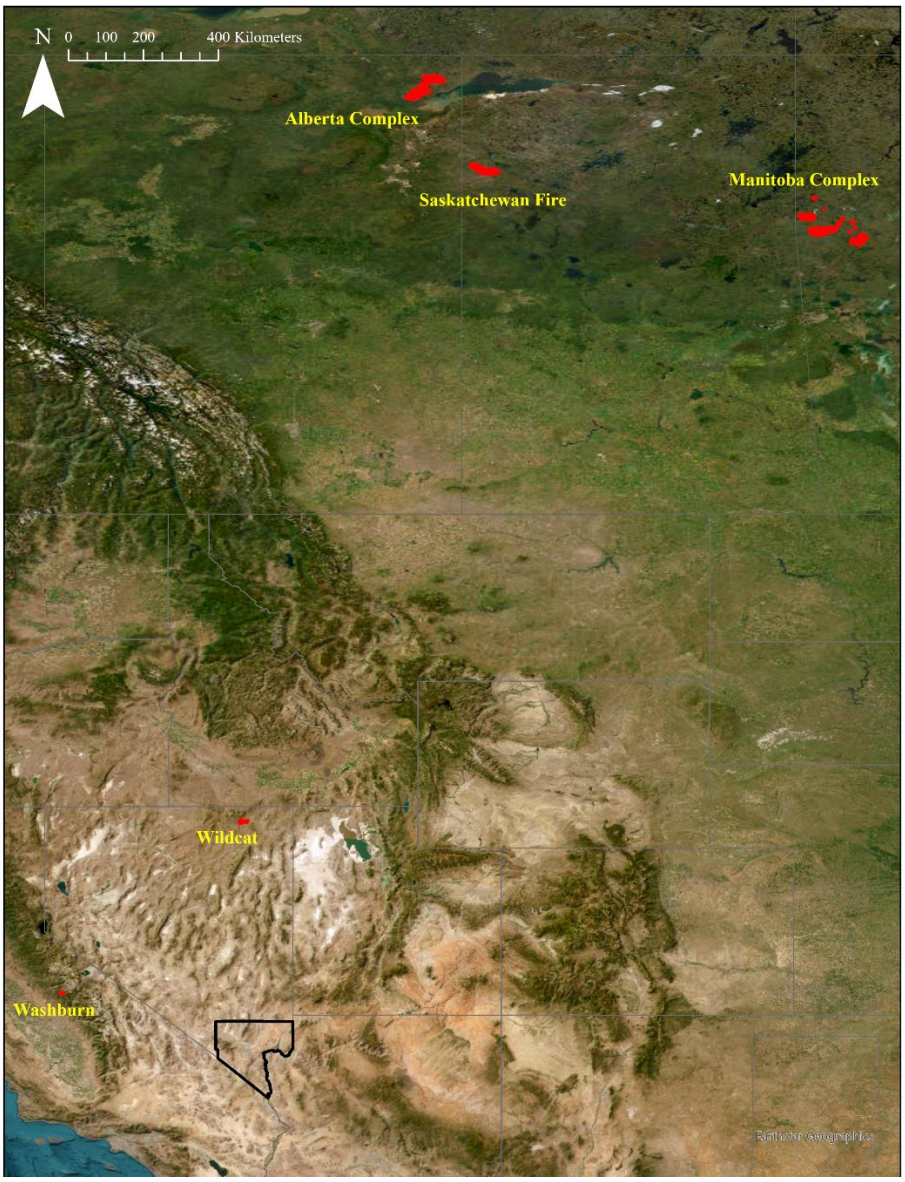

Figure 150. Final fire perimeters (red) for the five active fire regions during the July 17, 2022, exclusion date in relation to Clark County (black perimeter).

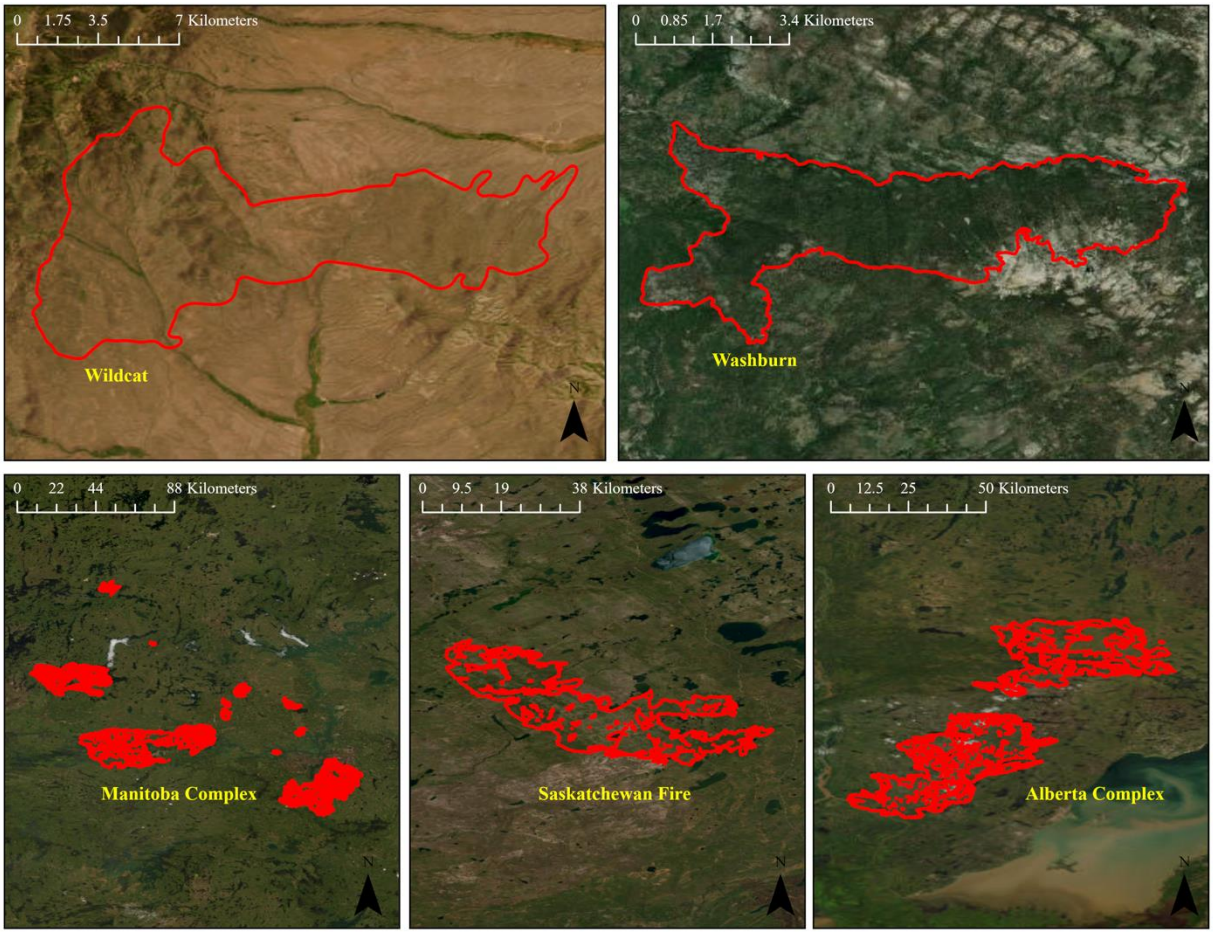

Figure 151. Final fire perimeters (red) for the five active fire regions during the July 17, 2022, exclusion date.

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 planetary boundary layer (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 152, show the vertical profile of the atmosphere 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 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 153; 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.

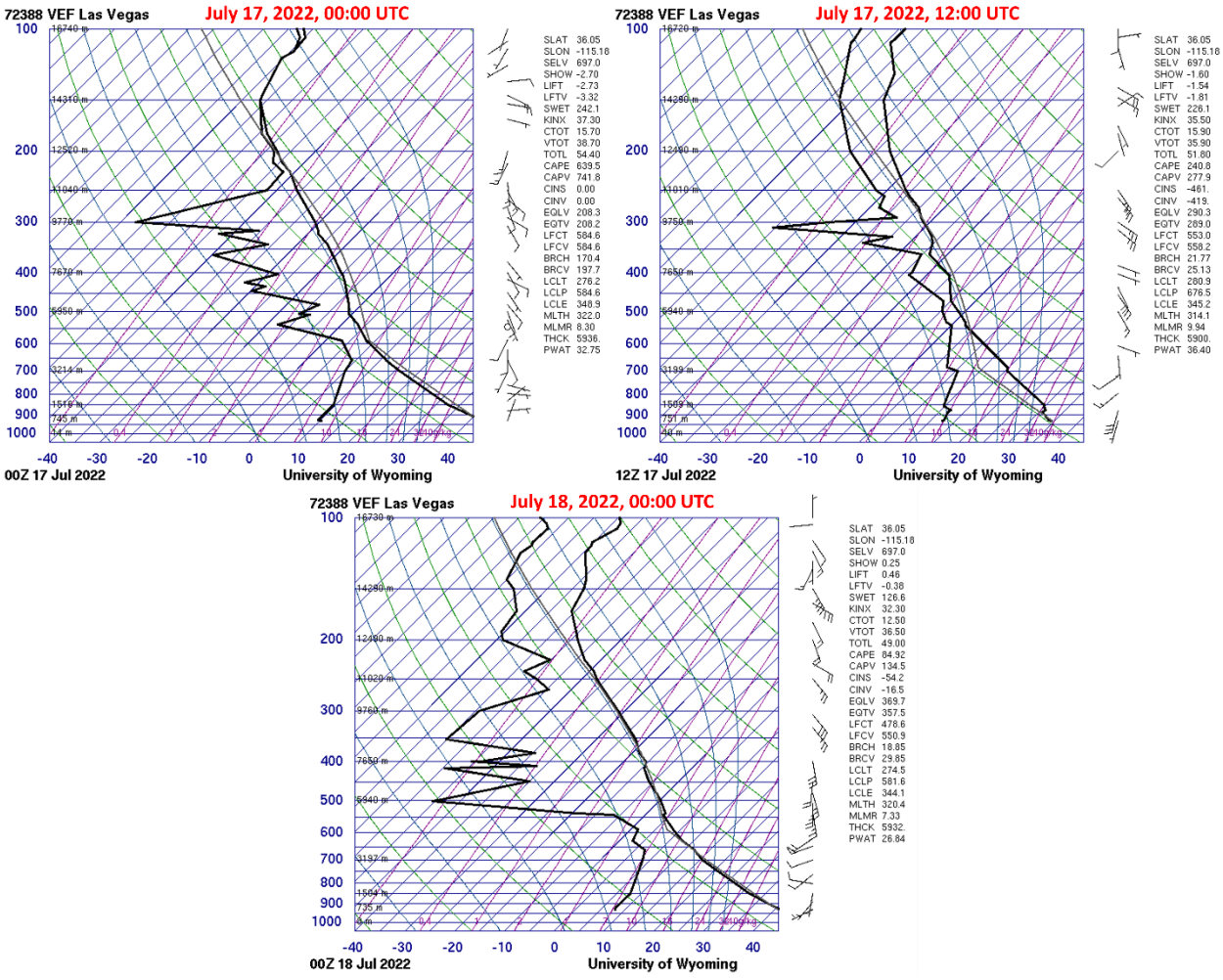

Figure 152. Skew-T soundings launched from the Las Vegas National Weather Service Office from July 17 at 00:00 UTC (July 16 at 16:00 PST) (top left) to July 18 at 00:00 UTC (July 17 at 16:00 PST) (bottom right).

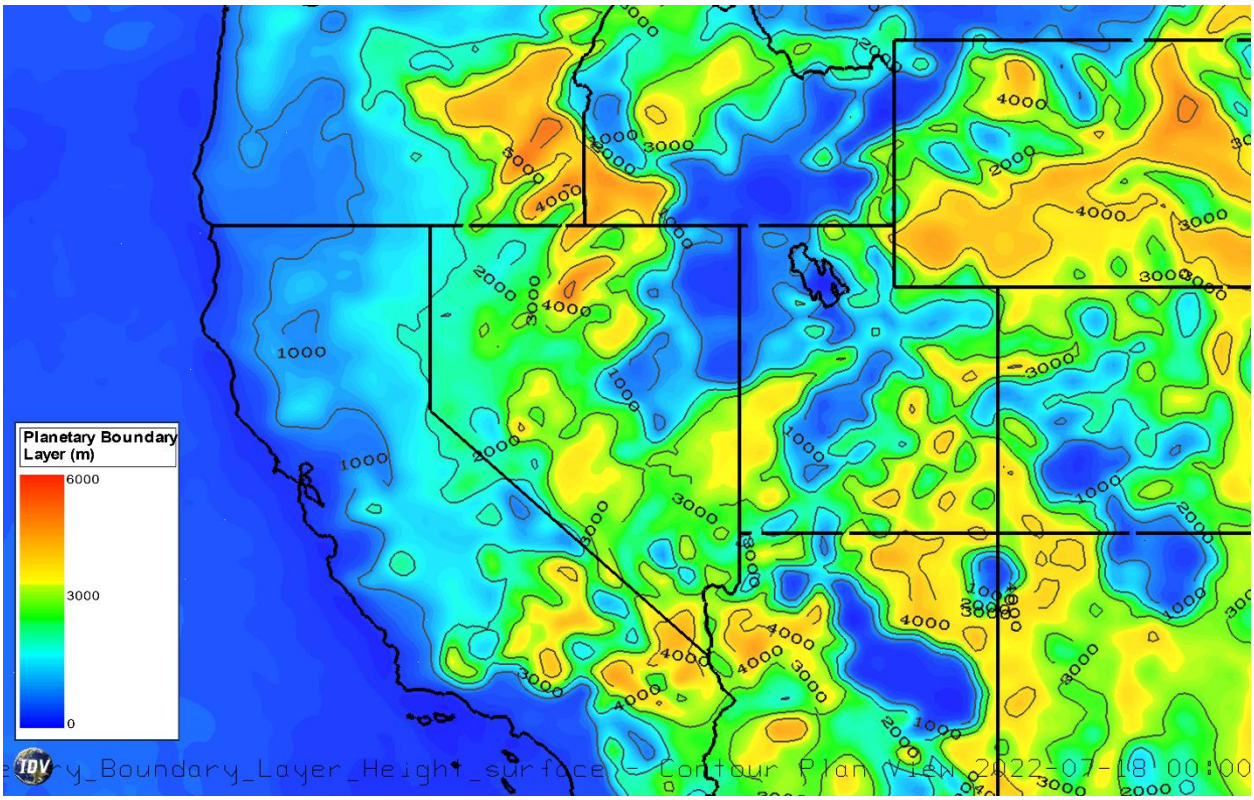

Figure 153. PBL height contour map based on the NAM model for July 18 at 00:00 UTC (July 17 at 16:00 PST). The gray lines denote PBL heights above 1 km in altitude in 1 km increments. Color contouring starts at 0 km.

HYSPLIT dispersion modeling could not be accurately performed for this exclusion date due to the large contributions from Canadian wildfires. Daily fire sizes 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 154**). 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, 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.

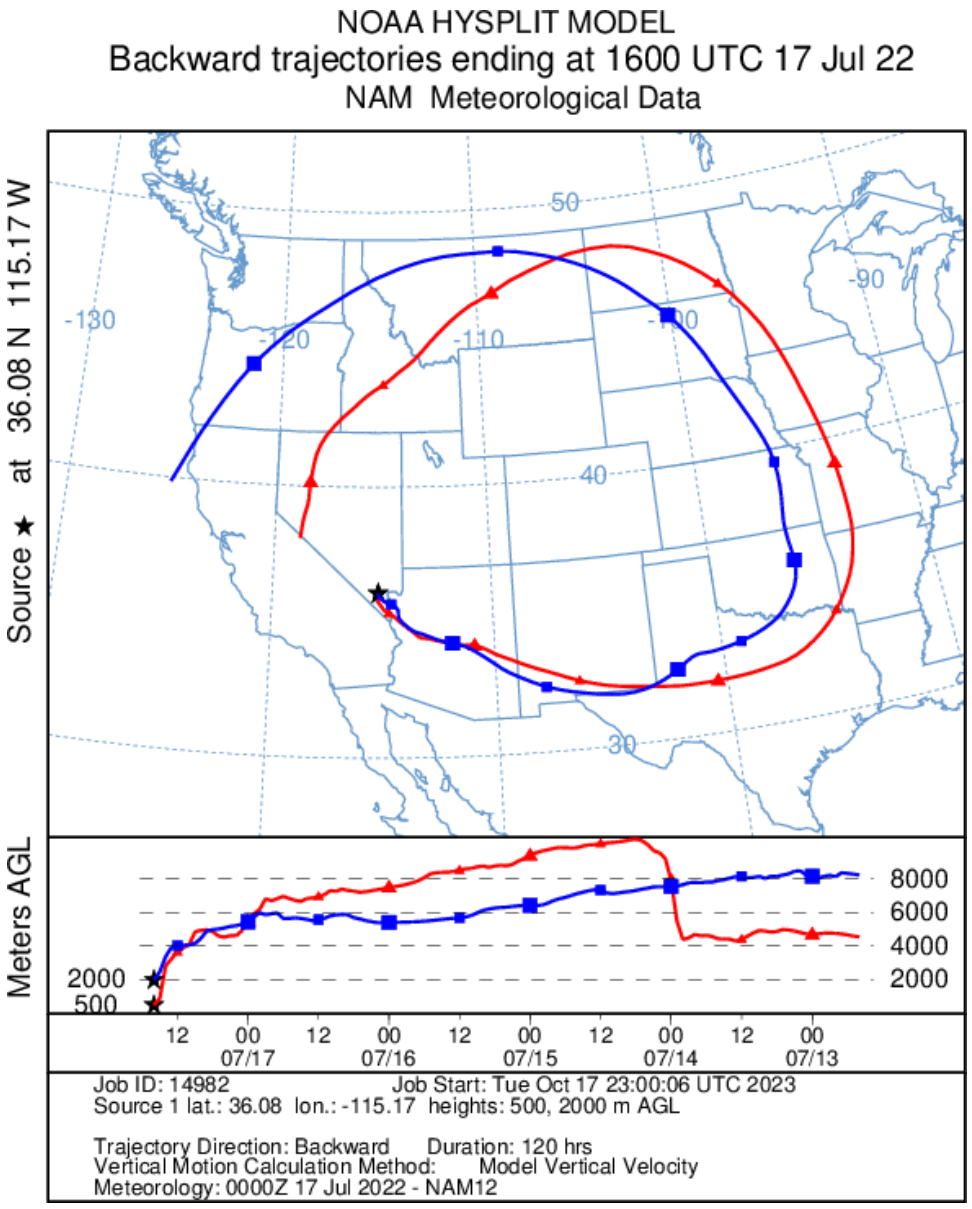

Figure 154. HYSPLIT back trajectory initiated at 16:00 UTC (08:00 PST) on July 17, 2022, using NAM 12 km meteorology. The back trajectory ran for 120 hours, ending in Las Vegas (36.08, -115.17) at 500 m and 2,000 m agl.

The HRRR smoke product shown in Figure 155 indicates low levels of 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 with the surface. Combining the HMS, meteorological information, PBL analysis, HYSPLIT back trajectories, and HRRR data, we see that smoke merged between the California, Nevada, and Canadian fires into a large, regional pool of smoke, which was transported around a high-pressure system in the southwest U.S. and descended into the well-mixed boundary layer in Las Vegas on July 17, 2022.

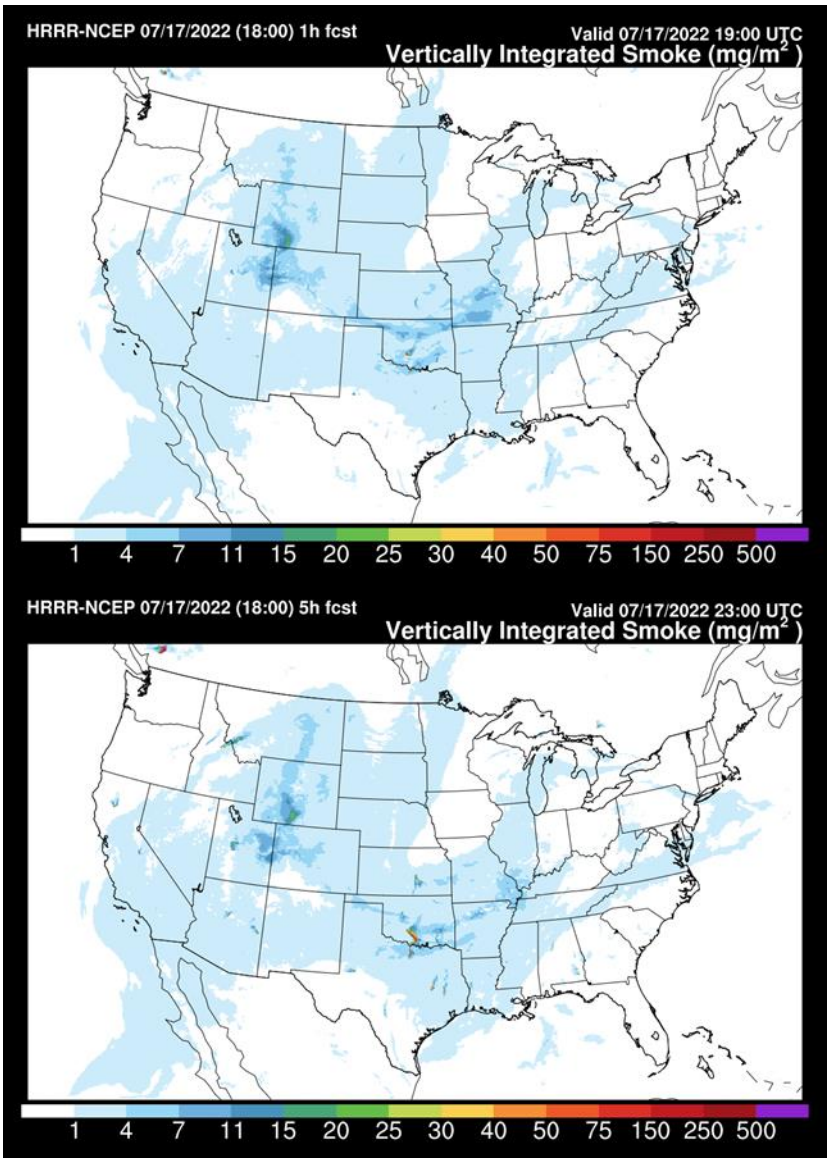

Figure 155. HRRR vertically integrated smoke forecast for July 17, 2022, at 11:00 PST and 15:00 PST.

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 156**.

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 156. 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 157. 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 158) 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 157). 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.

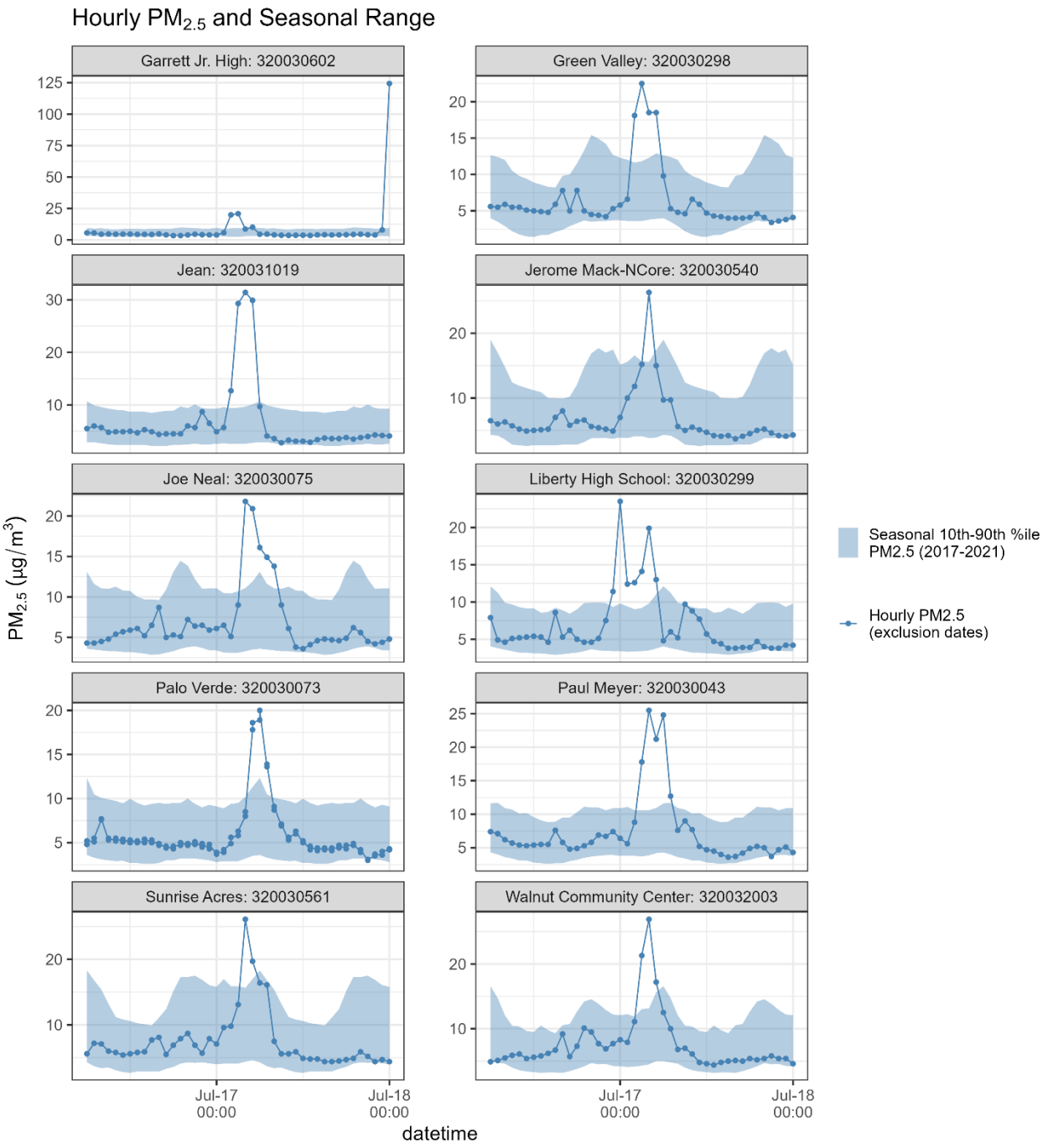

Figure 157. Hourly $PM_{2.5}$ measurements overlaid on the 10th-90th percentile diurnal concentration at event-affected measurement sites that measure $PM_{2.5}$ and supporting sites. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2022.

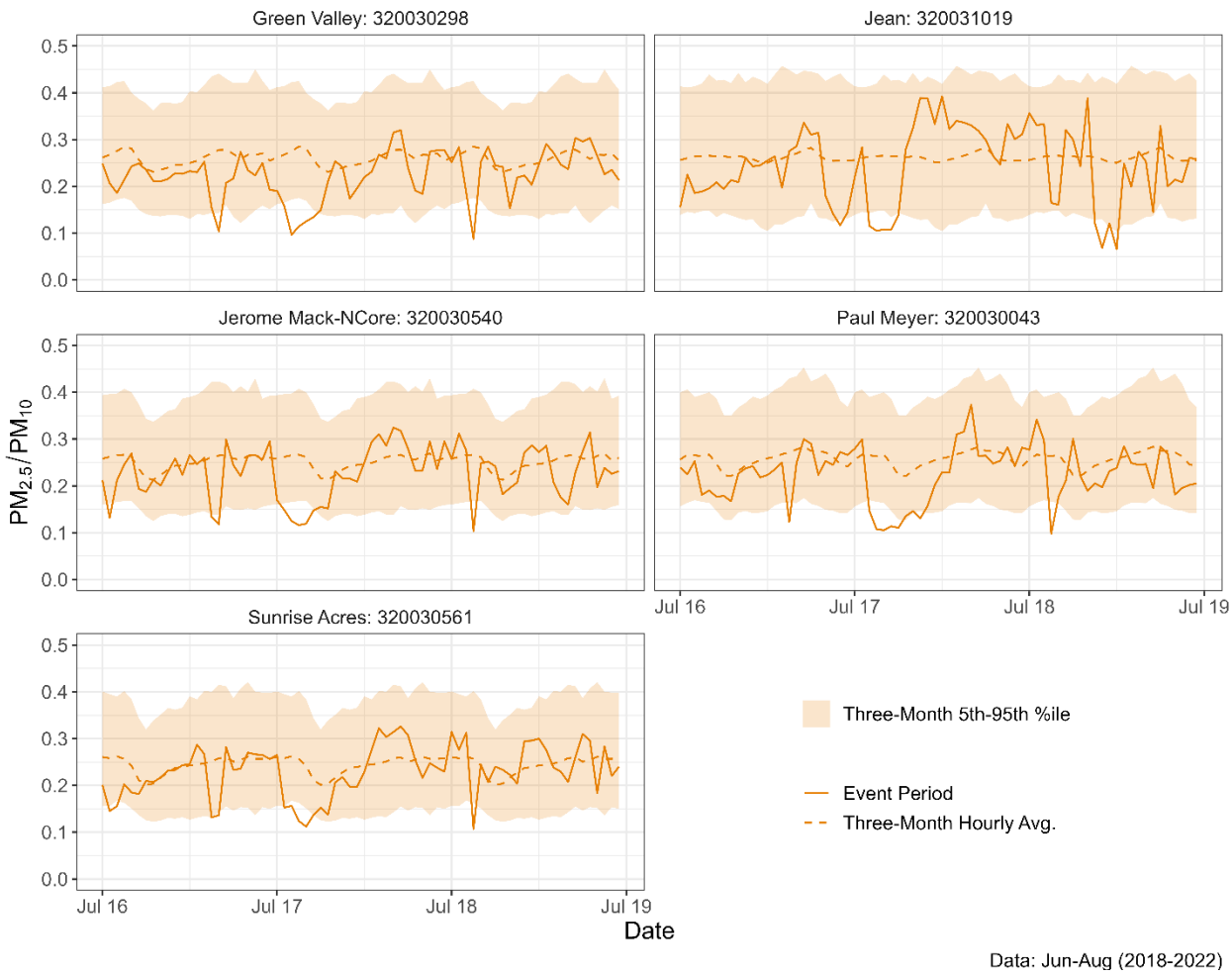

Figure 158. Ratio of $PM_{2.5}/PM_{10}$ concentrations at the Green Valley, Jean, Jerome Mack-NCore, Paul Meyer, and Sunrise Acres monitoring sites during the July 17, 2022, event period. The 5-yr average $PM_{2.5}/PM_{10}$ diurnal ratio is displayed as a dotted line, and the 5th-95th percentile range is shown as a shaded ribbon. The 5th-95th percentile concentration is calculated across the ozone production season (June-August) of 2018-2022.

5.2.5 Event Statistics

Table 34 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.

Table 34. 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.

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, meteorological data, and HRRR smoke modeling results 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 35). 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, with only the Palo Verde site experiencing an exceedance; on this day, the average MDA8 ozone concentration for the sites within the Las Vegas Valley was 65 ppb.

Table 35. 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	Mountains Edge Park	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 159.

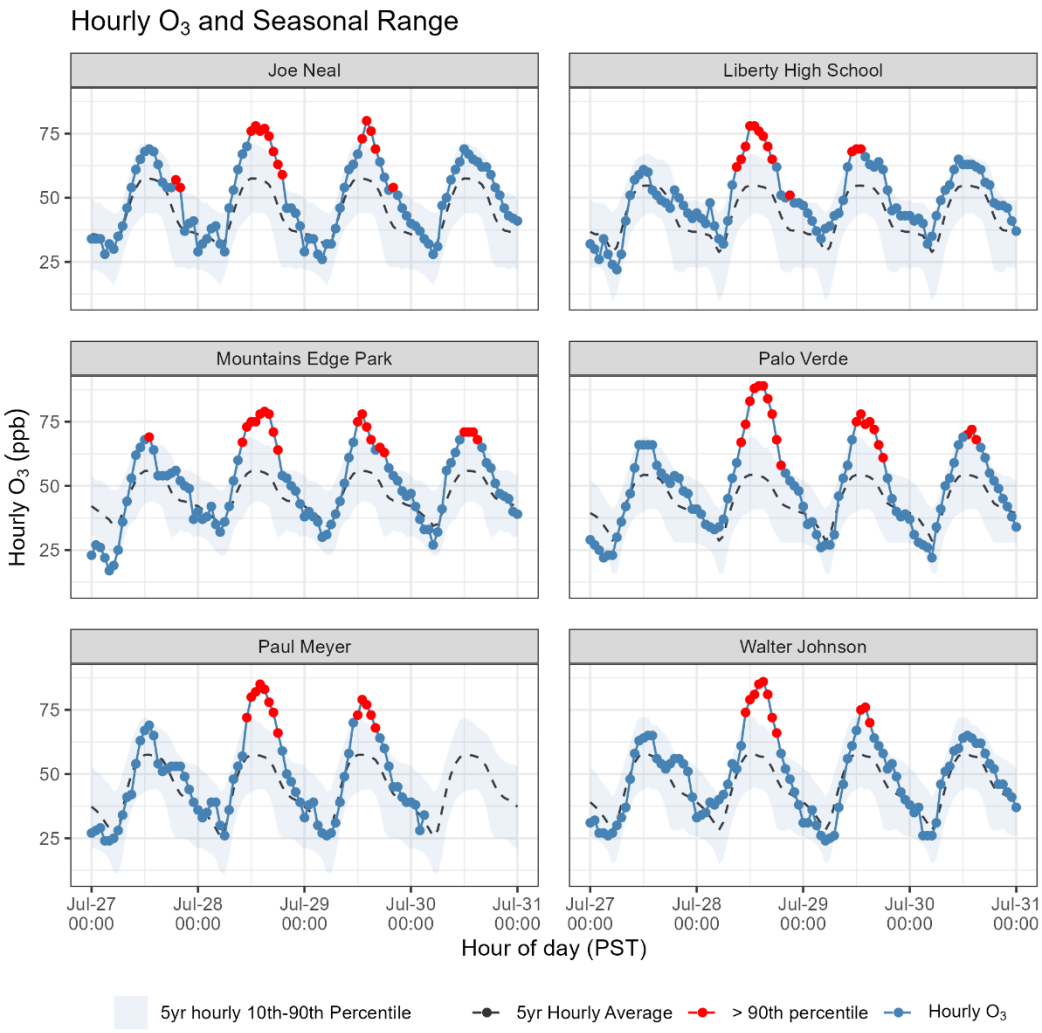

Figure 159. Hourly ozone concentrations (ppb) across June 27-31, 2022, compared to 5-yr* ozone season (May 1-October 31) hourly means and 10th-90th percentiles. Note: data collection at the Data collection at the Liberty High School and Mountains Edge Park sites did not begin until 2021.

5.3.2 Identification of Wildfires

Figure 160 shows HMS maps that display the progression of 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 dispersed over wider areas to blanket most of the western U.S., including Clark County, on July 28 and 29, 2022.

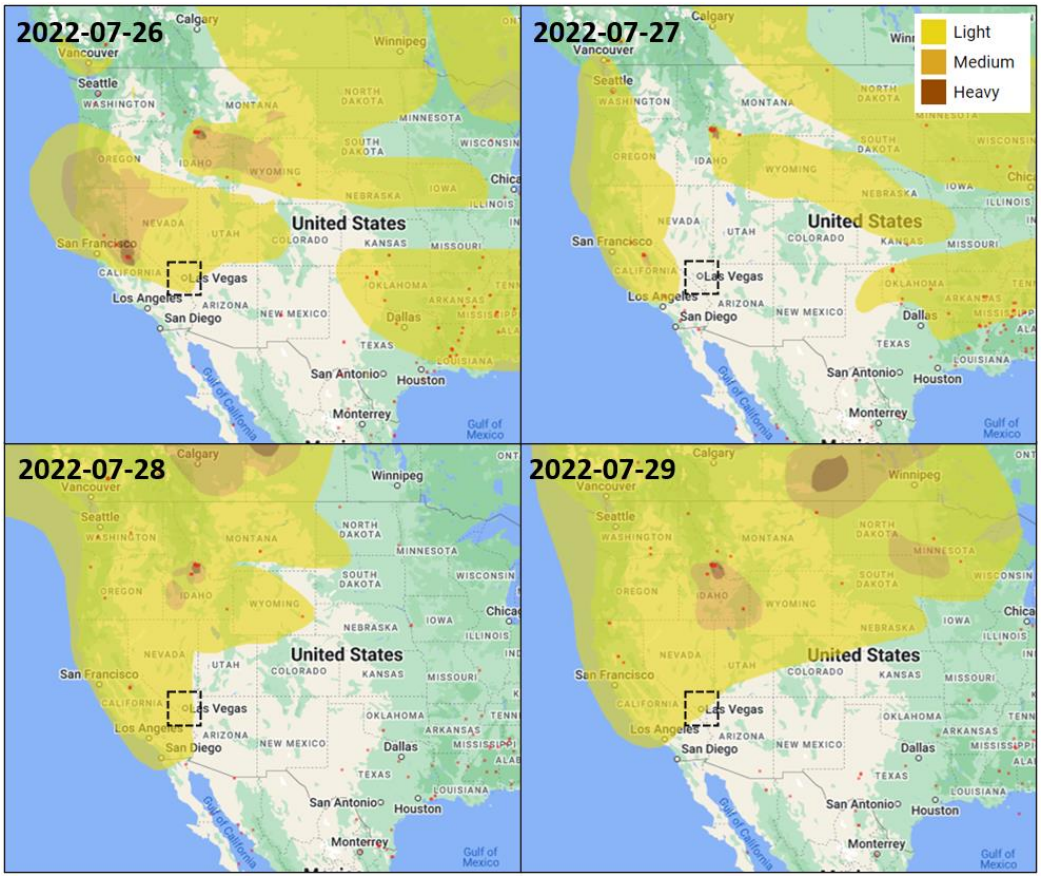

Figure 160. HMS smoke maps for July 26-29, 2022, showing smoke transport and qualitative smoke density. Clark County, NV, is enclosed by a dashed, black box on each map.

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 36). 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 161, and a closer view of each is in Figure 162.

Table 36. 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)[41]	Jul 17	Nov. 9
Oak	California	19,244	19,191 (July 28)[42]	Jul 22	Aug. 11

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

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

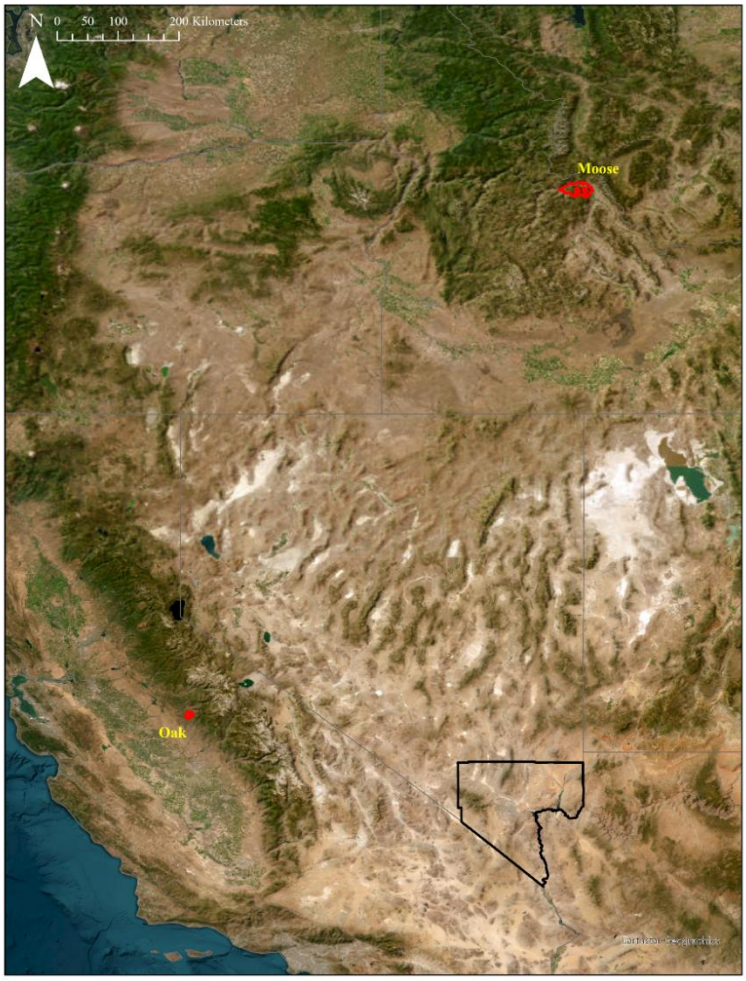

Figure 161. Final fire perimeters (red) for the two active fire regions during the July 28-29, 2022, exclusion dates in relation to Clark County (black perimeter).

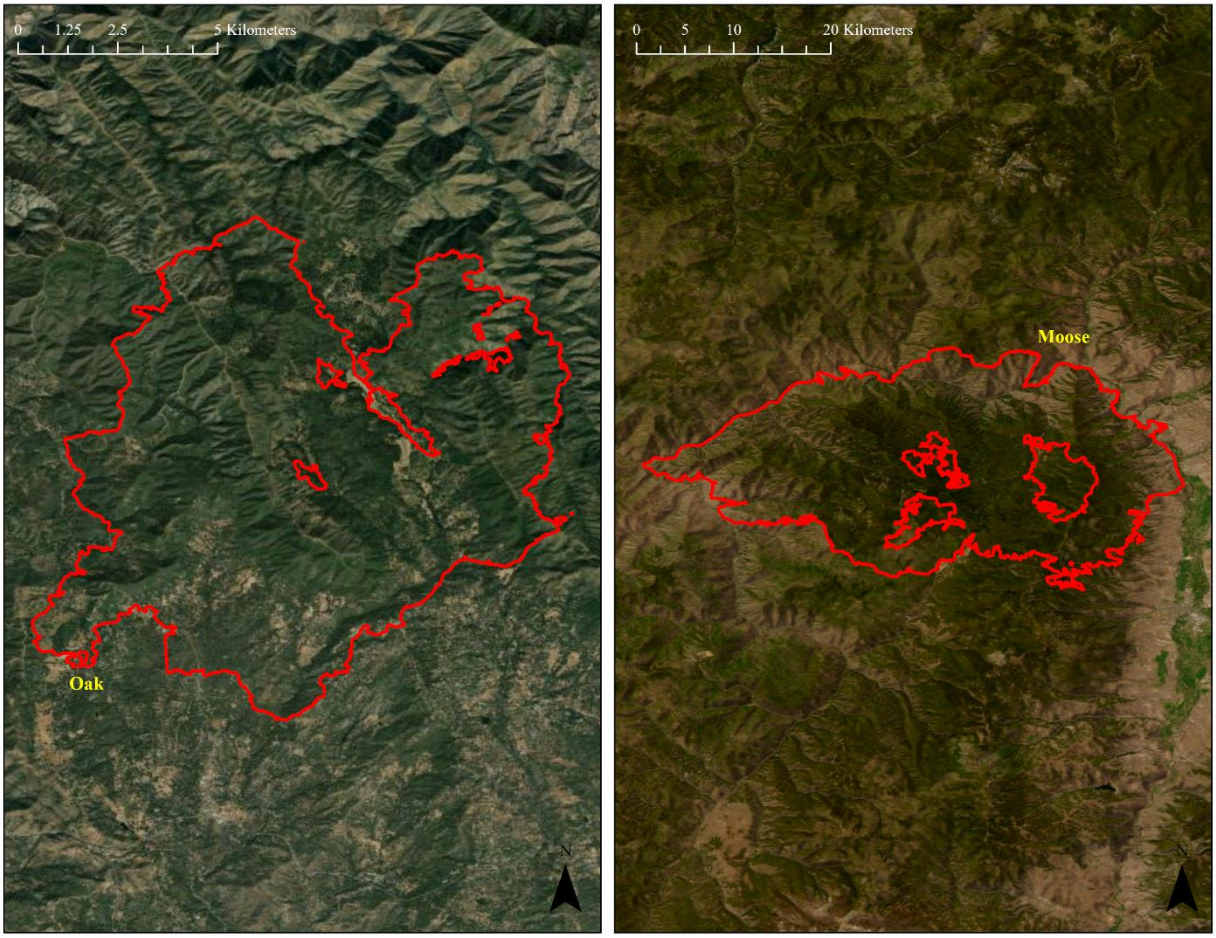

Figure 162. Final fire perimeters (red) for the two active fire regions during the July 28-29, 2022, exclusion dates.

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 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 with independent data sources (including HMS and HRRR data).

The planetary boundary layer (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 163** show the vertical profile of the atmosphere 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 above ground level (agl) (~700 mb). This indicates that, while morning conditions typically include capping inversions, by the afternoon a deep well-mixed boundary layer had formed in Clark County on the exclusion dates. To confirm the PBL heights estimated from the skew-T diagrams, we use the Sounding and Hodograph Analysis and Research Program in Python (SHARPpy). We use the raw theta temperature data to determine the PBL heights relative to the temperature profile. **Figure 164** shows the profile for July 28 at 16:00 PST and **Figure 165** shows the profile for July 29 at 16:00 PST. Using this method, we find a PBL height of 2,581 m in the afternoon on July 28 and 2,556 m in the afternoon on July 29. This confirms the initial estimate of the skew-T diagrams in Figure 163.

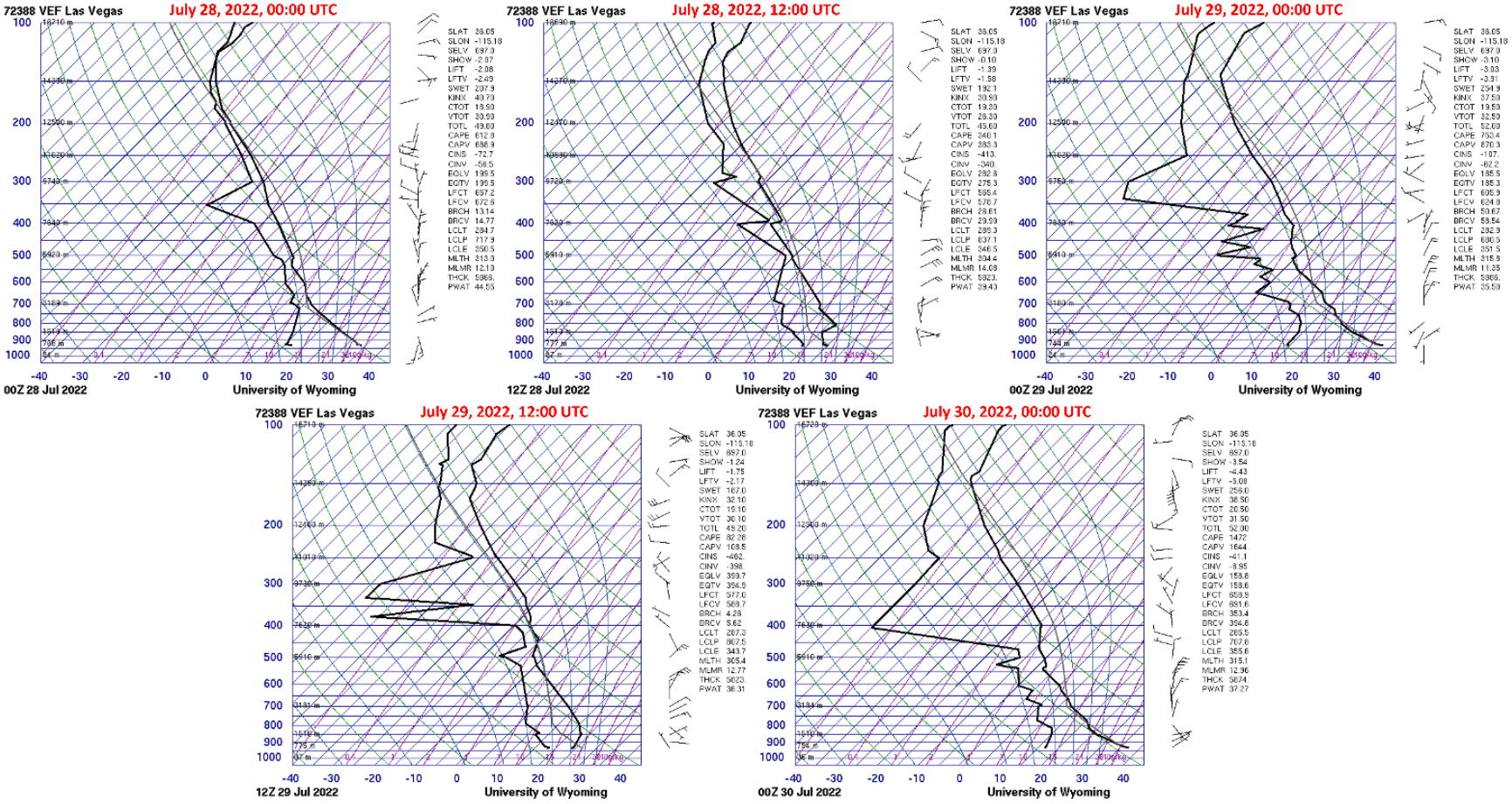

Figure 163. Skew-T soundings launched from the Las Vegas National Weather Service Office from July 28, 2022, at 00:00 UTC (July 27 at 16:00 PST) (top left), to July 30 at 00:00 UTC (July 29 at 16:00 PST) (bottom right).

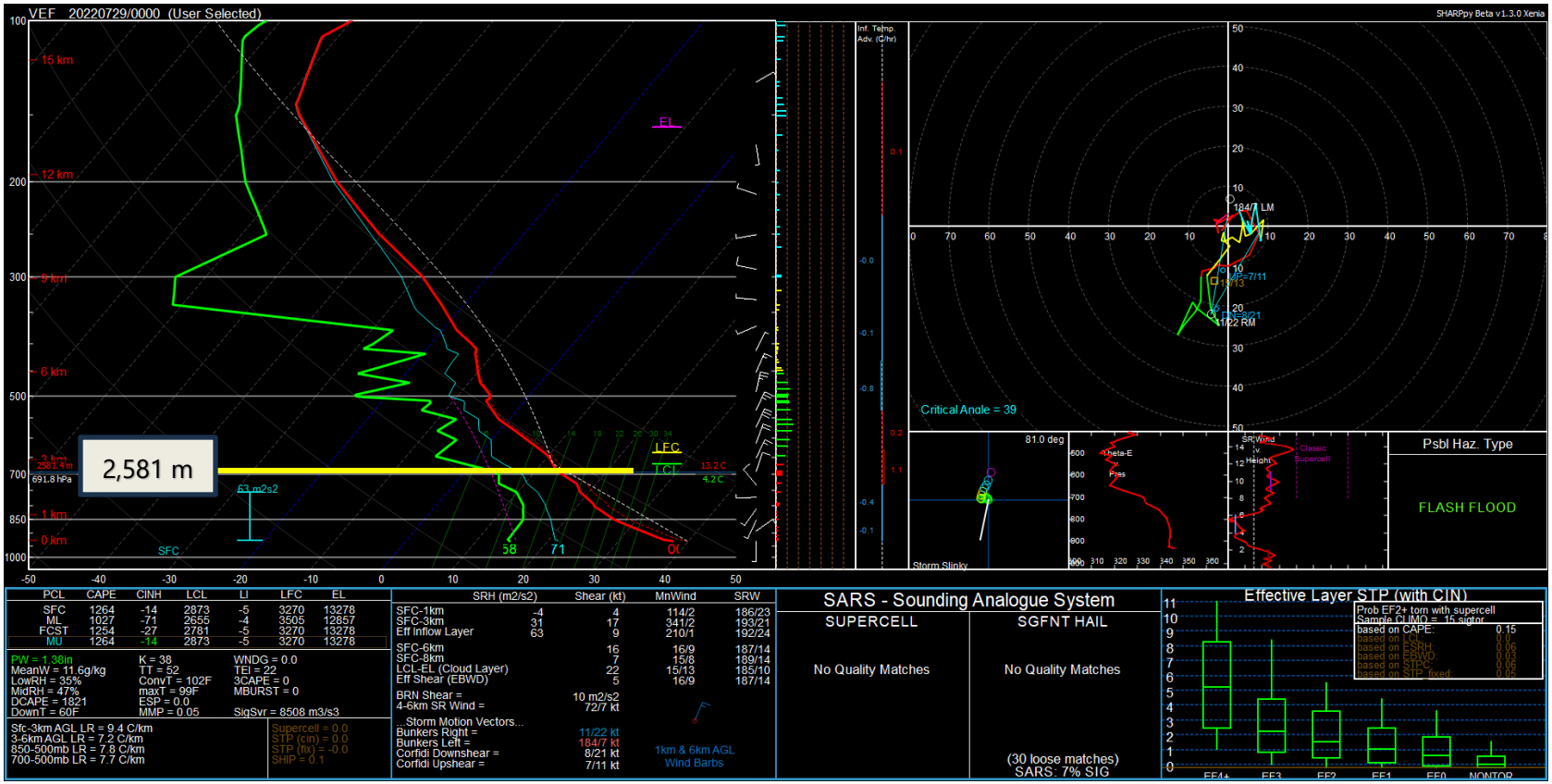

Figure 164. SHARPpy sounding output for July 29, 2022, at 00:00 UTC (July 28 at 16:00 PST). The yellow line indicates the level of the PBL height derived from the raw theta temperature and labeled for clarity.

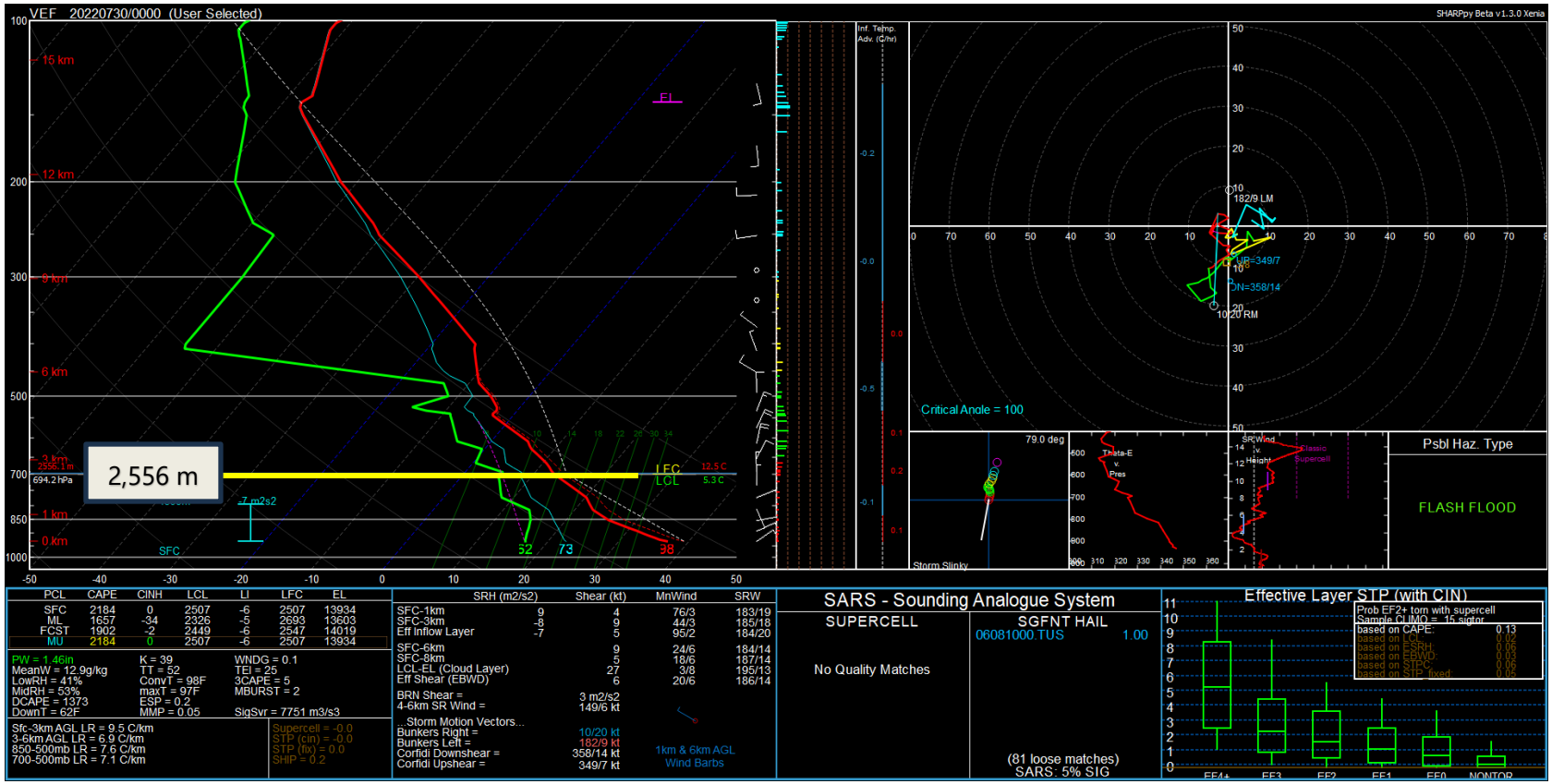

Figure 165. SHARPpy sounding output for July 30, 2022, at 00:00 UTC (July 29 at 16:00 PST). The yellow line indicates the level of the PBL height derived from the raw theta temperature and labeled for clarity.

To identify air mass source regions on the exclusion dates, HYSPLIT back trajectories were generated at four start points before and during the July 28-29, 2022, event within the PBL heights identified previously. Trajectories start and run backward for 72 hours on July 28, 2022, at 12:00 UTC (July 28 at 04:00 PST), July 29 at 00:00 UTC (July 28 at 16:00 PST), July 29 at 12:00 UTC (July 29 at 04:00 PST), and July 30 at 00:00 UTC (July 29 at 16:00 PST) to capture the overnight and daytime transport that would affect ozone precursors and concentrations (see **Figure 166**). These back trajectories are consistent with the skew-Ts presented previously. All back trajectories show the general pattern of air circulating around from the north/northwest and entering the Las Vegas area from the northeast. The trajectories travel through the merged smoke plume from the Moose and Oak Fires and enter Clark County at 2,000 agl. During the day, this air was well mixed within the boundary layer. Overnight the boundary layers were not as high, but smoke likely remained above the boundary layer. As PBL heights increased each day, aloft smoke and ozone precursors could mix to the surface. This smoke may have contributed ozone precursors to the area during the daytime higher PBL heights, enhancing ozone production. This transport path, with air mass source regions extending into areas covered by smoke, is consistent with the HMS and meteorological narrative from Section 5.3.2.

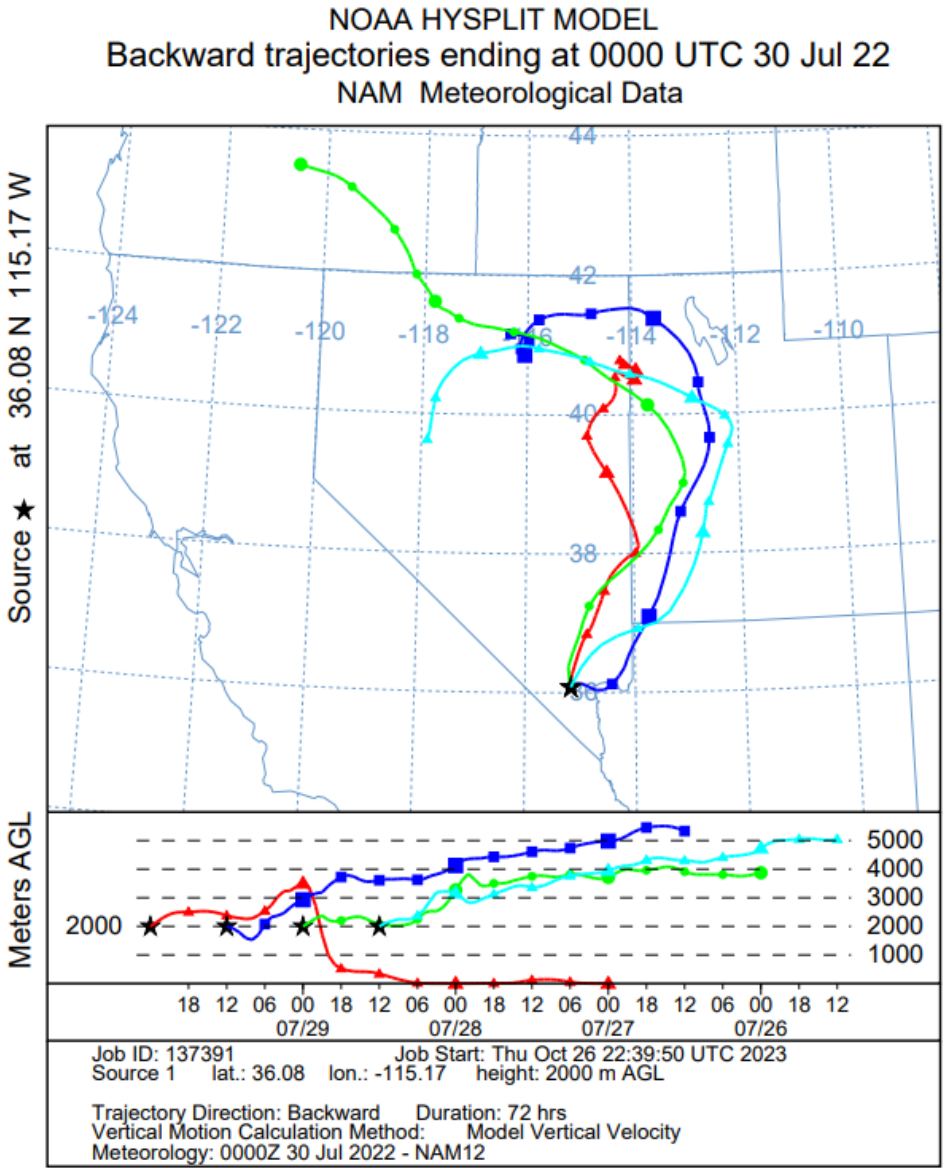

Figure 166. HYSPLIT back trajectories initiated at July 28, 2022, at 12:00 UTC (July 28 at 04:00 PST), July 29 at 00:00 UTC (July 28 at 16:00 PST), July 29 at 12:00 UTC (July 29 at 04:00 PST), and July 30 at 00:00 UTC (July 29 at 16:00 PST) using NAM 12 km meteorology. The back trajectories ran for 72 hours ending in Las Vegas (36.08, -115.17) at 2,000 m agl.

To 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 167.

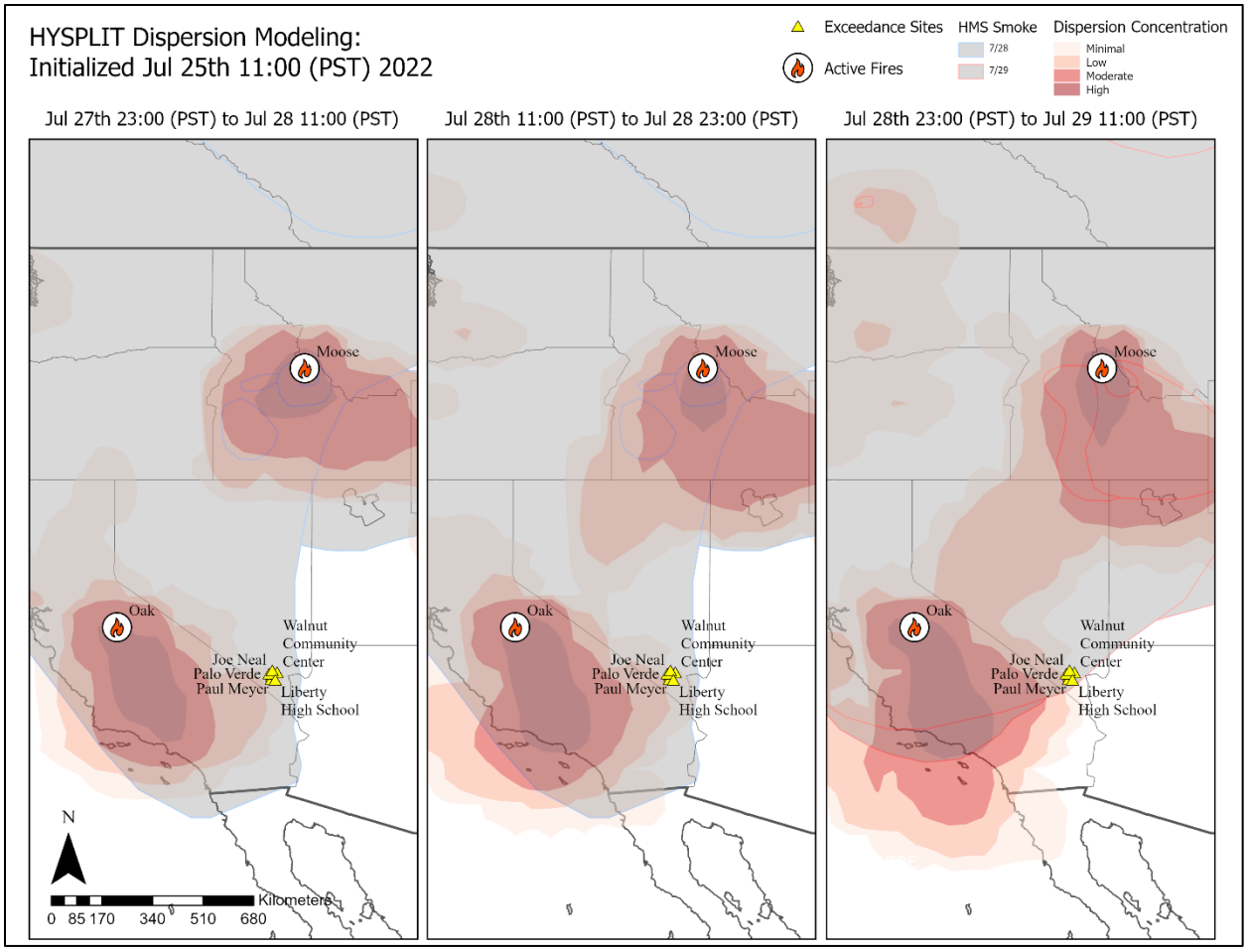

Figure 167. HYSPLIT dispersion modeling for two large fires (labeled as "Active Fires") in California and Idaho on or before the exclusion dates of July 28-29, 2022. GDAS 1.0° meteorological data was used, and dispersion was initiated on July 25 at 11:00 PST to model the regional smoke transport. HYSPLIT-modeled 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 167). The modeling results, and eastern smoke perimeters, are consistent with the HMS smoke plume (shown by the gray layer in Figure 167), 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.

Consistent with this analysis, the HRRR smoke product. Figure 168 shows low levels of vertically integrated smoke over the Clark County region on July 28-29, 2022. Figure 169 provides meteorological reports (METAR) that show the stagnant conditions on July 29, allowing any wildfire

smoke products to remain in the area and affect ozone on the following day. Note that there was one 30-min instance of high winds on the night of July 28 at 20:24 PST, due to a thunderstorm.

Taken together, the HMS smoke analysis, PBL analysis, HYSPLIT dispersion modeling, meteorological data, and HRRR forecast products suggest light regional smoke was merged between the California and Idaho fires, which was then transported southwest towards Clark County within the well-mixed boundary layer in on July 28, 2022. This smoke continued to affect ozone concentrations in Clark County on July 29 due to stagnation.

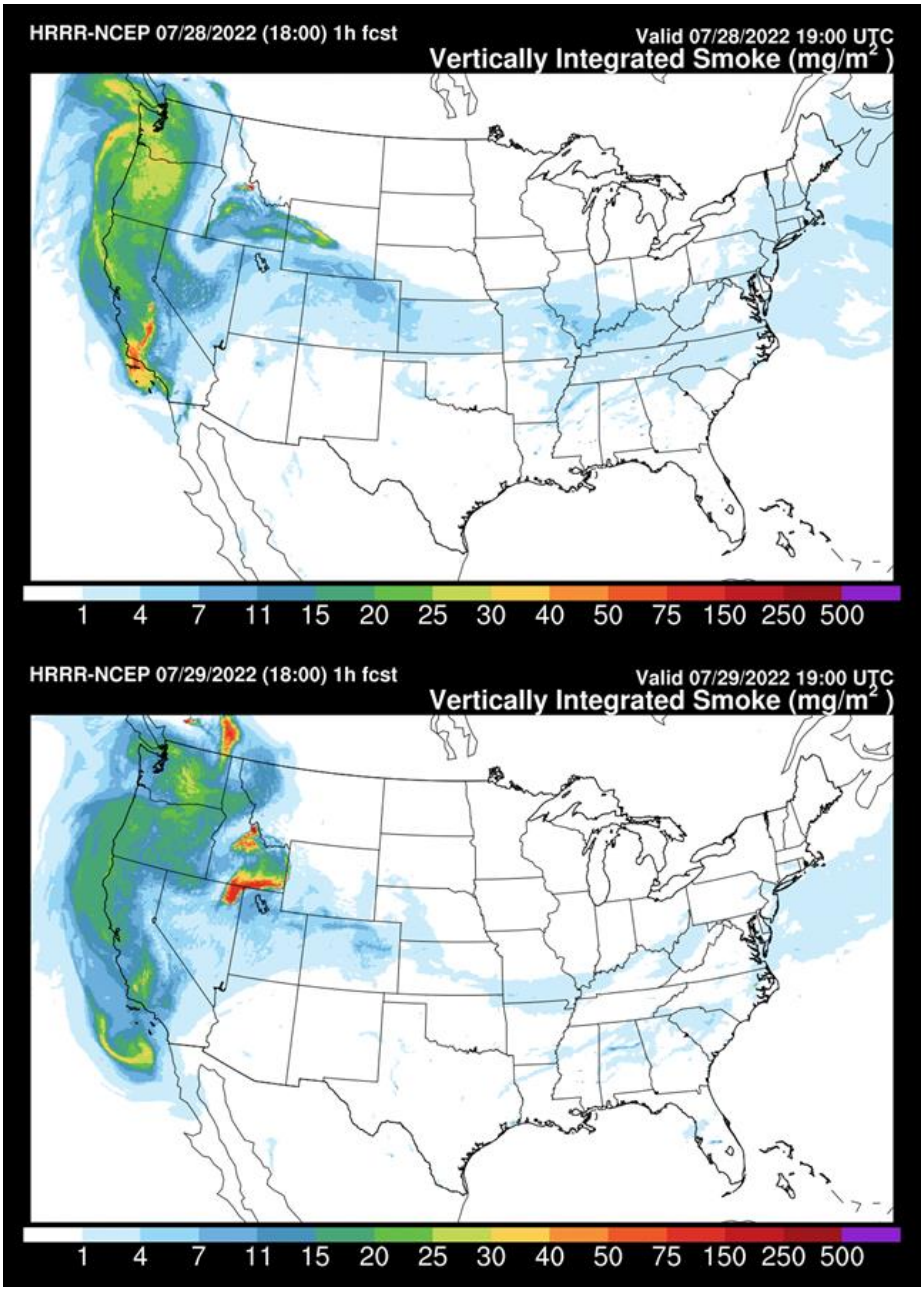

Figure 168. HRRR vertically integrated smoke forecast for July 28 and July 29, 2022, at 11:00 PST.

Time	Temperature	Dew Point	Humidity	Wind	Wind Speed	Wind Gust	Pressure	Precip.	Condition
12:53 AM	78 °F	68 °F	71 %	E	5 mph	0 mph	27.62 in	0.0 in	Fair
1:53 AM	77 °F	69 °F	76 %	E	7 mph	0 mph	27.61 in	0.0 in	Fair
2:53 AM	78 °F	67 °F	68 %	ENE	3 mph	0 mph	27.62 in	0.0 in	Fair
3:53 AM	77 °F	66 °F	69 %	ESE	8 mph	0 mph	27.64 in	0.0 in	Fair
4:53 AM	78 °F	66 °F	66 %	SSW	5 mph	0 mph	27.64 in	0.0 in	Fair
5:53 AM	79 °F	64 °F	60 %	CALM	0 mph	0 mph	27.64 in	0.0 in	Fair
6:53 AM	80 °F	65 °F	60 %	CALM	0 mph	0 mph	27.64 in	0.0 in	Fair
7:53 AM	82 °F	65 °F	56 %	CALM	0 mph	0 mph	27.64 in	0.0 in	Fair
8:53 AM	84 °F	63 °F	49 %	E	5 mph	0 mph	27.65 in	0.0 in	Fair
9:53 AM	87 °F	63 °F	44 %	VAR	5 mph	0 mph	27.64 in	0.0 in	Fair
10:53 AM	89 °F	61 °F	39 %	ESE	5 mph	0 mph	27.64 in	0.0 in	Fair
11:53 AM	92 °F	62 °F	37 %	ESE	8 mph	0 mph	27.62 in	0.0 in	Fair
12:53 PM	94 °F	62 °F	35 %	SE	7 mph	0 mph	27.60 in	0.0 in	Fair
1:53 PM	95 °F	61 °F	32 %	S	5 mph	0 mph	27.57 in	0.0 in	Fair
2:53 PM	98 °F	59 °F	27 %		0 mph	0 mph	27.55 in	0.0 in	Fair
3:53 PM	100 °F	58 °F	25 %	NE	5 mph	0 mph	27.52 in	0.0 in	Fair
4:53 PM	100 °F	58 °F	25 %	ESE	6 mph	0 mph	27.51 in	0.0 in	Fair
5:53 PM	100 °F	56 °F	23 %		0 mph	0 mph	27.52 in	0.0 in	Fair
6:53 PM	99 °F	56 °F	24 %	E	8 mph	0 mph	27.51 in	0.0 in	Fair
7:53 PM	98 °F	56 °F	24 %	E	10 mph	0 mph	27.51 in	0.0 in	Fair

Figure 169. METAR report at the Las Vegas International Airport (KLAS) for July 29, 2022, showing calm to light winds throughout the day.

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 170 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 170. 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 171**). The $PM_{2.5}/PM_{10}$ ratios for this event at all sites throughout Clark County (**Figure 172 and Figure 173**) 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 171). 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 174 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.

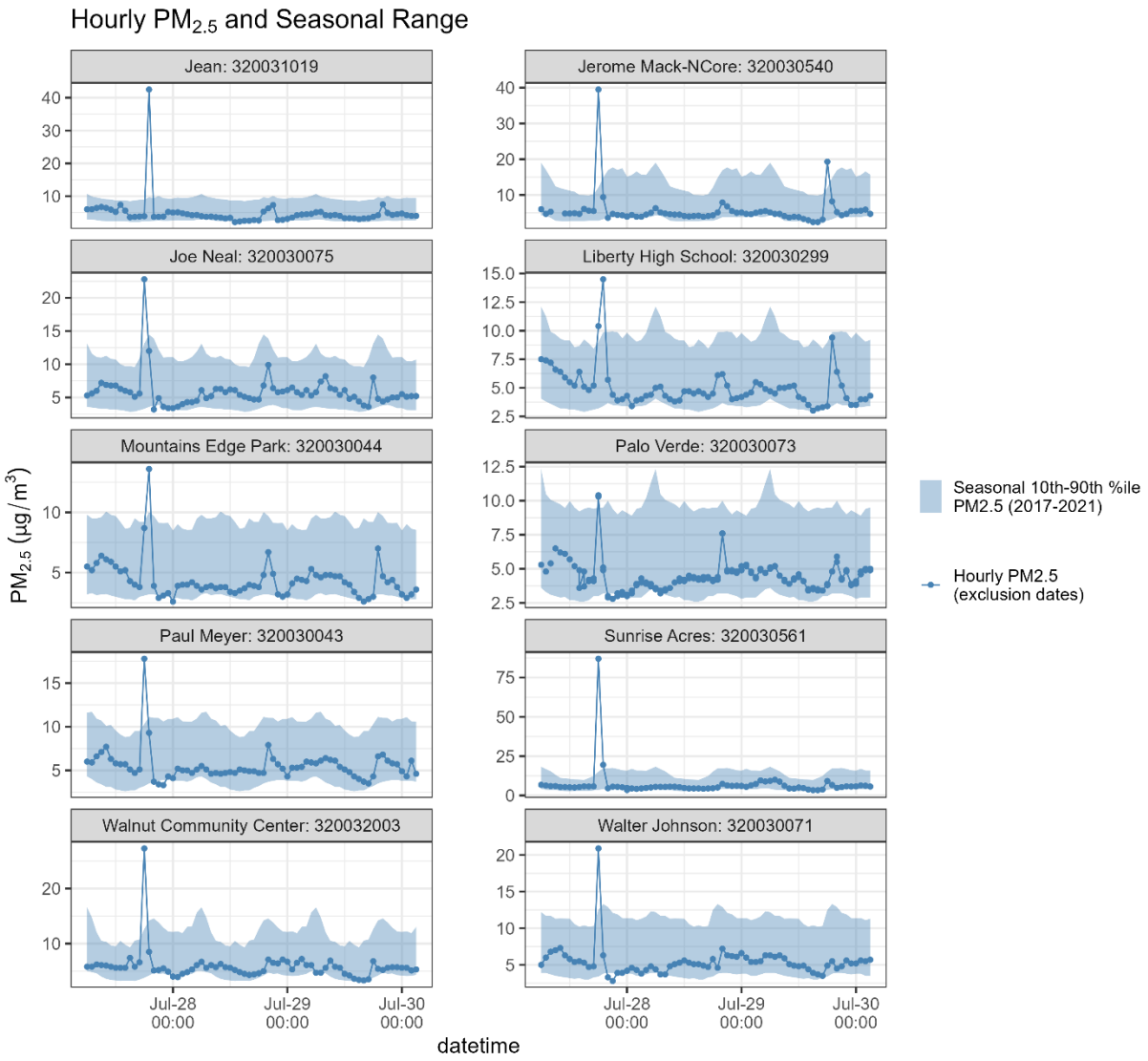

Figure 171. Hourly $PM_{2.5}$ measurements overlaid on the 10th-90th percentile diurnal concentration recorded at the event-affected measurement sites and supporting sites that measure $PM_{2.5}$ concentrations. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2022.

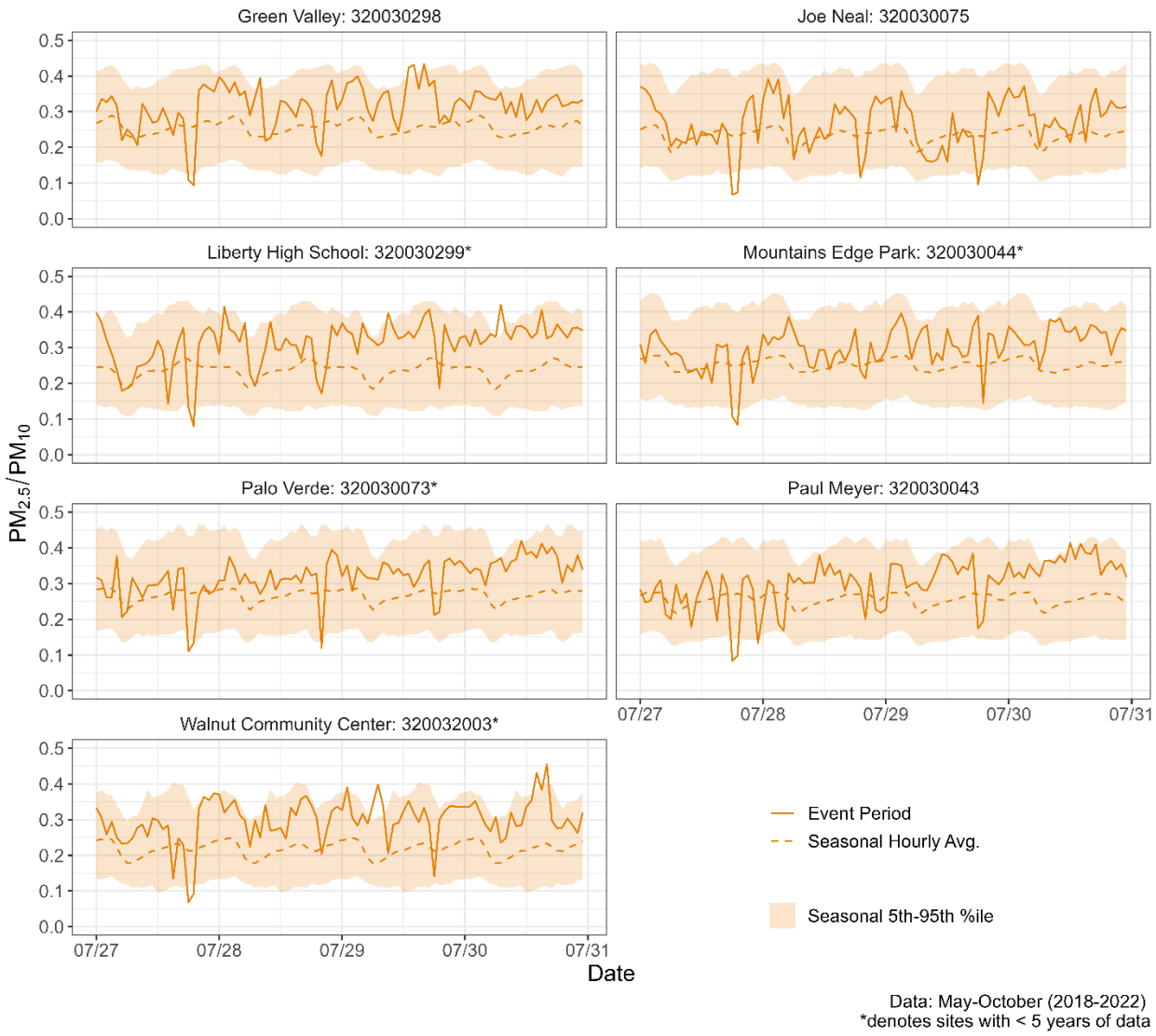

Figure 172. Ratio of $PM_{2.5}/PM_{10}$ concentrations recorded at the Green Valley, Joe Neal, Liberty High School, Mountains Edge Park, Palo Verde, Paul Meyer, and Walnut Community Center sites during the July 28-29, 2022, event period. The 5-yr average $PM_{2.5}/PM_{10}$ diurnal ratio is displayed 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.

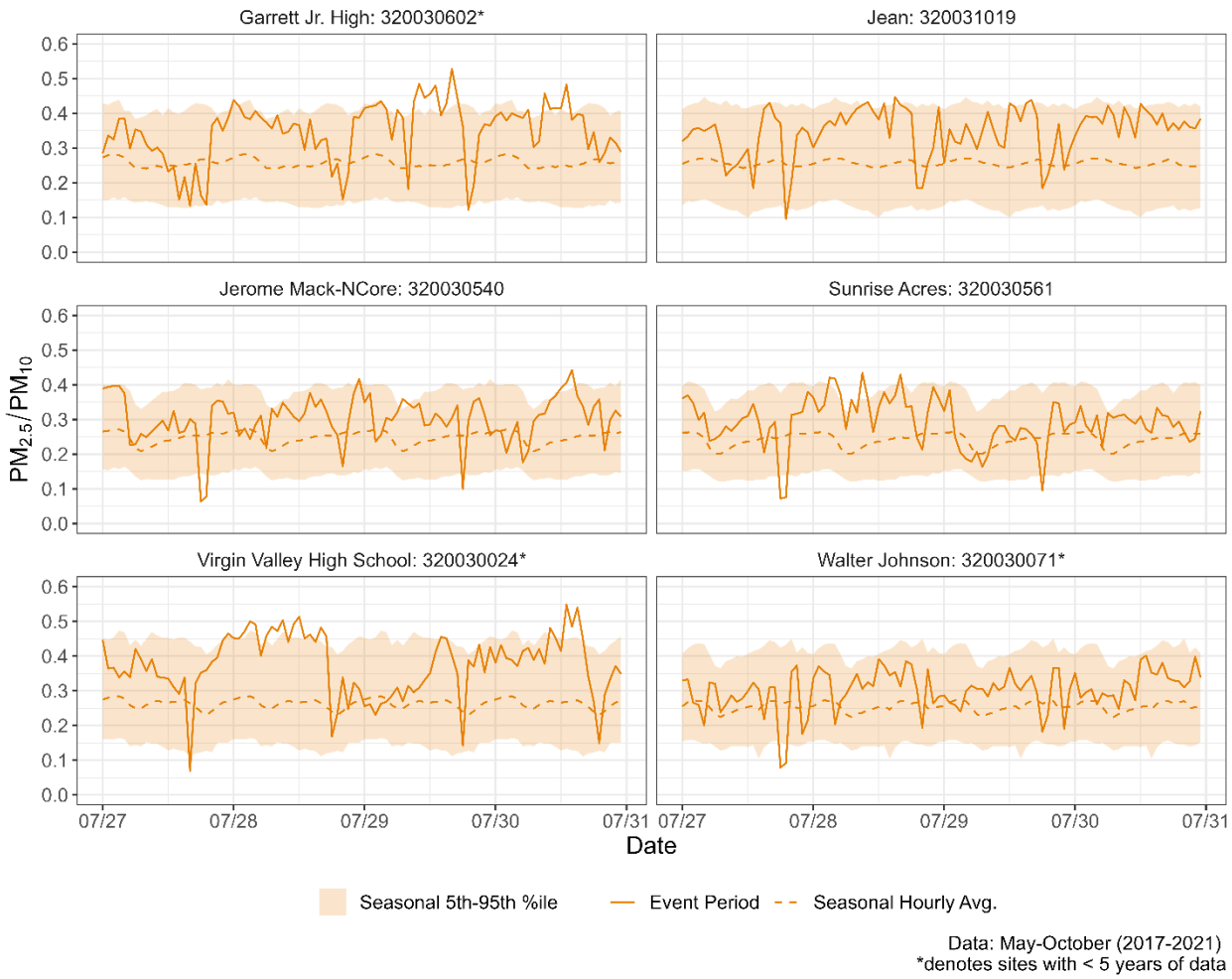

Figure 173. Ratio of $PM_{2.5}/PM_{10}$ concentrations recorded at the Garrett Jr. High, Jean, Jerome Mack, Sunrise Acres, Virgin Valley High School, and Walter Johnson monitoring sites during the July 28-29, 2022, event period. The 5-yr average $PM_{2.5}/PM_{10}$ diurnal ratio is displayed as a dotted 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.

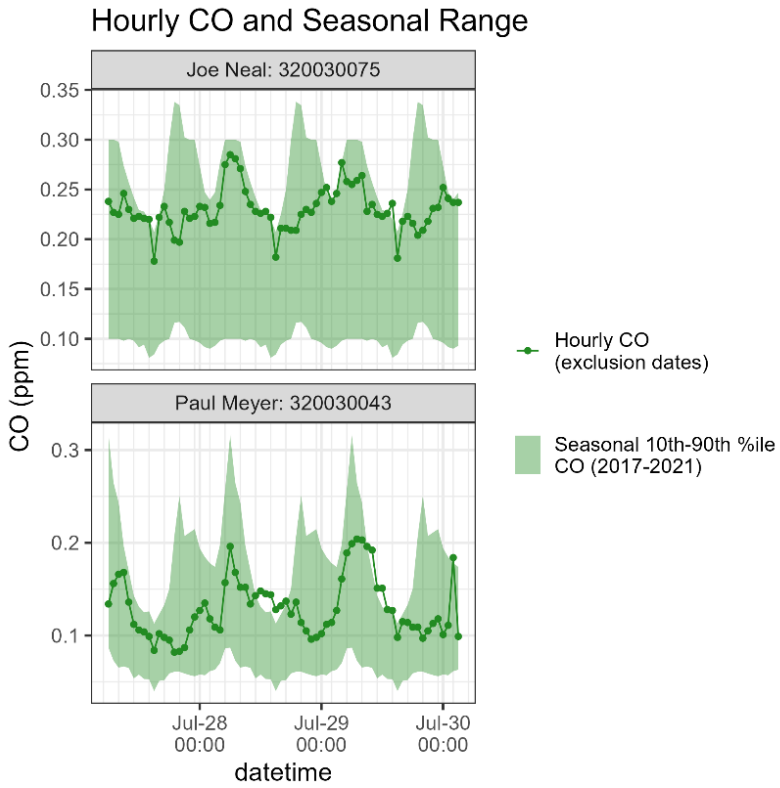

Figure 174. Hourly CO measurements overlaid on the 10th-90th percentile diurnal concentrations recorded at each event-affected measurement site that measures CO concentrations. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2022.

5.3.5 Event Statistics

Table 37 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.

Table 37. 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	Mountains Edge Park	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, and affected the Paul Meyer monitoring site in Clark County, Nevada. The MDA8 ozone concentration was 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 experienced MDA8 values ranging from 51 to 74 ppb (with an average of 63 ppb) on September 1, and MDA8 values ranging from 53 to 73 (with an average of 63 ppb) on September 2. 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 175, 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 site.

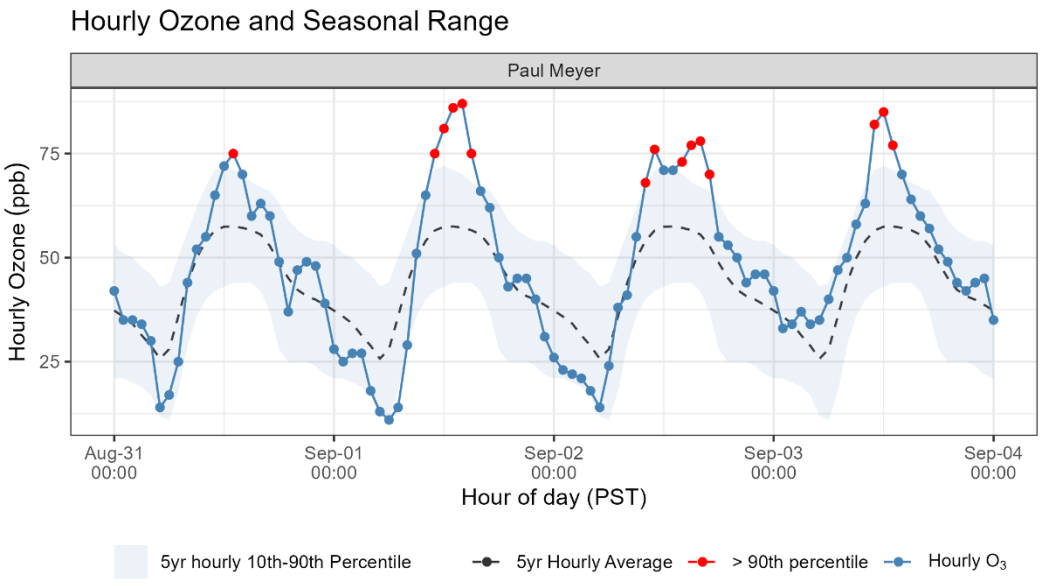

Figure 175. Hourly ozone concentrations (ppb) recorded at the Paul Meyer site across August 31-September 4, 2022, compared to 5-yr ozone season (May 1-October 31) hourly means and 10-90th percentiles.

5.4.2 Identification of Wildfires

Figure 176 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 a surface and upper-level high-pressure system. HMS smoke was present over Clark County, Nevada, on September 1 and 2. Figure 177 and Figure 178 show the surface-level and 500-mb weather maps for the days corresponding to the HMS maps in Figure 176. 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.

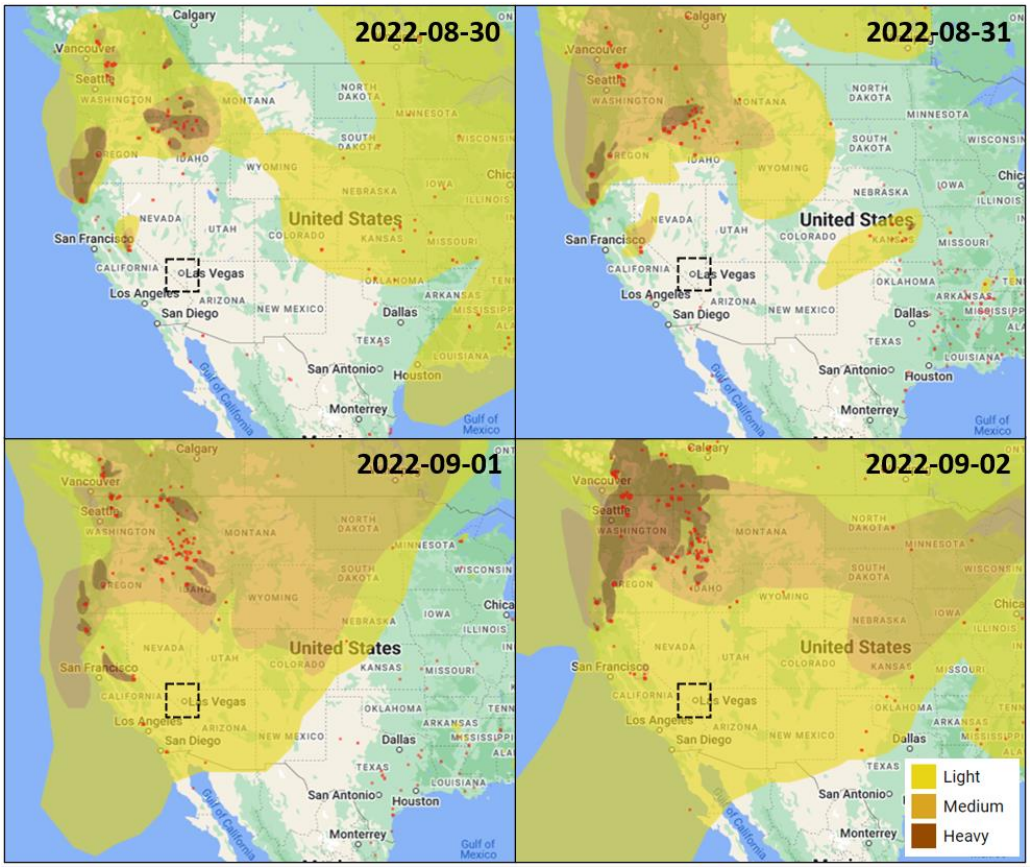

Figure 176. HMS smoke maps for August 30-September 2, 2022, showing smoke transport and qualitative smoke density. Clark County, NV, is enclosed by a dashed, black box on each map.

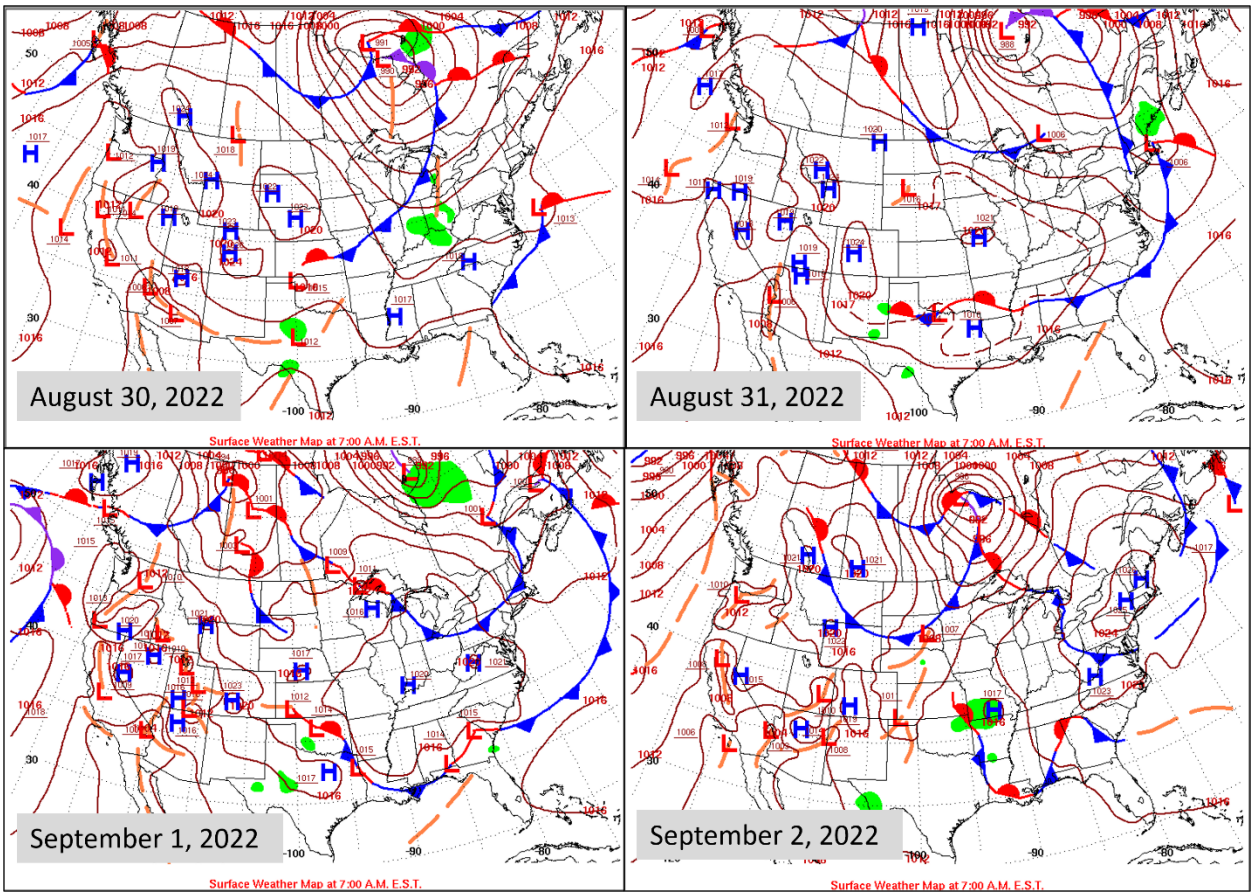

Figure 177. Daily surface-level weather maps for August 30-September 2, 2022.

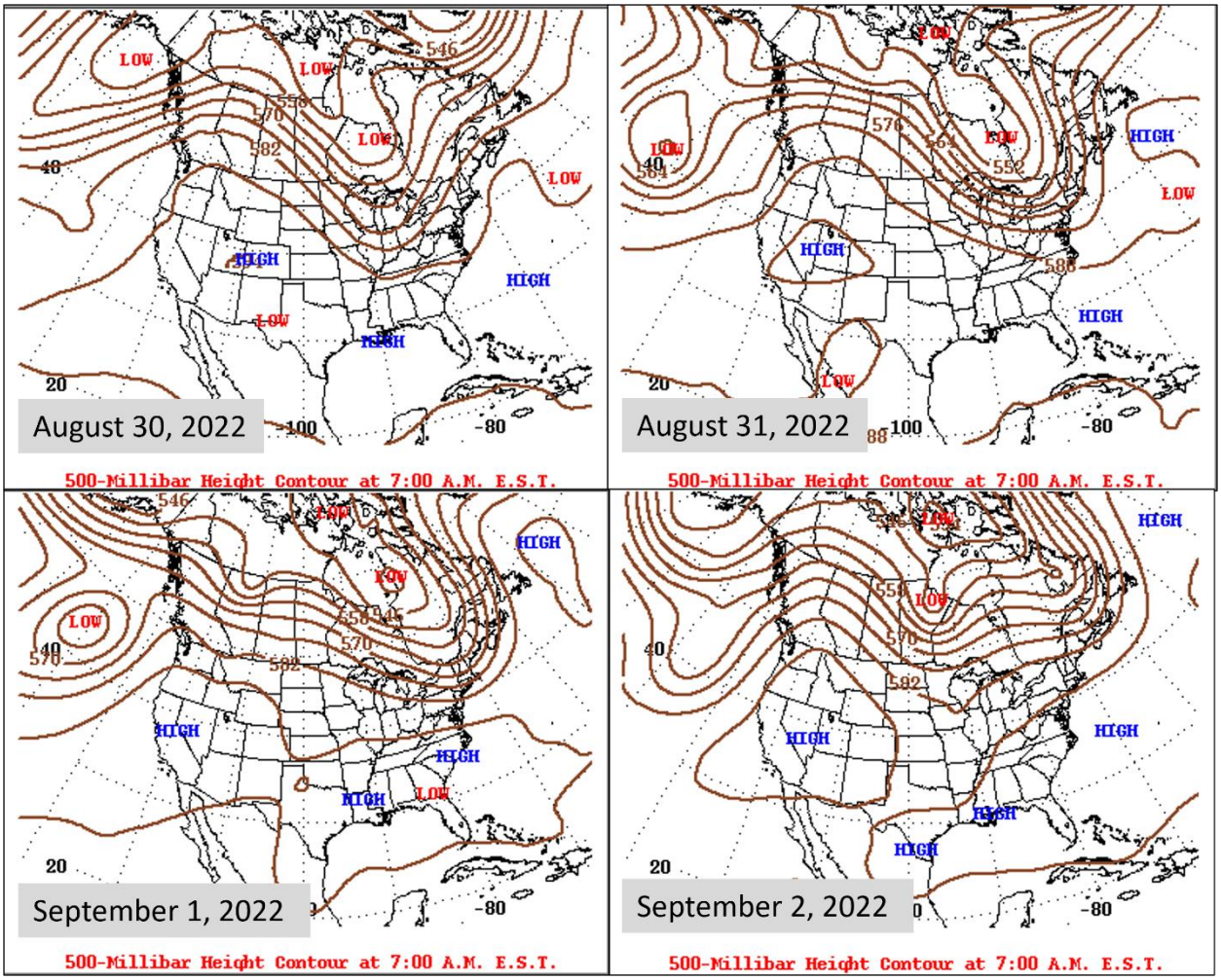

Figure 178. Daily 500-mb weather maps for August 30-September 2, 2022.

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 38. 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 179. Zoomed-in views of most of the fires are shown in Figure 180 through Figure 182. 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 38. 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)[43]	Aug. 5	Nov. 3
Cedar Creek	Oregon	128,602	8,817 (Sept. 1)[44]	Aug. 1	Nov. 1
Crockets Knob	Oregon	4,333	2,840 (Sept. 1)[45]	Aug. 22	Oct. 27
Dismal	Idaho	8,197	1,876 (Aug. 31)[46]	July 23	Nov. 3
Double Creek	Oregon	175,938	2,946 (Sept. 1)[47]	Aug. 30	Oct. 25
Four Corners	Idaho	13,703	12,817 (Sept. 1)[48]	Aug. 13	Oct. 20
Moose	Idaho	130,144	99,232 (Sept. 1)[49]	July 17	Nov. 09
Nebo	Oregon	12,608	3,086 (Sept. 1)[50]	Aug. 25	Oct. 25
Norton	Idaho	9,080	1,859 (Aug. 29)[51]	Aug. 1	Oct. 25
Patrol Point	Idaho	16,130	735 (Sept. 1)[52]	Aug. 20	Nov. 03
Rum Creek	Oregon	21,227	15,635 (Sept. 1)[53]	Aug. 17	Sep. 30
Sturgill	Oregon	21,636	4,815 (Sept. 1)[54]	Aug. 22	Oct. 24
Trail Ridge	Montana	17,509	517 (Sept. 1)[55]	Aug. 26	Oct. 29
Williams Creek	Idaho	16,083	626 (Sept. 1)[56]	Aug. 29	Nov. 3
Ross Fork	Idaho	37,928	1,944 (Sept. 1)[57]	Aug. 14	Nov. 1
Red	California	8,408	3,558 (Sept. 1)[58]	Aug. 4	*Nov. 6*
Rodgers	California	2,774	1,644 (Sept. 1)	Aug. 8	*Nov. 6*

[43] https://www.facebook.com/plugins/post.php?href=https%3A%2F%2Fwww.facebook.com%2FSixRivers NF%2Fposts%2Fpfbid0Yth9ZfKE3izWXzkn3wDoMyuDm4iHKgKf7CYoUVGasnxAU4MkhNTPfutK9ii7KsMul&
[44] https://inciweb.nwcg.gov/incident-publication/orwif-cedar-creek-fire/cedar-creek-fire-update-sept-1
[45] https://inciweb.nwcg.gov/incident-publication/ormaf-crockets-knob-fire/912022-crockets-knob-fire-update
[46] https://inciweb.nwcg.gov/incident-maps-gallery/idpaf-dismal-fire?page=0
[47] https://inciweb.nwcg.gov/incident-information/orwwf-double-creek-fire
[48] https://inciweb.nwcg.gov/incident-information/idpaf-four-corners-fire
[49] https://inci-web-media-bucket.s3.us-gov-west-1.amazonaws.com/s3fs-public/2022-10/pict20220805-153223-0.pdf
[50] https://incitest.nwcg.gov/incident-information/orwwf-nebo-fire
[51] https://inci-web-media-bucket.s3.us-gov-west-1.amazonaws.com/s3fs-public/2022-10/pict20220805-153223-0.pdf
[52] https://incitest.nwcg.gov/incident-information/idpaf-patrol-point
[53] https://inciweb.nwcg.gov/incident-maps-gallery/ormed-rum-creek-fire?page=2
[54] https://inciweb.nwcg.gov/incident-maps-gallery/orwwf-sturgill-fire?page=3
[55] https://inciweb.nwcg.gov/incident-information/mtbdf-trail-ridge-fire
[56] https://inciweb.nwcg.gov/incident-information/idncf-williams-creek-fire
[57] https://inciweb.nwcg.gov/incident-information/idstf-ross-fork
[58] https://www.facebook.com/YosemiteFire/posts/5724107654307870?ref=embed_post

Figure 179. 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).

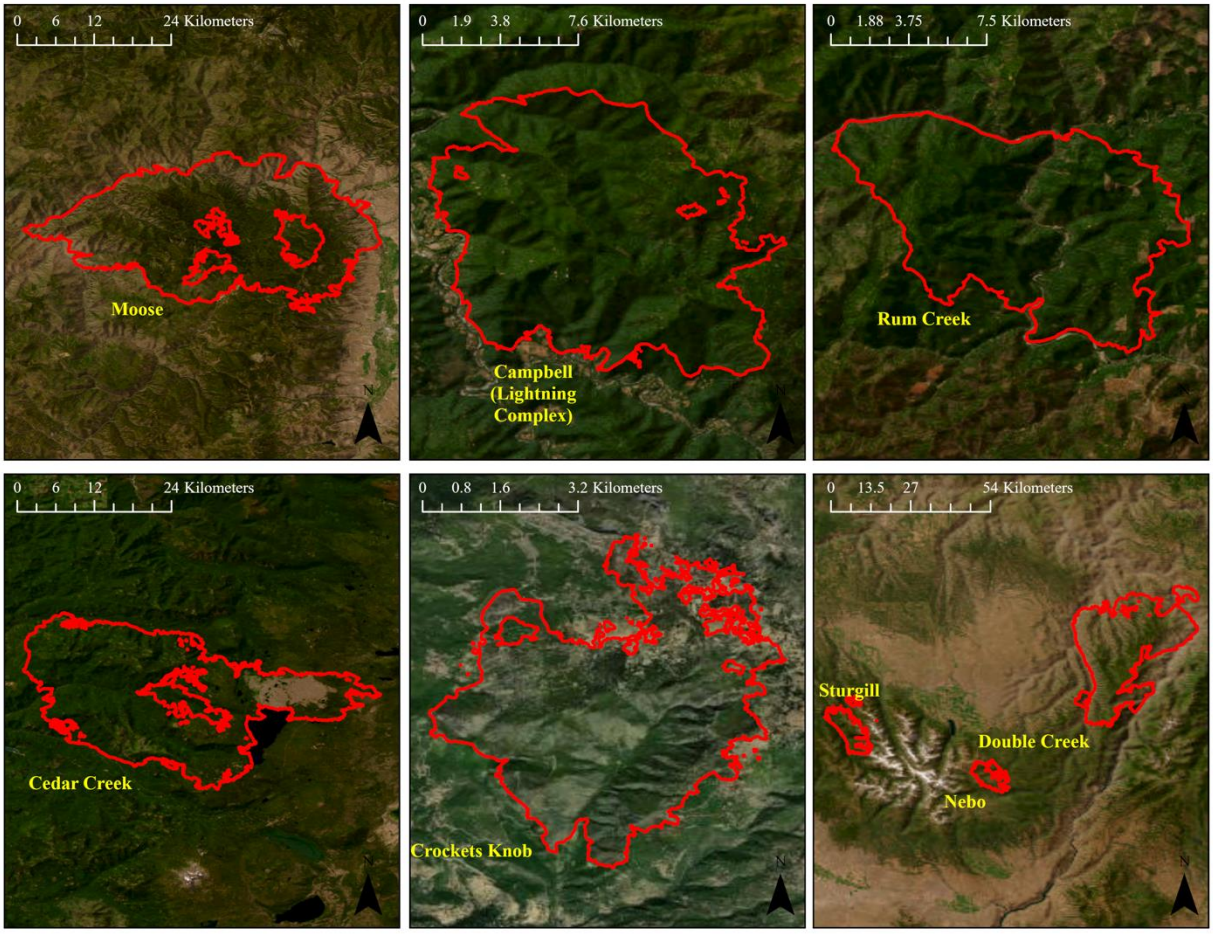

Figure 180. Final fire perimeters (red) for six of the 17 active fire regions during the September 1-2, 2022, exclusion dates.

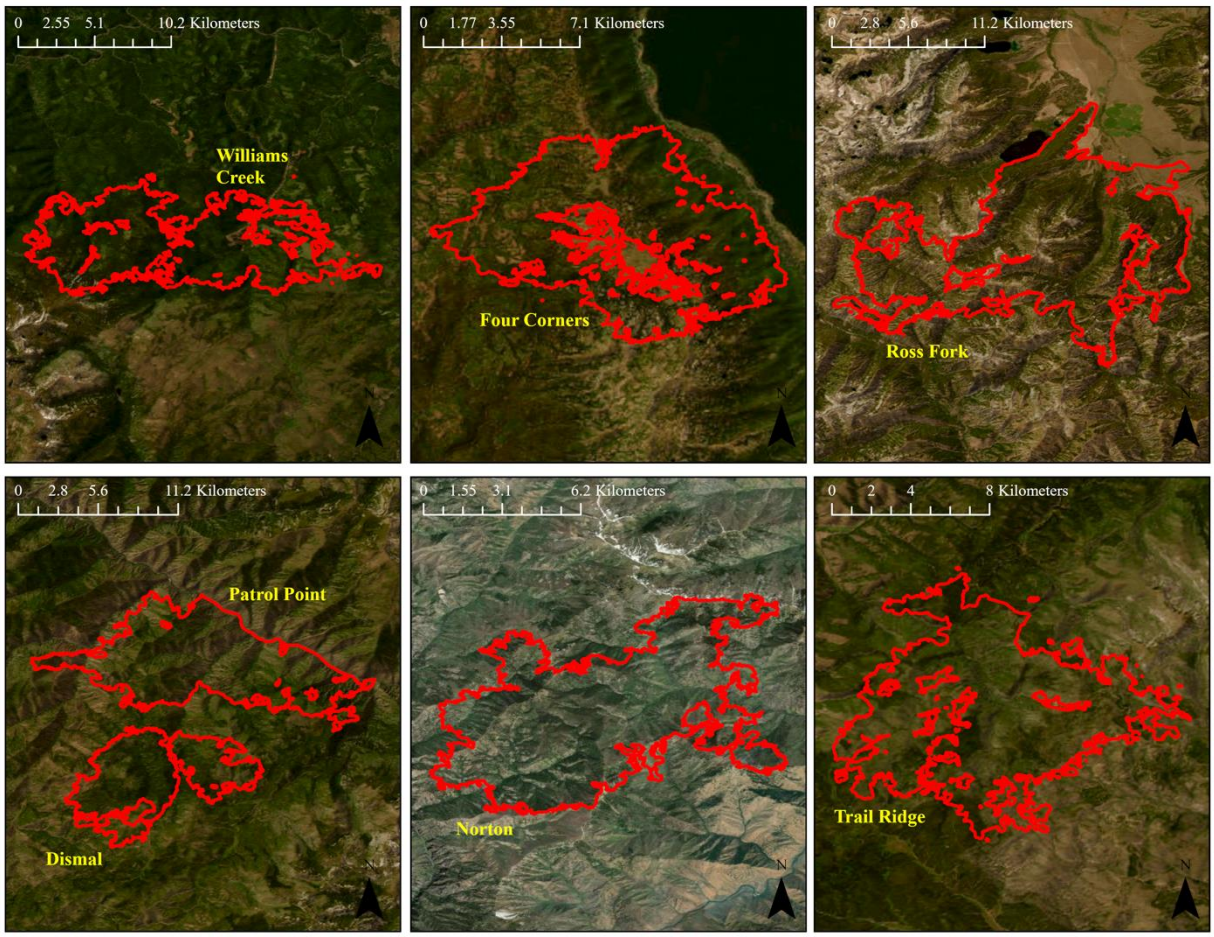

Figure 181. Final fire perimeters (red) for six of the 17 active fire regions during the September 1-2, 2022, exclusion dates.

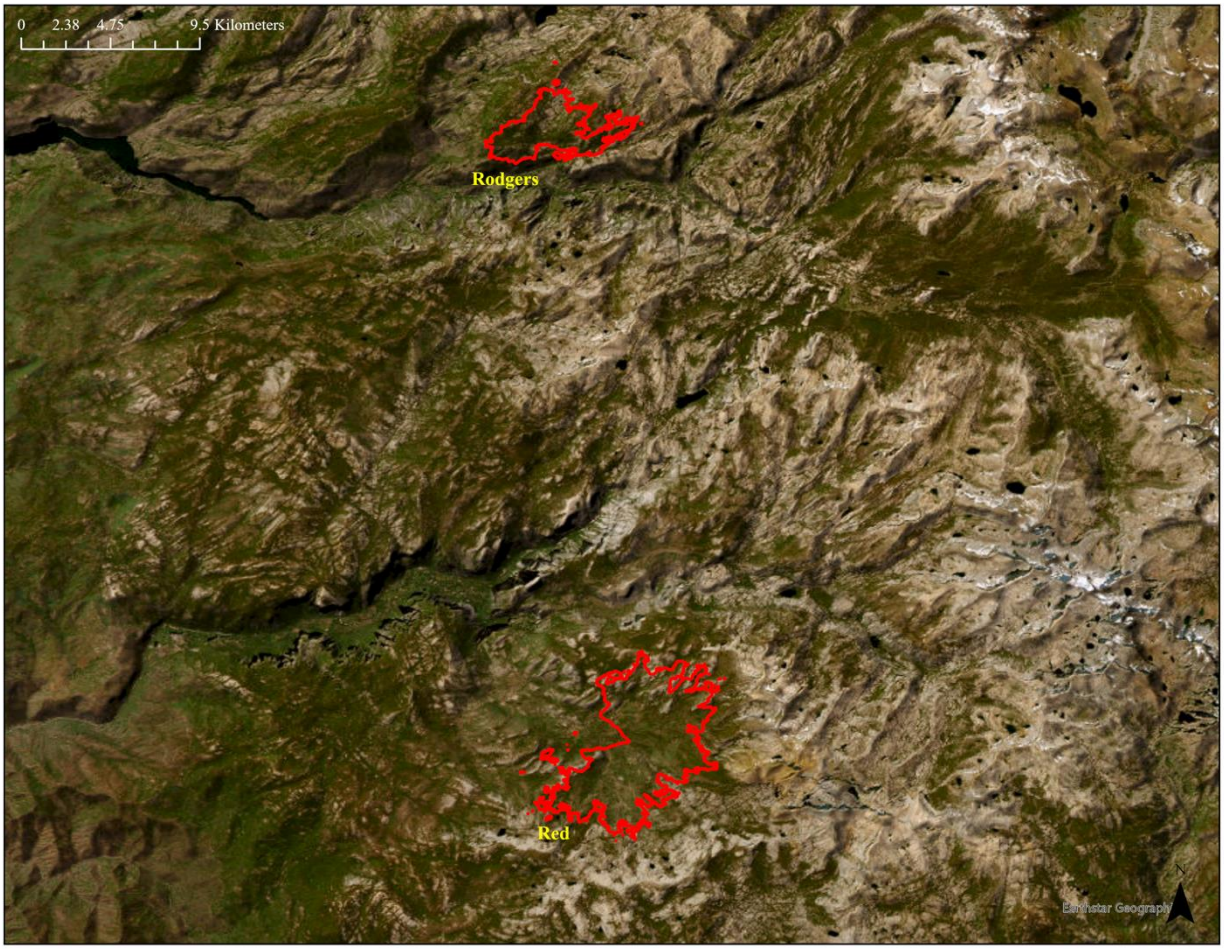

Figure 182. Final fire perimeters (red) for two of the 17 active fire regions during the September 1-2, 2022, exclusion dates.

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 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 in Figure 183 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 due to low PBL heights, 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 to 6,000 m on each day (~500-600 mbar). The NAM-modeled PBL heights over Clark County on September 1 at 16:00 PST (**Figure 184**) and September 2 at 16:00 PST (**Figure 185**) 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 on each afternoon, conducive to smoke mixing to the surface.

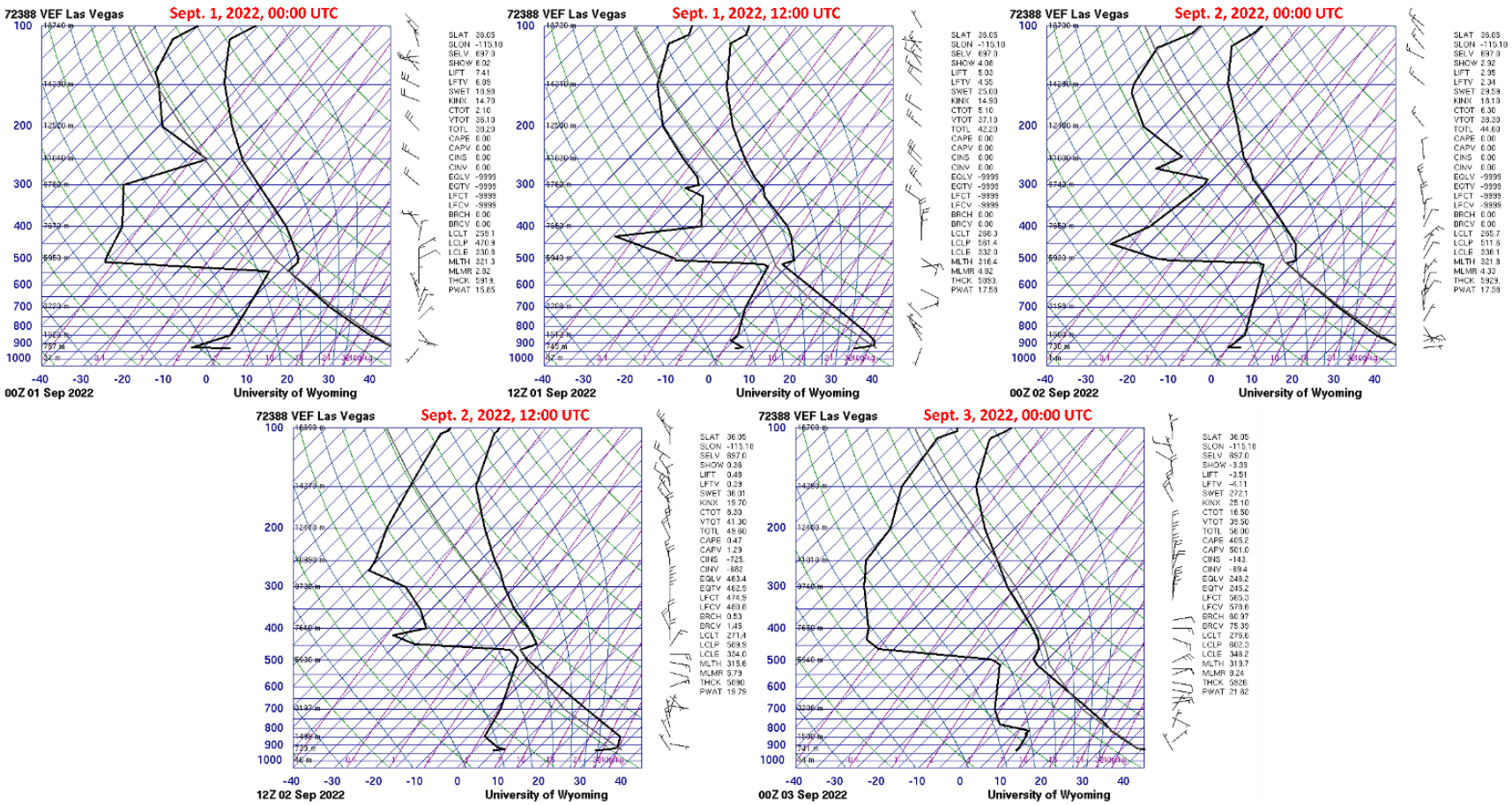

Figure 183. Skew-T soundings launched from the Las Vegas National Weather Service Office from September 1, 2022, at 00:00 UTC (August 31 at 16:00 PST) (top left), to September 3 at 00:00 UTC (September 2 at 16:00 PST) (bottom right).

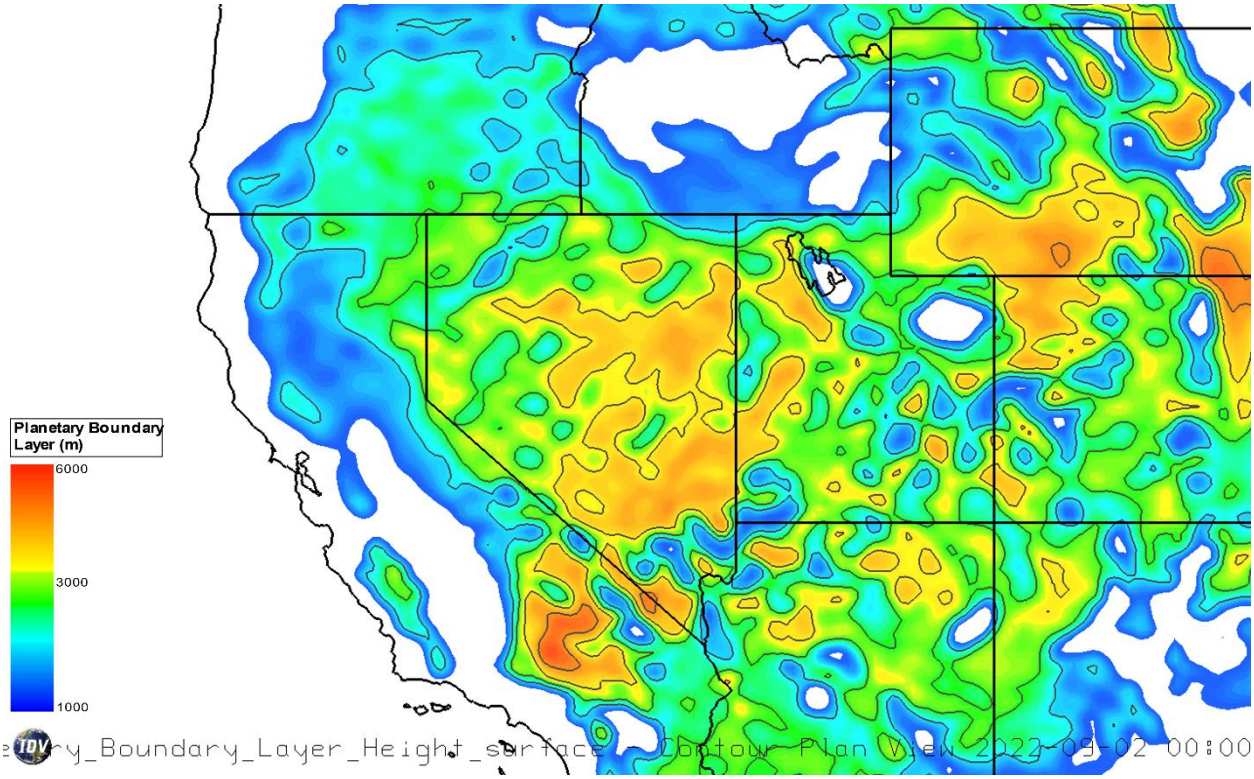

Figure 184. PBL height contour map based on the NAM model for September 2, 2022, at 00:00 UTC (September 1 at 16:00 PST). The gray lines denote PBL heights above 2 km in altitude in 1 km increments. Color contours start at 1 km.

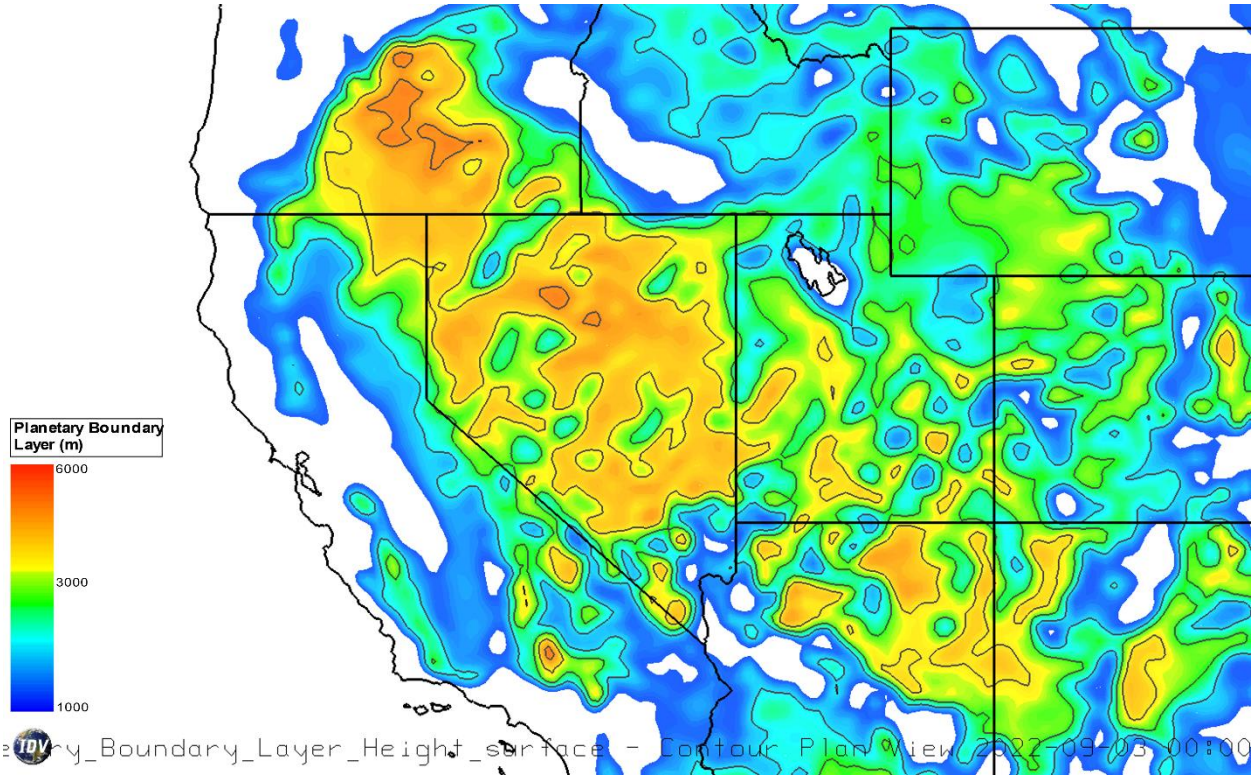

Figure 185. PBL height contour map based on the NAM model for September 3, 2022, at 00:00 UTC (September 2 at 16:00 PST). The gray lines denote PBL heights above 2 km in altitude in 1 km increments. Color contours start at 1 km.

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. Global Data Assimilation System (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 are shown in **Figure 186**. The modeling results are somewhat consistent with the HMS smoke plume shown in Figure 176; 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.

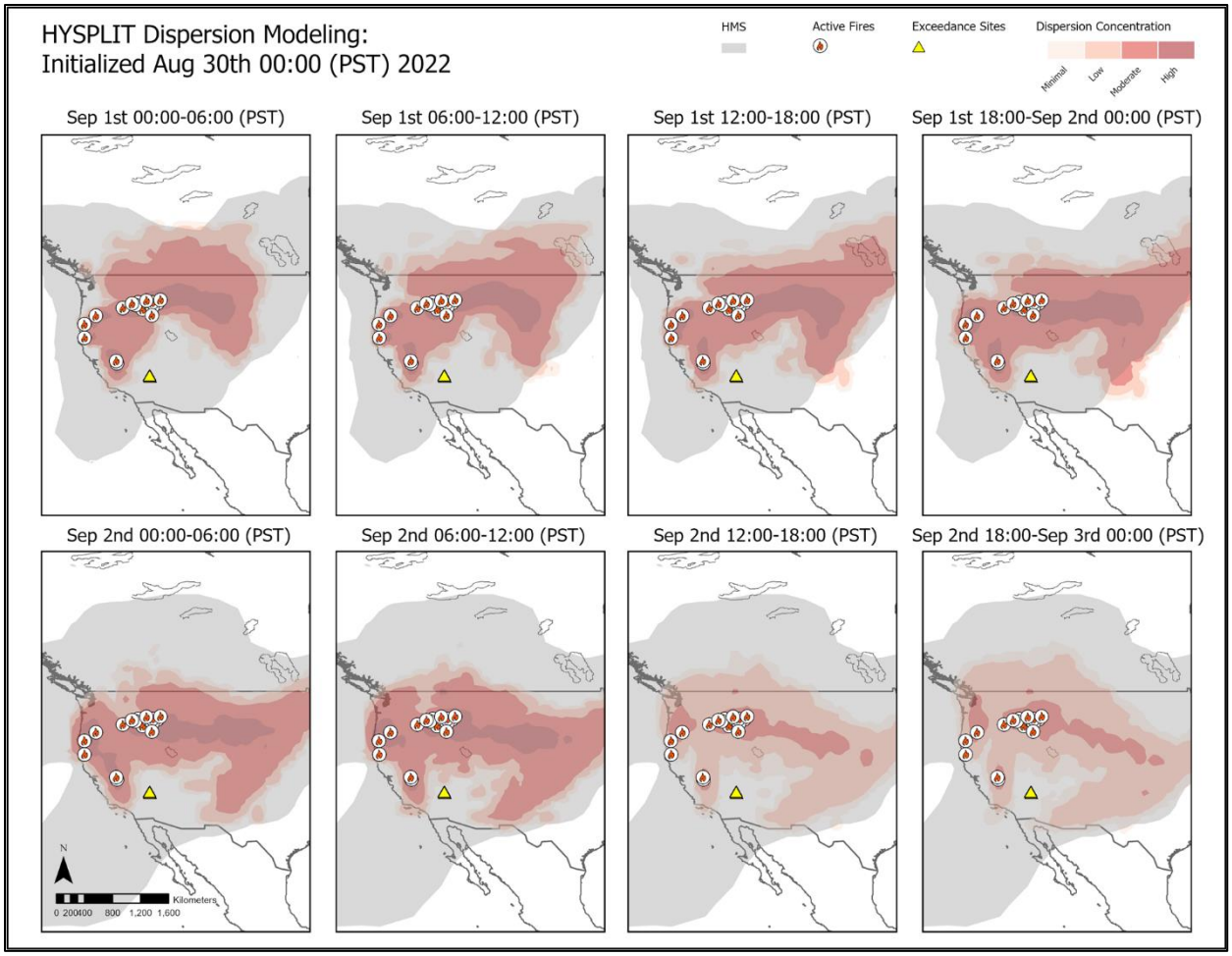

Figure 186. HYSPLIT dispersion modeling for 17 large fires (labeled as "Active Fires") in the western U.S. on or before the exclusion dates of September 1-2, 2022. GDAS 1.0° meteorological data was used, and dispersion was initiated on August 30, at 00:00 PST to model the regional smoke observed in satellite 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.

A HYSPLIT back trajectory was performed for 16:00 UTC (08:00 PST) on September 1, 2022, shown in Figure 187. The back trajectory shows the general pattern of air from the western U.S. fires, through the resulting regional smoke plume, and finally the descent of air from high altitude into the boundary layer in the Las Vegas area on the morning on September 1; this brought smoke and associated ozone precursors into the area, setting up for enhanced 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.

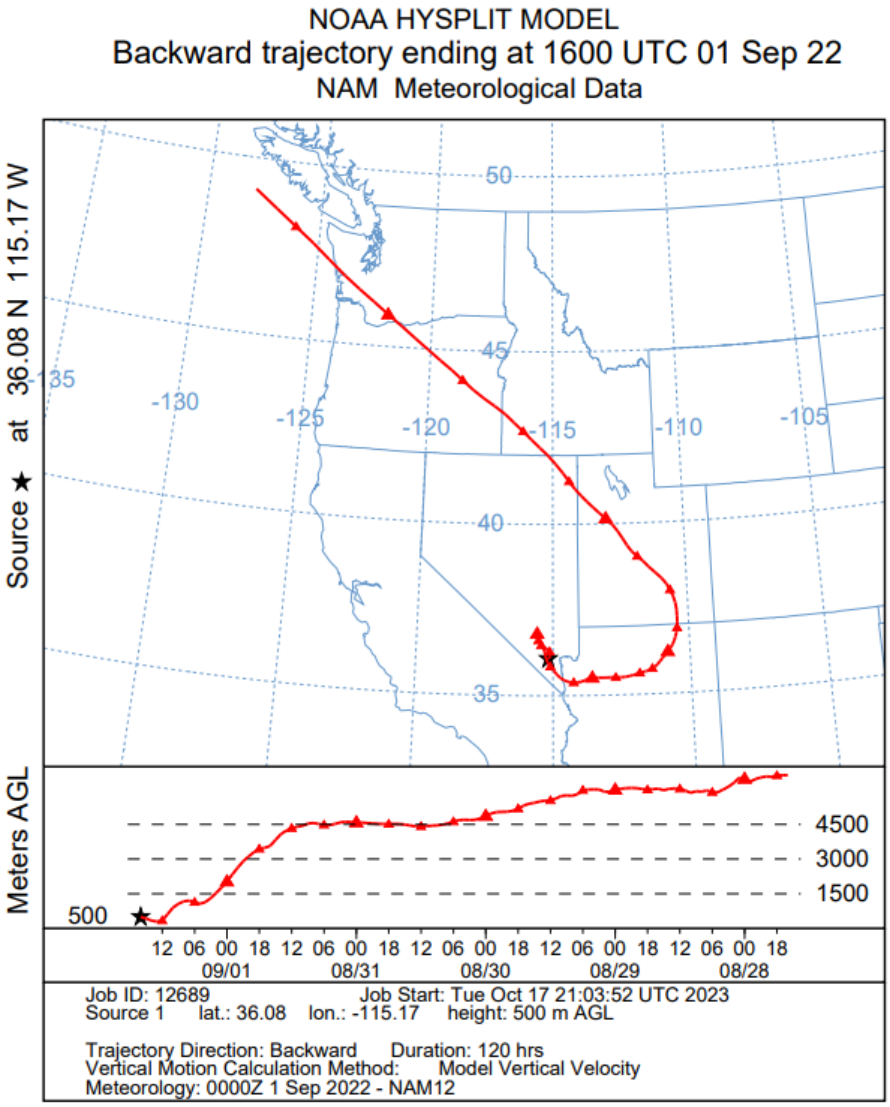

Figure 187. HYSPLIT back trajectory initiated at 16:00 UTC (08:00 PST) on September 1, 2022, using NAM 12 km meteorology. The back trajectory ran for 120 hours ending in Las Vegas (36.08, -115.17) at 500 m agl.

The HYSPLIT dispersion and back trajectory modeling shows transport through the regional smoke plume and into Clark County on the exclusion dates. The dispersion modeling does not specifically show smoke in the Clark County area but does confirm the general pattern of smoke movement and mixing. The back trajectory modeling does show advection of air from the regional smoke plume in the southern Idaho area into Clark County at the beginning of the exclusion dates. The HRRR smoke product forecast (Figure 188) agrees with the HYSPLIT dispersion and back trajectory analysis, showing low levels of vertically integrated smoke over the Clark County region on September 1-2, 2022. The combination of the HMS maps, meteorological information, PBL analysis, HYSPLIT analysis, and HRRR data suggests that regional smoke likely merged from fires throughout the western U.S.,

transported through a high-pressure system into the southwest U.S., and descended into the well-mixed boundary layer in Las Vegas Valley on September 1-2, 2022.

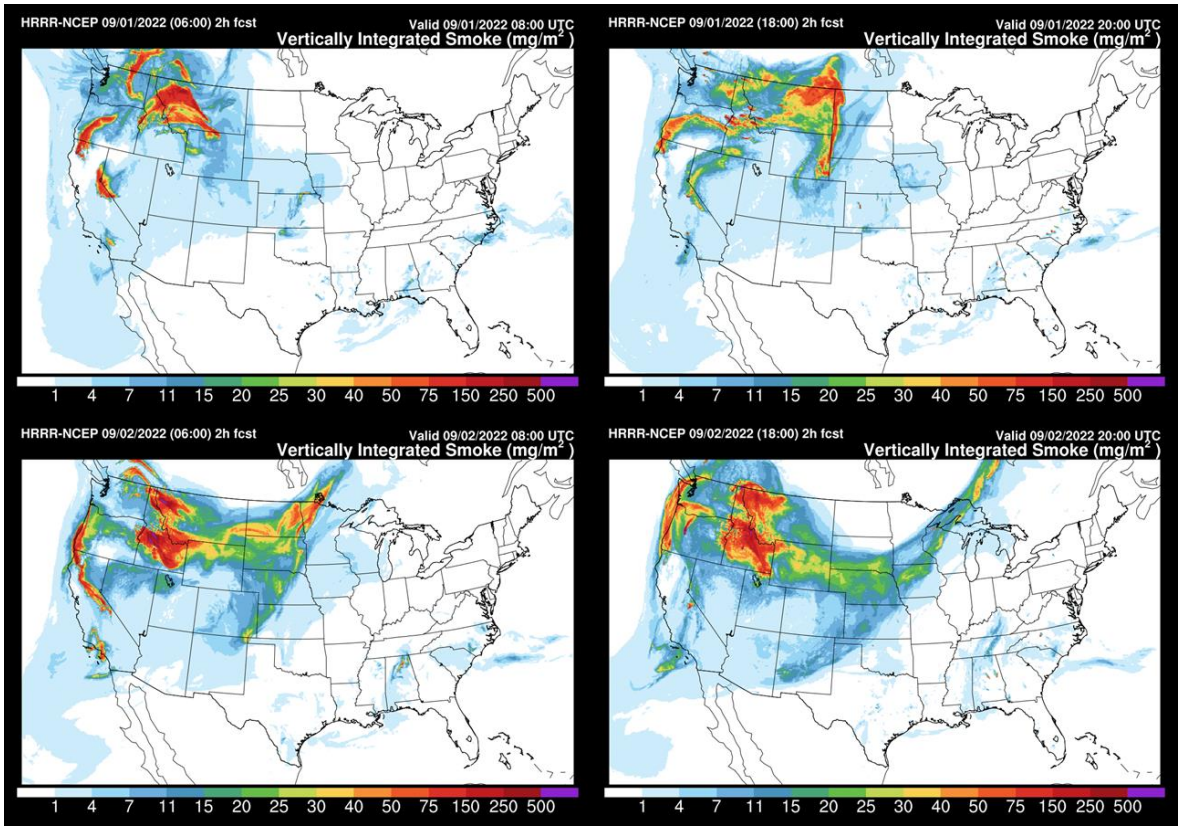

Figure 188. HRRR vertically integrated smoke forecast for September 1-2, 2022, at 00:00 PST and 12:00 PST.

5.4.4 Impacts at the Surface

Figure 189 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.

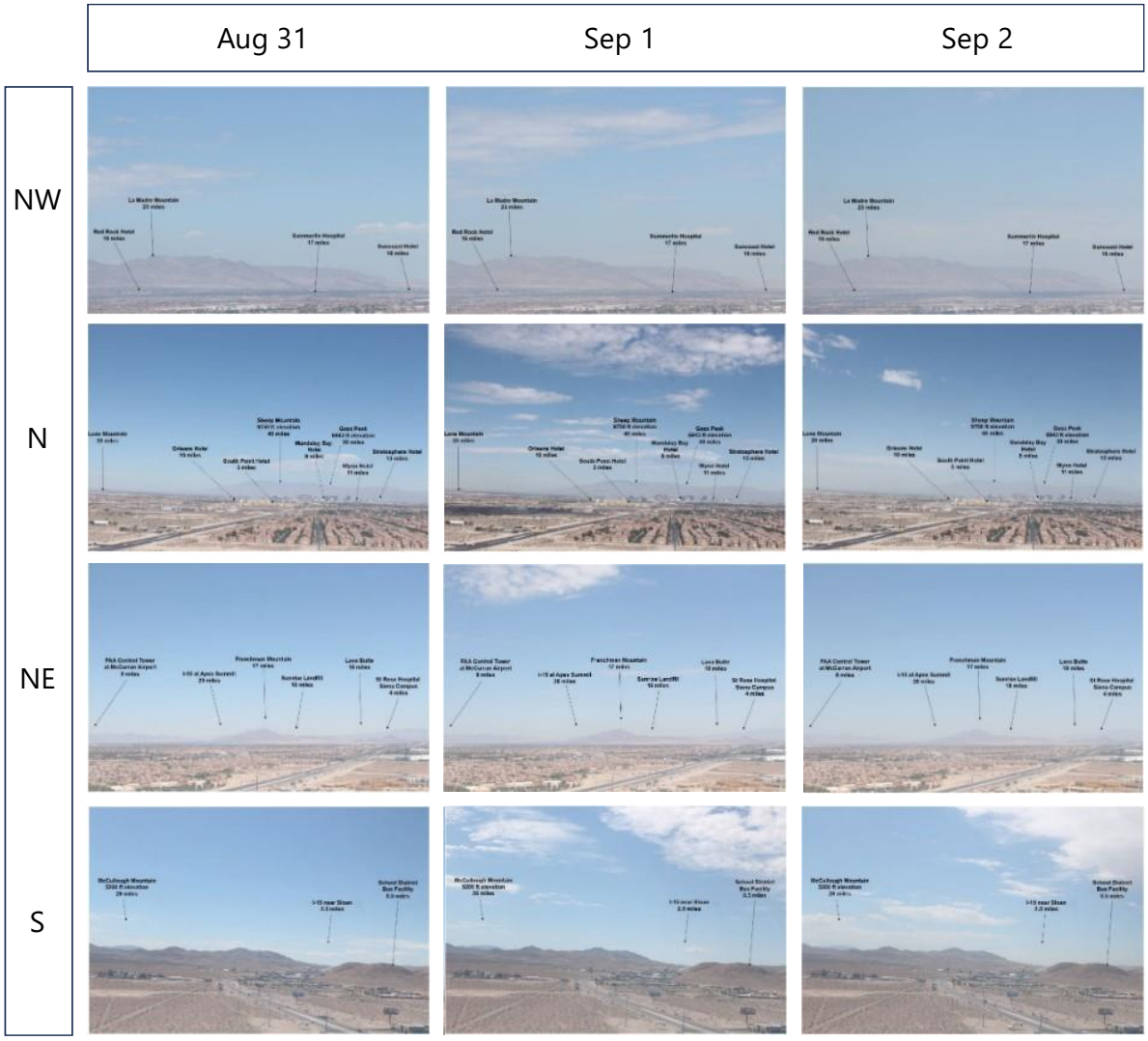

Figure 189. Camera images for August 31, 2022 (left column), September 1 (middle column), and September 2 (right column), taken at 12:00 PST on each day from the M Resort Hotel in Las Vegas. These images face northwest (top row), north (second row), northeast (third row), and south (bottom row).

Figure 190 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 190 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 189.

Figure 191 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. There were no large enhancements of NO_2 concentrations during the event period. This is consistent with both the light layer of smoke, as modeled via HYSPLIT and HRRR, and long-range transport.

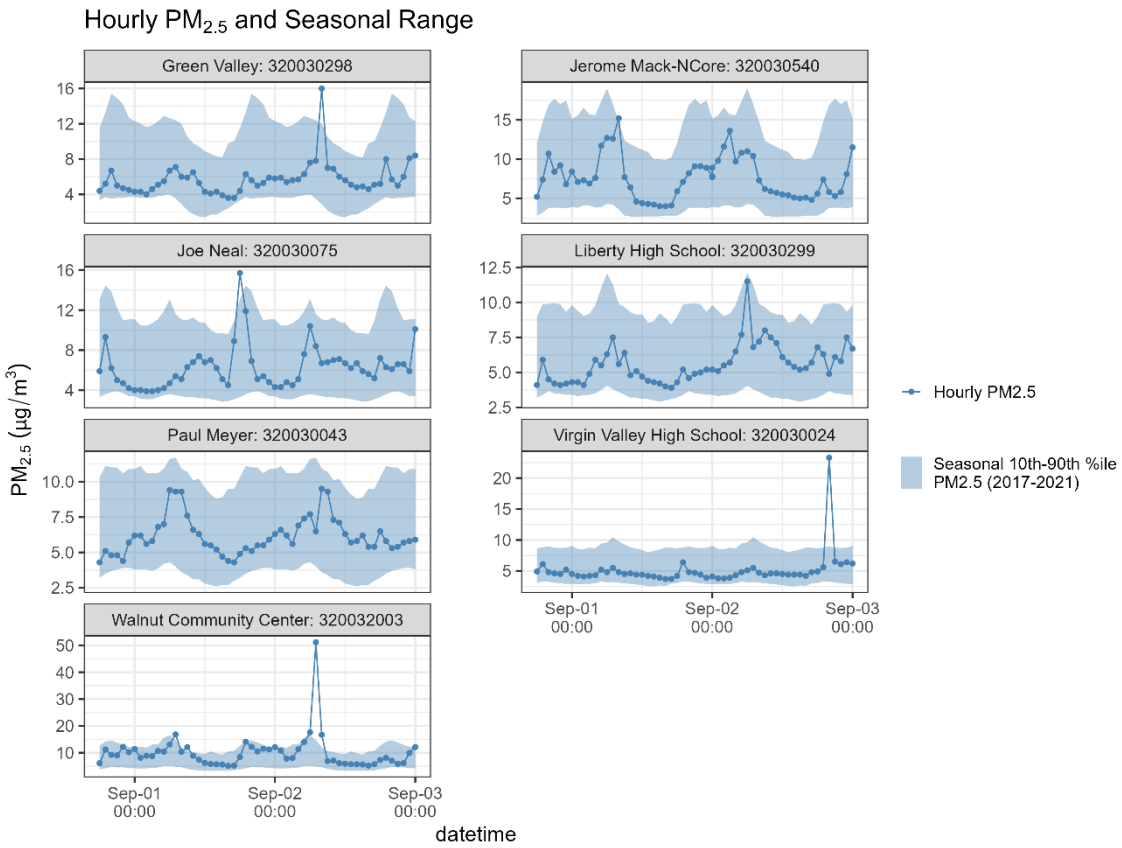

Figure 190. Hourly $PM_{2.5}$ measurements overlaid on the 10th-90th percentile diurnal concentrations recorded at the event-affected measurement sites and supporting sites that measure $PM_{2.5}$ concentrations. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2022.

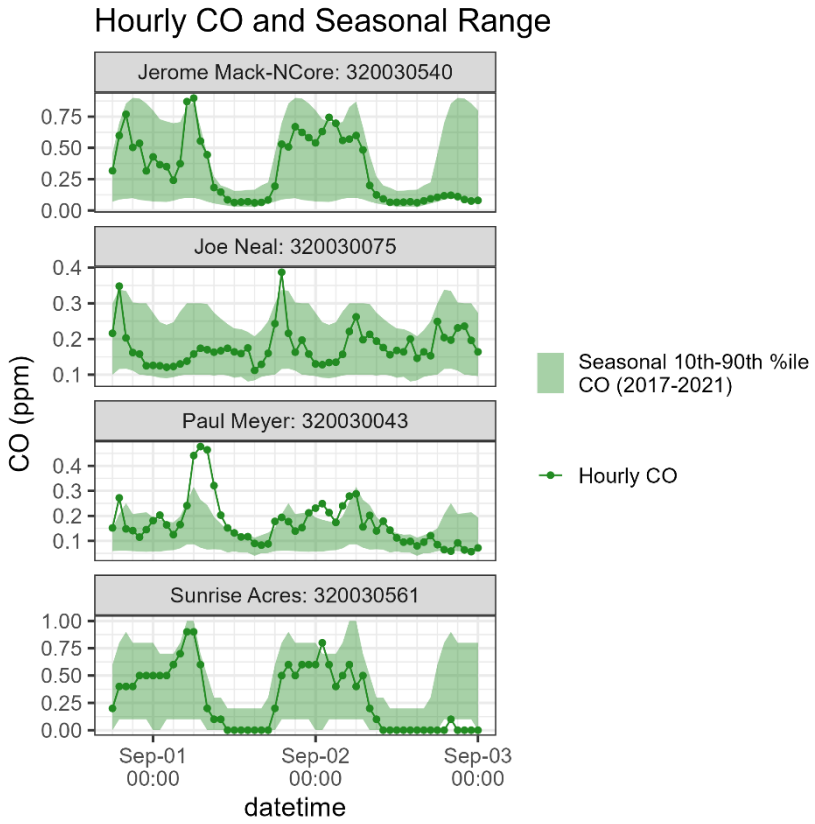

Figure 191. Hourly CO measurements overlaid on the 10th-90th percentile diurnal concentrations at each event-affected measurement site and supporting sites that measure CO concentrations. The 10th-90th percentile concentration is calculated across the ozone production season (May-October) of 2017-2022.

5.4.5 Event Statistics

Table 39 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. 24-hr average $PM_{2.5}$ concentrations ranged from the 58th - 63rd percentile. CO 1-hr daily maximum concentrations 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 site) were in the 87th percentile on September 1 and in the 71st percentile on September 2.

Table 39. 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 site.

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	*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	*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 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 40 provides the evidence and exclusion narrative for each date.

Table 40. Evidence provided for each exclusion date.

Exclusion Date(s)	Event Summary
June 16, 2022	Regional transport of smoke from large wildfires in Arizona, New Mexico, and Baja Mexico in the afternoon of June 16 enhanced ozone concentrations outside of the typical diurnal profile, keeping ozone values high and affecting the maximum daily 8-hr average (MDA8) ozone concentrations at two sites. Smoke maps from the National Oceanic and Atmospheric Administration (NOAA)'s Hazard Mapping System (HMS)., dispersion modeling, Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) trajectories, 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. HMS smoke maps and trajectories confirm a regional smoke plume drifted westward from June 16 to June 17 until it fully encompassed the Las Vegas area. 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, planetary boundary layer (PBL) analysis, HYSPLIT back trajectories, and High-Resolution Rapid Refresh (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.