Technical Support Documentation
Ozone NAAQS Exceedances Occurring June 8 and 9, 2015
Uinta Basin of Utah

Prepared by:
Ute Indian Tribe of the Uinta and Ouray Reservation
U. S. EPA Region 8
Utah State University Bingham Energy Center
Utah Division of Air Quality

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1. EXCEPTIONAL EVENTS RULE REQUIREMENTS

The U. S. Environmental Protection Agency promulgated the Exceptional Events Rule (EER) in 2007, pursuant to the 2005 amendment of Clean Air Act (CAA) Section 319. 42 U.S.C. §7619. The EER added 40 CFR 50.1(j), (k) and (l); 50.14; and 51.930 to the Code of Federal Regulations (CFR). These sections contain definitions, criteria for the EPA approval, procedural requirements, and requirements for air agency demonstrations, all of which must be met before the EPA can concur under the EER on the exclusion of air quality data from regulatory decisions.

Under 40 CFR 50.14(c)(3)(iv), the air agency demonstration to justify exclusion of data must provide evidence that:

1. The event satisfies the criteria set forth in 40 CFR §50.1(j) for the definition of an exceptional event;
    - The event affects air quality;
    - The event is not reasonably controllable or preventable; and
    - The event is caused by human activity that is unlikely to recur at a particular location or [is] a natural event.[1]
2. There is a clear causal relationship between the measurement under consideration and the event that is claimed to have affected the air quality in the area;
3. The event is associated with a measured concentration in excess of normal historical fluctuations, including background; and
4. There would have been no exceedance or violation but for the event.

A. EVENT DETAILS

The Ute Indian Tribe of the Uintah and Ouray Reservation operates ozone monitors at four locations (Myton, Whiterocks, Ouray and Redwash) shown in Figure 1. These four monitors recorded their highest and second highest 8-hour ozone in 2015 on June 8 and 9. Data presented in this document show that the high ozone recorded on those days was unseasonably high, not consistent with historical readings and patterns, and that they coincided with the intrusion of stratospheric air into the troposphere contributing ozone to the surface measurements. With this demonstration, the Ute Indian Tribe is requesting that the EPA concur on stratospheric ozone exceptional event flags the tribe has applied to the impacted data in the AQS database, and that the EPA exclude the exceedances caused on June 8 and 9, 2015 by stratospheric intrusion from calculations of ozone exceedances and violations for 2015.

Monitored ozone details are shown in Table 1.

[1] A natural event is further described in 40 CFR 50.1(k) as "an event in which human activity plays little or no direct causal role".

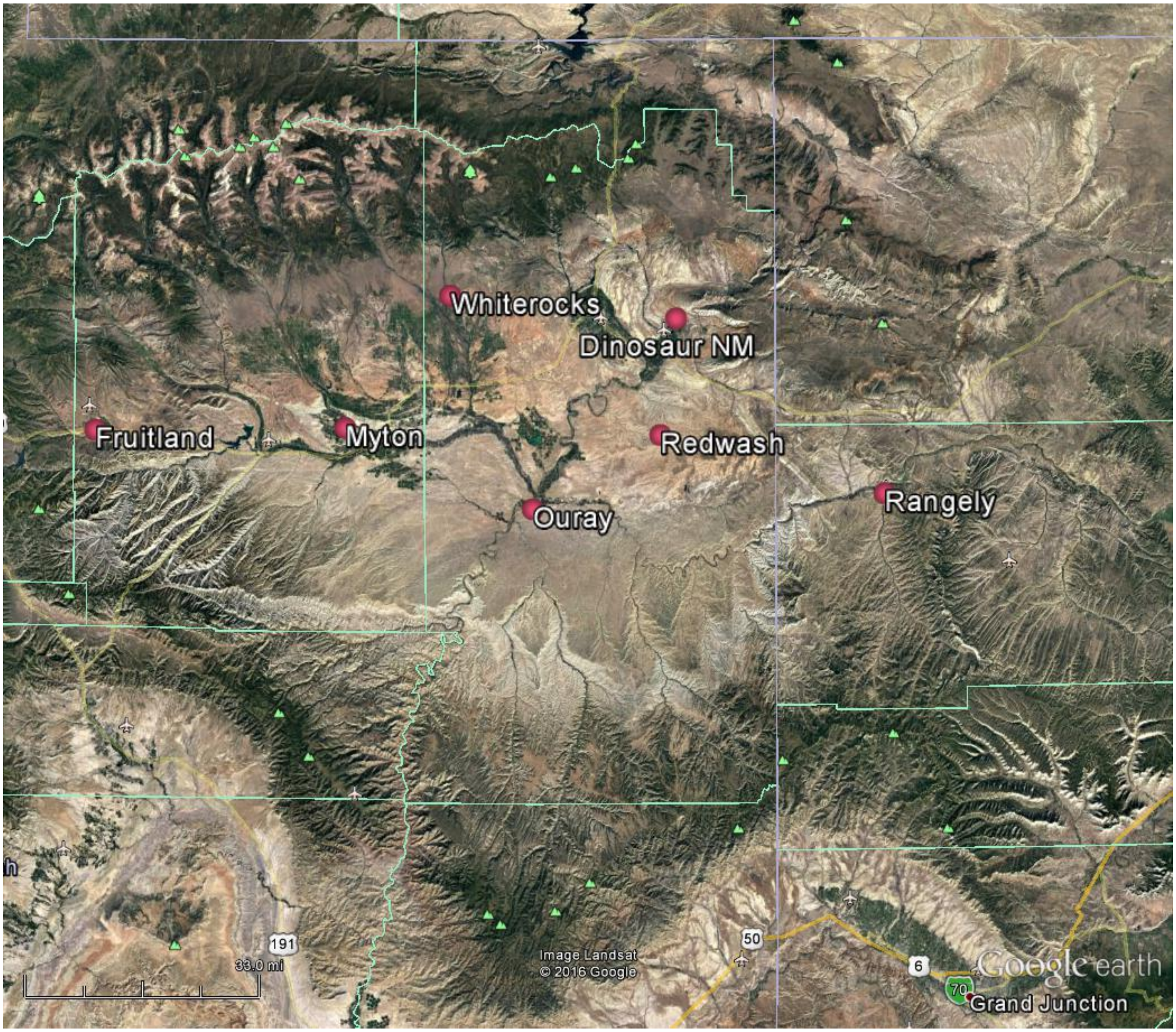

Figure 1 Locations of the Myton, Whiterocks, Ouray and Redwash Ozone Monitors in the Uinta Basin of Utah. Fruitland, Dinosaur National Monument and Rangely, Colorado Monitors Also Shown

Table 1 Ute Indian Tribe Stratospheric Intrusion Impacted Data, 2015

Monitor Name	Monitor Number	June 8, 2015 8-hr Ozone	June 8, 2015 Annual Rank	June 9, 2015 8-hr Ozone	June 9, 2015 Annual Rank
Ouray	49-047-2003	71 ppb	1st	71 ppb	2nd
Redwash	49-047-2002	74 ppb	1st	72 ppb	2nd
Myton	49-013-7011	71 ppb	2nd	72 ppb	1st
Whiterocks	49-047-7022	73 ppb	1st	73 ppb	2nd

2. CONCEPTUAL MODEL

The Uinta Basin of Utah is a winter ozone region; in a typical year, the highest ozone concentrations are recorded in December through mid-March under cold, clear high pressure conditions, with low wind speeds and significant snow cover. Strong temperature inversions at lower elevations in the basin concentrate local ozone precursor emissions near the surface, and photochemical ozone production accumulates over multiday inversion episodes causing exceedances of the ozone NAAQS. In contrast, elevated ozone in spring and summer months are rare because better dispersion conditions are not as conducive to the accumulation of high concentrations of ozone and its precursors.

In contrast to the typical situation, when snow cover is not significant in the winter season, winter ozone does not form, and the highest ozone levels in low snow years can occur in the spring and summer. The two highest ozone days in the Uinta Basin in 2015 occurred on June 8 and 9. With little or no persistent snow cover in the basin in January through March and in December of 2015, wintertime ozone was not observed.

In early June of 2015, relatively high levels of ozone were observed at remote, rural high elevation ozone monitors in Nevada (Great Basin National Park, 6,767 feet elevation, on the Utah-Nevada Border), Utah (Fruitland, 6,641 feet, in the western portion of the Uinta Basin), Wyoming (Murphy Ridge, 6,906 feet, on the Utah-Wyoming border; and Centennial, 10,445 feet in the Medicine Bow/Snowy Mountains) and Colorado (Niwot Ridge, 9,463 feet, 15 miles west of Boulder; Rocky Mountain NP, 9,006 feet; and Gothic, 9,580 feet, north of Mt. Crested Butte) beginning on June 2, 2015. In the last week of May, from May 25 through June 1, none of these high elevation sites recorded 8-hour ozone levels as high as 60 ppb. The Great Basin National Park monitor recorded 8-hour ozone greater than 60 ppb each day from June 3 through 9. Other high elevation monitors were generally above 60 ppb on June 3 and 4 and on June 7, 8 and 9, as shown in Figure 2. On June 9, 2015 the Fruitland monitor in the western side of the Uinta basin recorded an 8-hour average ozone concentration of 77 ppb, the highest ozone ever observed by this monitor (considering data from April 2011 through June of 2016).

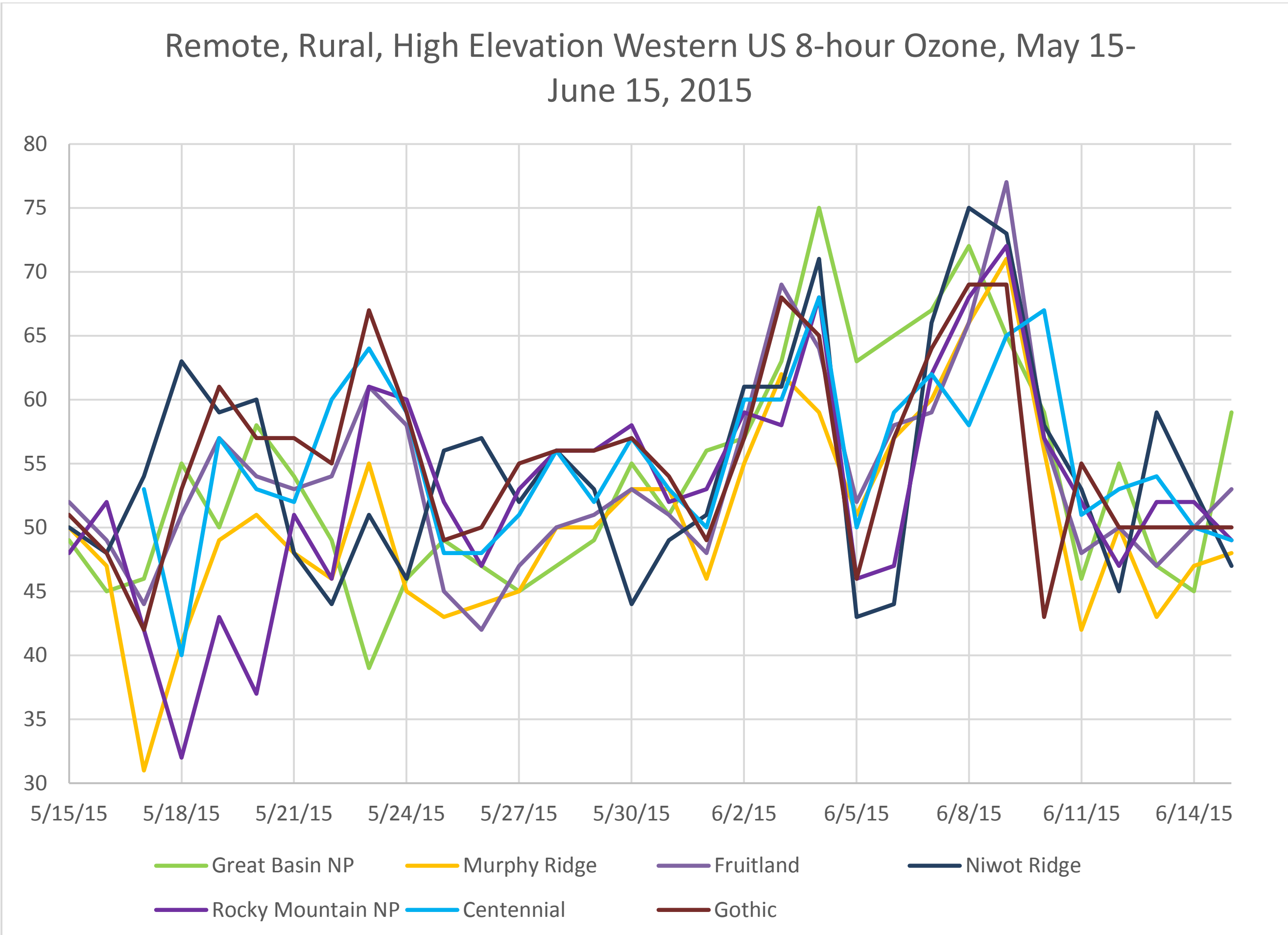

Figure 2 High-elevation 8-hour Ozone in the Intermountain West, May 15-June 15, 2015

Beginning on June 4, 2015, a closed upper level low around California slowly moved east and weakened, leaving an elongated zone of lowered tropopause heights, low pressure, and elevated free troposphere and total column O_3 stretching from Nevada into Colorado and Wyoming, where it affected surface O_3 for a number of days.

Complicating matters, the summer anthropogenic O_3 season was underway, and contributions from anthropogenic O_3 were observable in the urbanized Wasatch Front of Utah and along Colorado's Front Range around Denver. In addition, there was evidence during the period that in some locations thunderstorms both enhanced the transport or mixing of free troposphere and stratospheric O_3 to the surface and, at other times, also lowered surface O_3, even while free tropospheric O_3 concentrations may have shown the effects of the intrusions.

Beginning on June 7, a complex west-east pattern of residual high total column O_3 and high O_3 concentrations aloft, high and low satellite water vapor, and thunderstorms was draped across Nevada, Utah and northern Colorado. This pattern was an extension of the remnants of the upper level low and seemed to be causing high O_3 at the surface from Nevada and Utah to Colorado and southern Wyoming.

3. CLEAR CAUSAL RELATIONSHIP

A. COMPARISON TO HISTORICAL DATA

This demonstration applies to monitoring data from the four monitors operated by the Ute Indian Tribe of the Uintah and Ouray Reservation, namely, Myton, Whiterocks, Ouray and Redwash. Nearby monitors at Fruitland, operated jointly by the Utah Division of Air Quality and the Bureau of Land Management (BLM), and at Dinosaur National Monument and Rangely, Colorado, operated by the National Park Service were also impacted on June 8 and 9, 2015, and data from these monitors are included in the demonstration where appropriate. June 8 and 9, 2015 do not contribute to regulatory violations of the ozone NAAQS at these monitors, so demonstrations and requests to exclude data from these monitors are not expected.

Summary statistics comparing the June 8 and 9, 2015 maximum 8-hour average ozone to historical data is presented in Table 2. It includes statistics considering all data available (all 12 months of the year), as well as statistics considering only April through June data. When considering all data, June 8, 2015 data represents a range of percentile ranks from 94th percentile for Ouray to 98.6th percentile for Whiterocks. June 9, 2015 similarly ranks from 94th percentile at Ouray to 99.9th percentile 98.5th percentile at Whiterocks. For comparison, June 9, 2015 at Fruitland represents the 99.9th percentile value (highest ever concentration in 2011-2015). June 8 or 9th ranked as the highest ever 8-hour ozone at the Fruitland, and as the highest ever April-June 8-hour ozone at Fruitland, Myton, Whiterocks, and Redwash. Myton, Whiterocks and Redwash recored June 8 and 9 as both the 1st and 2nd highest ever April-June 8-hour ozone.

The June 8 and 9, 2015 ozone data can be viewed in context by plotting each available daily maximum 8-hour average against the day of year. Figures 3 through 9 show this for the seven monitors in Table 2. The June 8 and 9 data points are displayed as red triangles. The Fruitland data show only very slightly elevated ozone in winter months, and show June 9 as the highest 8-hour ozone in the 2011-2015 period. The remaining monitors all include elevated winter data, but show the June 8 and 9, 2015 as the highest or among the highest of the non-winter measurements in each monitors data set.

Table 2 Summary Statistics Comparing June 8 and 9, 2015 Uinta Basin Data with Historical Data

Statistics Considering All Data							
Statistic	Fruitland	Myton	Whiterocks	Ouray	Redwash	Dinosaur NM	Rangely, CO
Data Years	April 2011-2015	2011, 2013-2015	2011, 2013-2015	Aug. 2009-2015	Aug. 2009-2015	Apr.-Sept., 2007-2010; 2011-2015	Aug 2010-2015
Number of Samples	1,716	1,316	1,254	2.313	2,279	2,447	1,934
June 8 Max 8-hr Ozone	66 ppb	71 ppb	73 ppb	71 ppb	74 ppb	74 ppb	70 ppb
June 8 Rank	34 of 1,716	58 of 1,316	18 of 1,254	138 of 2,313	95 of 2,279	51 of 2,447	21 of 1,934
June 8 Percentile	97.9th	95.6th	98.6th	94th	95.8th	97.9th	98.9th
June 9 Max 8-hr Ozone	77 ppb	72 ppb	73 ppb	71 ppb	72 ppb	72 ppb	70 ppb
June 9 Rank	1 of 1,716	55 of 1,316	19 of 1,254	139 of 2,313	104 of 2,279	54 of 2,447	22 of 1,934
June 9 Percentile	99.9th	95.8th	98.5th	94th	93.9th	97.8th	98.9th
Mean Daily Max 8-hr O_3	48.4 ppb	49.7 ppb	49.3 ppb	51.2 ppb	49.8 ppb	49.8 ppb	45.6 ppb
Max Daily Max 8-hr O_3	77 ppb	124 ppb	107 ppb	141 ppb	125 ppb	126 ppb	106 ppb
Standard Deviation of Daily Max 8-hr O_3	8.8 ppb	12.6 ppb	10.1 ppb	15.2 ppb	12.8 ppb	11.9 ppb	10.7 ppb
Statistics Considering Only April-June Data							
Statistic	Fruitland	Myton	Whiterocks	Ouray	Redwash	Dinosaur NM	Rangely, CO
Data Years	April 2011-2015	2011, 2013-2015	2011, 2013-2015	2010-2015	2010-2015	2007-2015	2011-2015
Number of Samples	455	364	362	514	542	755	449
June 8 Max 8-hr Ozone	66 ppb	71 ppb	73 ppb	71 ppb	74 ppb	74 ppb	70 ppb
June 8 Rank	20 of 455	2 of 364	1 of 362	4 of 514	1 of 542	3 of 755	2 of 449
June 8 Percentile	95.6th	99.5th	99.7th	99.2th	99.8th	99.6th	99.6th
June 9 Max 8-hr Ozone	77 ppb	72 ppb	73 ppb	71 ppb	72 ppb	72 ppb	70 ppb
June 9 Rank	1 of 455	1 of 364	2 of 362	5 of 514	2 of 542	4 of 755	3 of 449
June 9 Percentile	99.8th	99.7th	99.4th	99th	99.6th	99.5th	99.3rd
Mean Daily Max 8-hr O_3	55.9 ppb	54.3 ppb	55.3 ppb	55.4 ppb	54.2 ppb	54.8 ppb	53.6 ppb
Max Daily Max 8-hr O_3	77 ppb	72 ppb	73 ppb	73 ppb	74 ppb	80 ppb	71 ppb
Standard Deviation of Daily Max 8-hr O_3	6.2 ppb	5.7 ppb	5.8 ppb	6.2 ppb	5.9 ppb	6.5 ppb	6.1 ppb

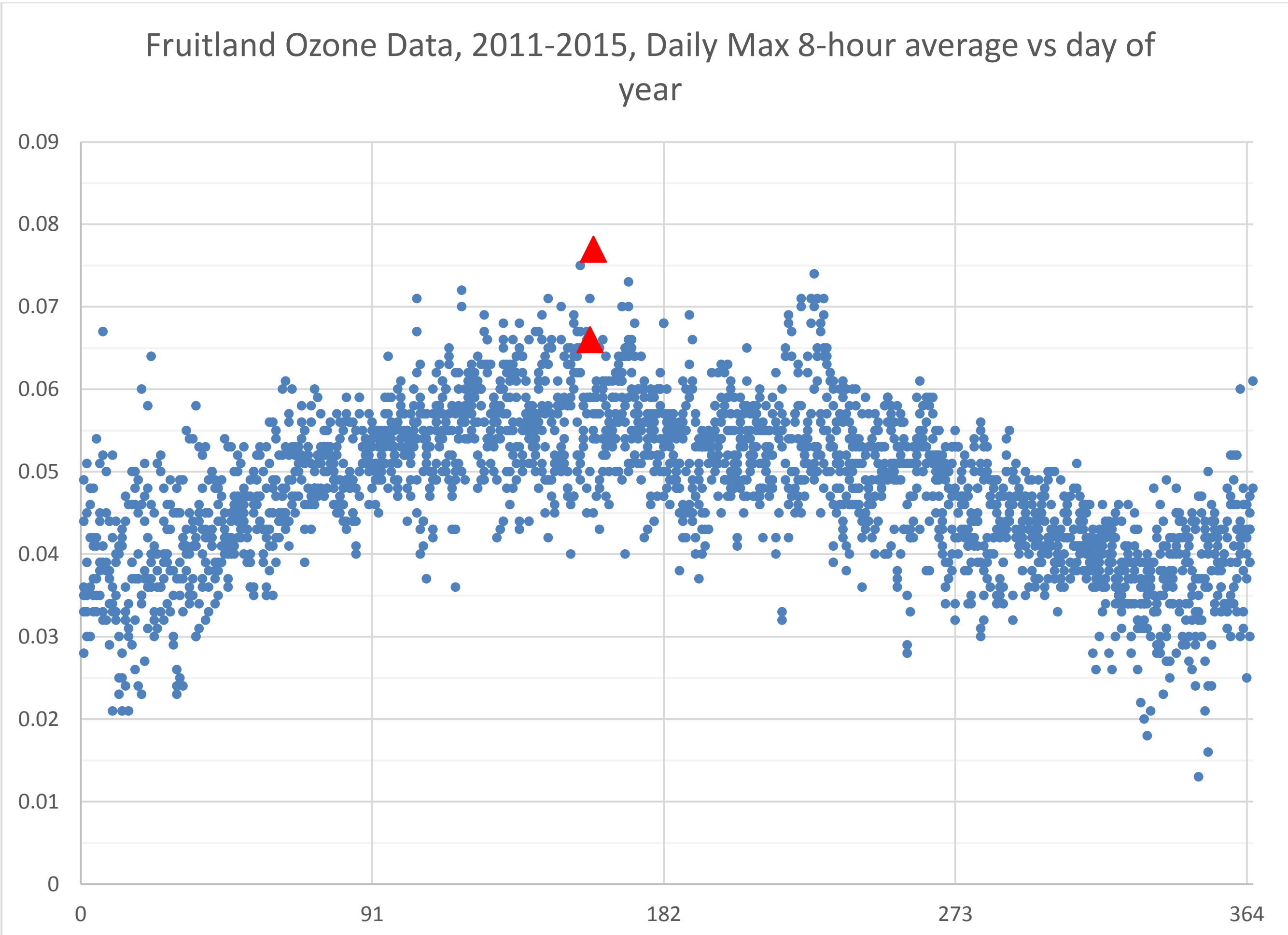

Figure 3 Fruitland Daily Maximum 8-hour Ozone vs. Day of Year, 2009-2015; June 8-9, 2015 in Red

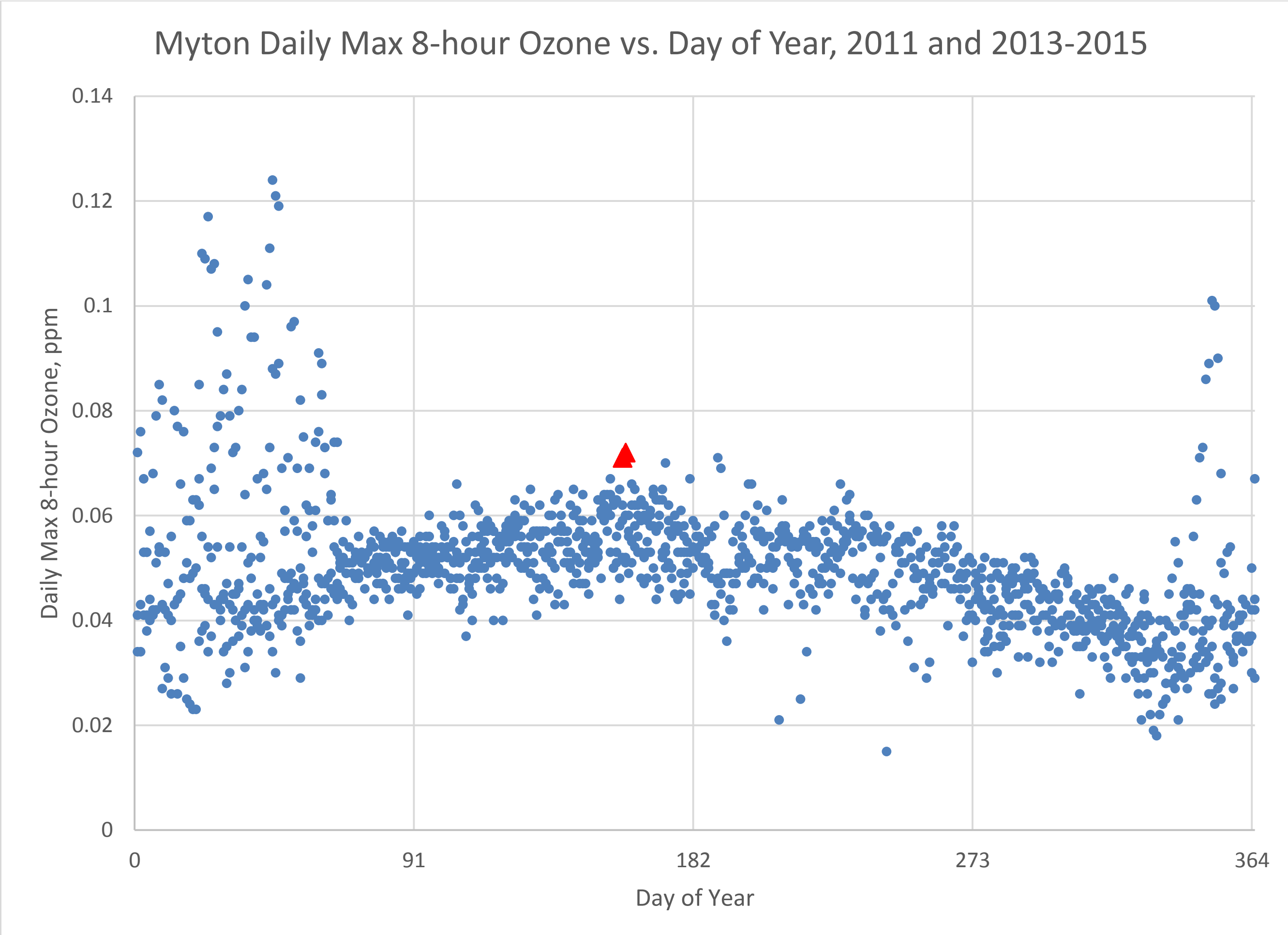

Figure 4 Myton Daily Maximum 8-hour Ozone vs. Day of Year, 2011 and 2013-2015; June 8-9, 2015 in Red

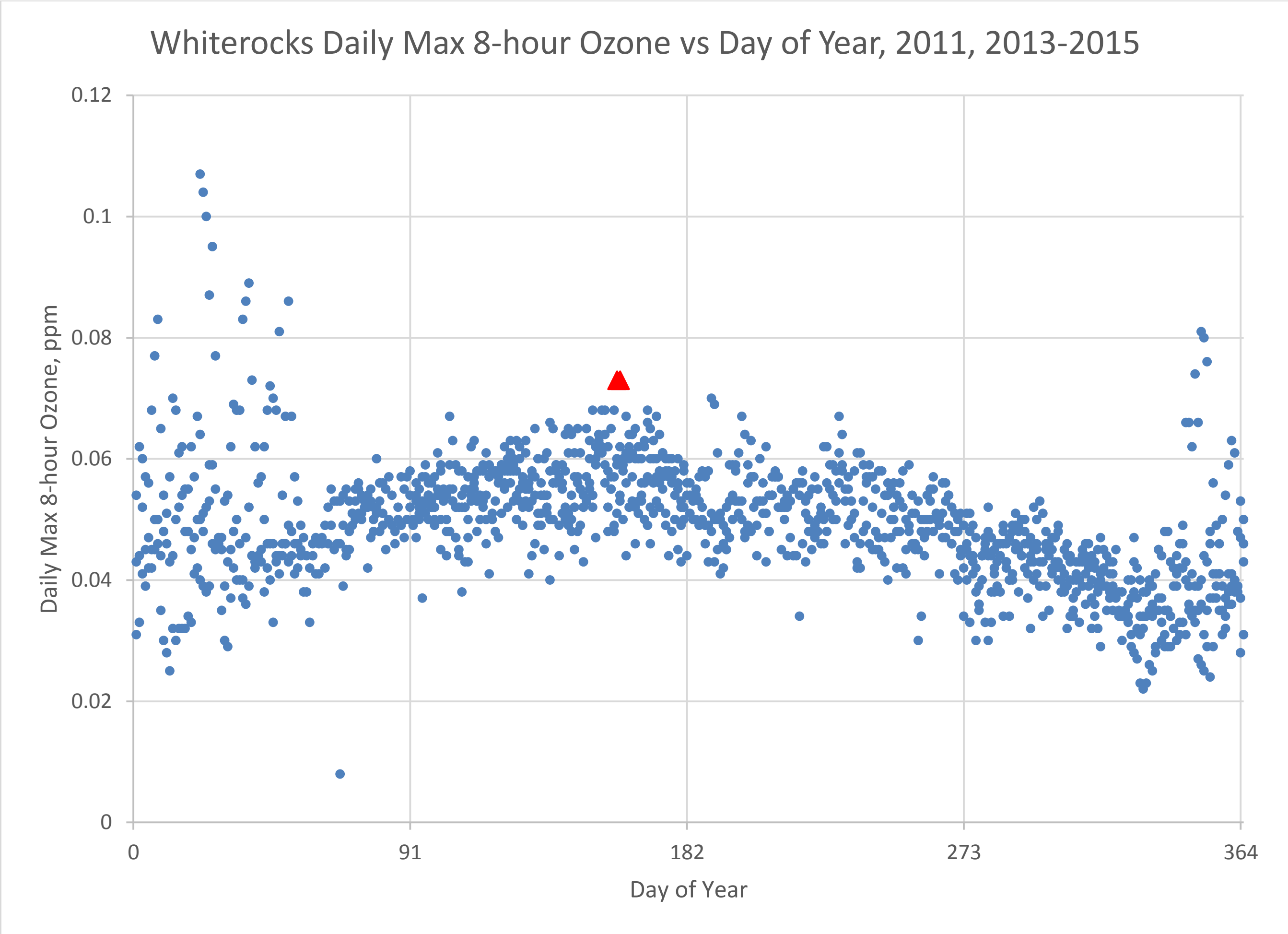

Figure 5 Whiterocks Daily Maximum 8-hour Ozone vs. Day of Year, 2011 and 2013-2015; June 8-9, 2015 in Red

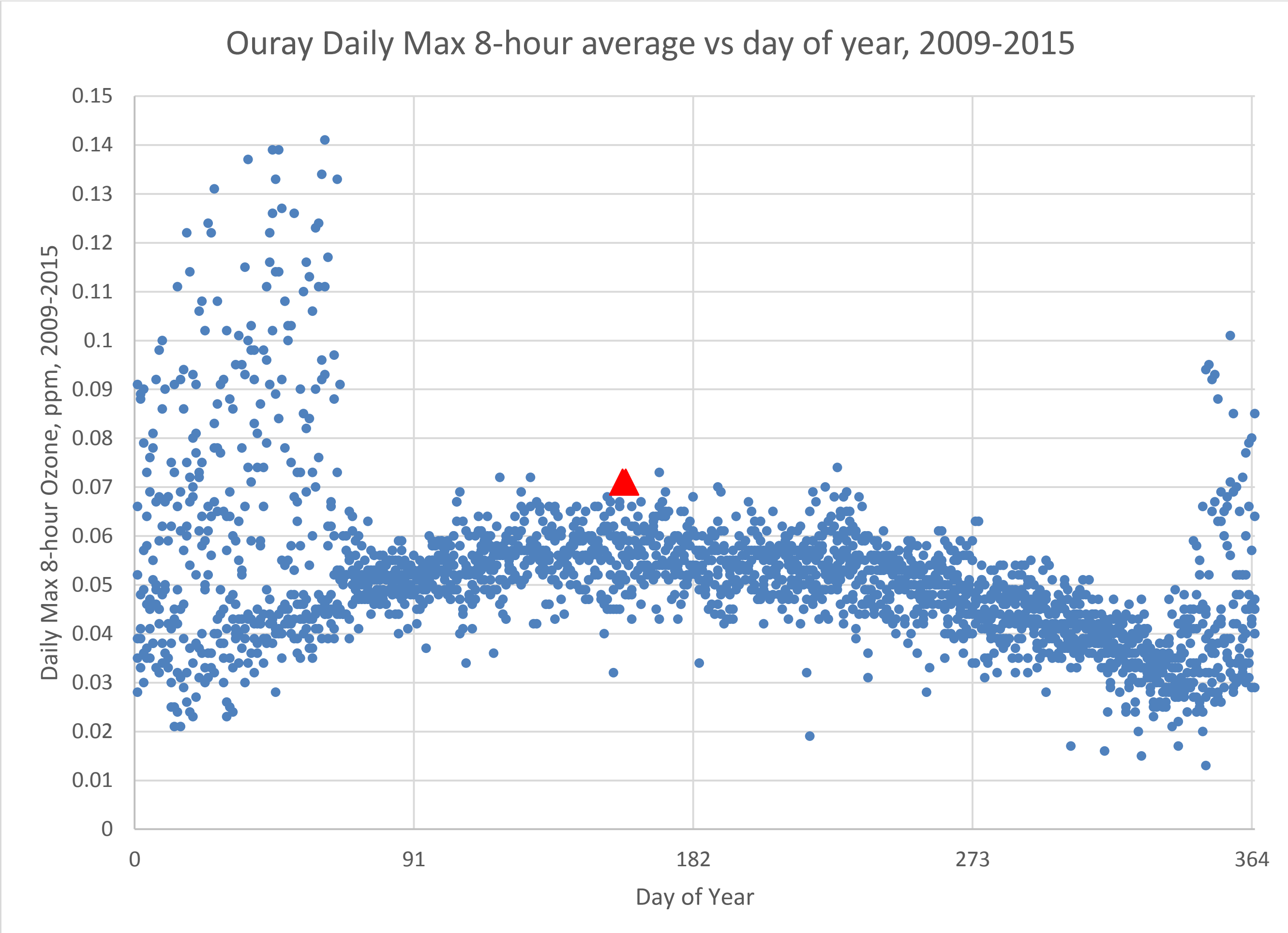

Figure 6 Ouray Daily Maximum 8-hour Ozone vs. Day of Year, 2009-2015; June 8-9, 2015 in Red

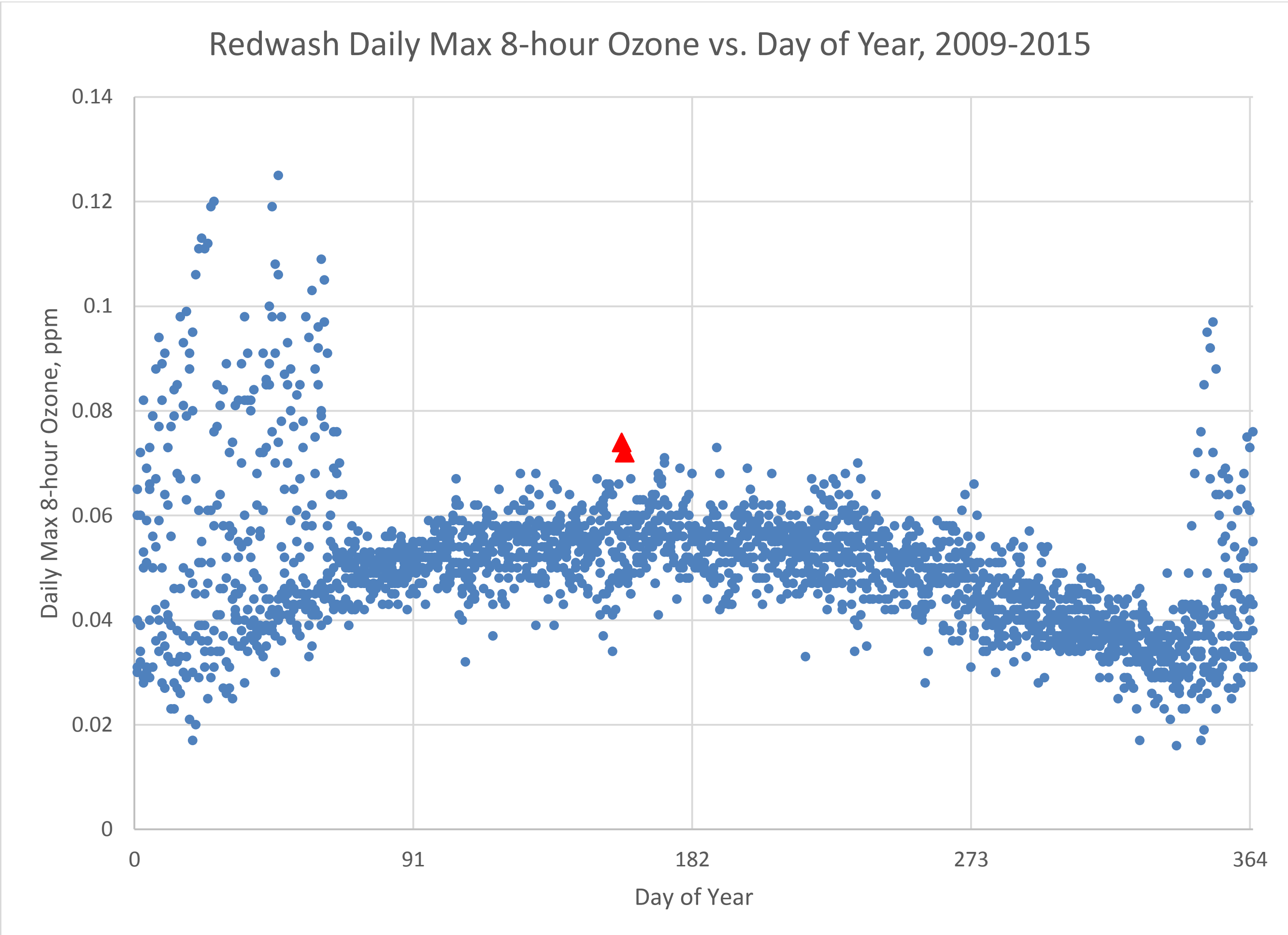

Figure 7 Redwash Daily Maximum 8-hour Ozone vs. Day of Year, 2009-2015; June 8-9, 2015 in Red

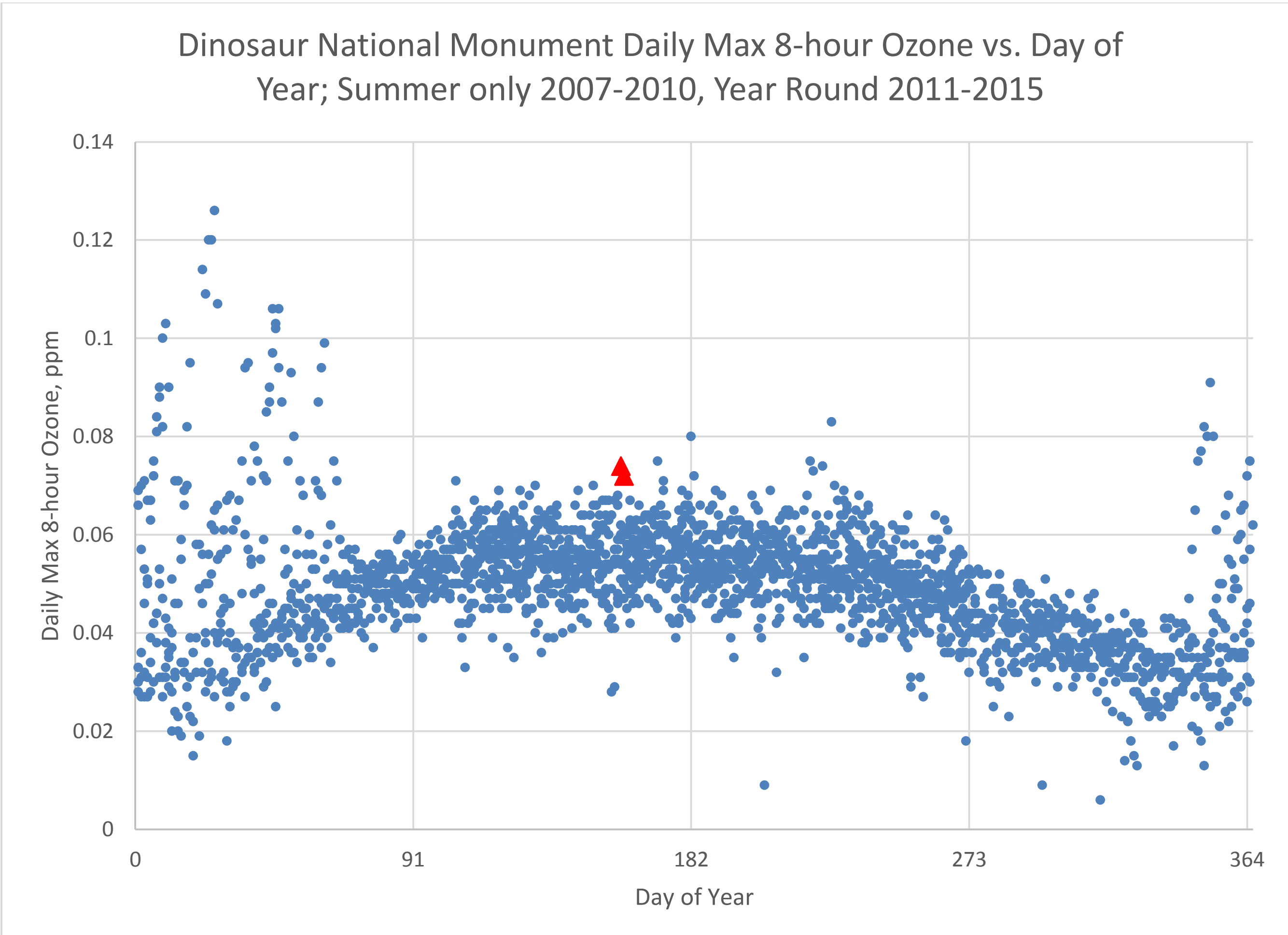

Figure 8 Dinosaur National Monument Daily Maximum 8-hour Ozone vs. Day of Year, 2007-2015; June 8-9, 2015 in Red

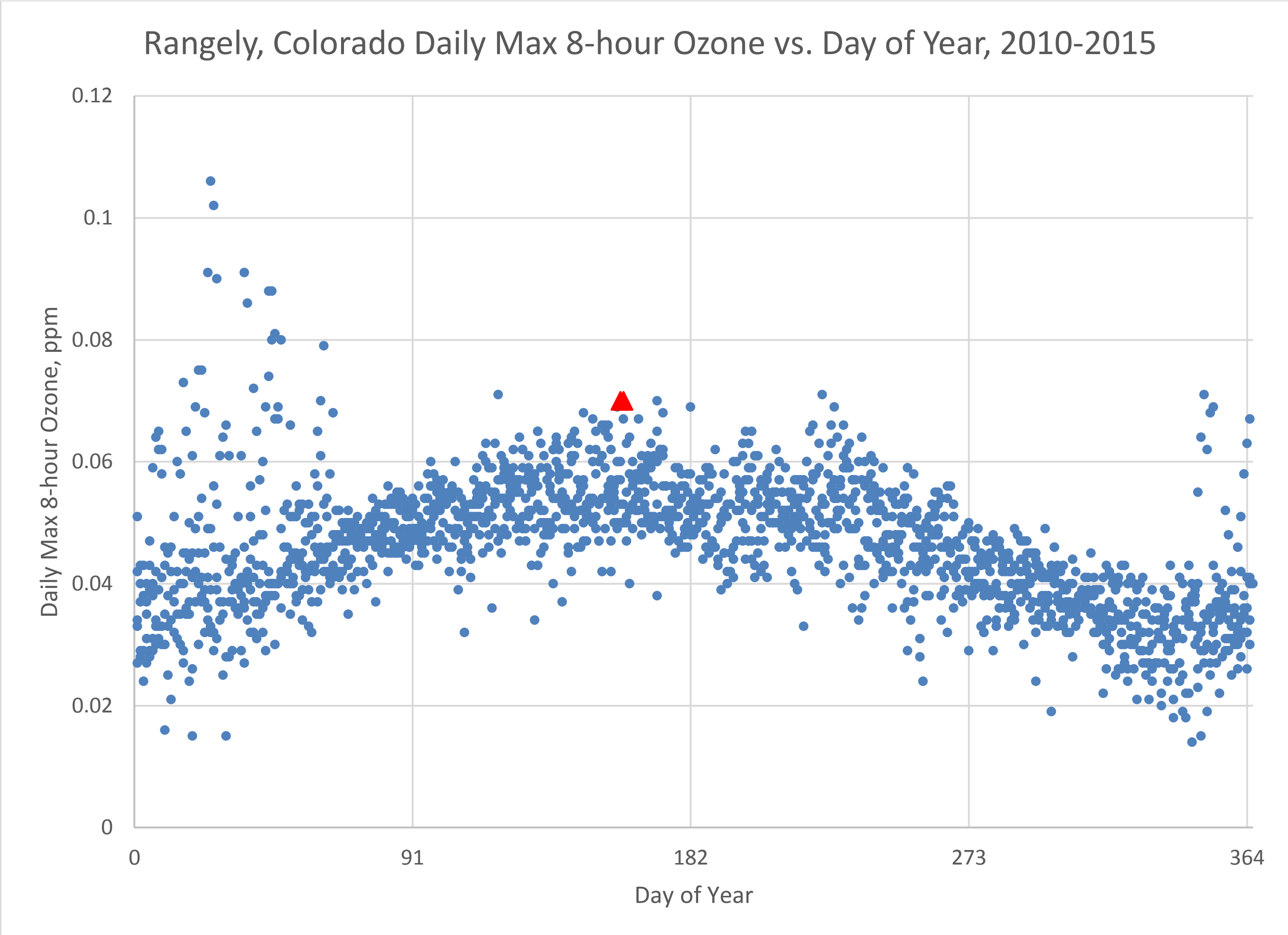

Figure 9 Rangely, Colorado Daily Maximum 8-hour Ozone vs. Day of Year, 2010-2015 in Red

In addition to comparisons of daily maximum 8-hour ozone by day of year, the diurnal profile of June 8 and 9, 2015 were compared to the profiles for all historical June days. Figure 10, showing the diurnal profiles at Fruitland show above average ozone data on June 8, 2015 with a shape very similar to the mean diurnal profile, but with a very unusual ozone profile at Fruitland on June 9, 2015. Ozone rose from 64 ppb at 9:00 am to 88 ppb at 10:00 am, 16 ppb higher than the highest 10:00 am reading on all other June days. This concentration of ozone at 10:00 am would not be expected in most areas of the U. S. (urban or rural), and is very suggestive of an unusual source for the ozone other than local photochemical production. Winds at Fruitland during this unusual morning ozone are summarized in Table 3; they were generally very light and from the northeast to southeast.

Table 3 Fruitland Winds, Morning of June 9, 2015 (from http://mesowest.utah.edu/)

Hour (MST)	Wind Speed (mph)	Wind Direction (degrees from North)	Hour (MST)	Wind Speed (mph)	Wind Direction (degrees from North)
8:00	2.6	119	9:30	2.2	115
8:15	3.3	164	9:45	1.8	117
8:30	3.4	168	10:00	1.9	105
8:45	2.2	121	10:15	2.8	118
9:00	1.9	87	10:30	3.6	104
9:15	2.3	92	10:45	5.7	62

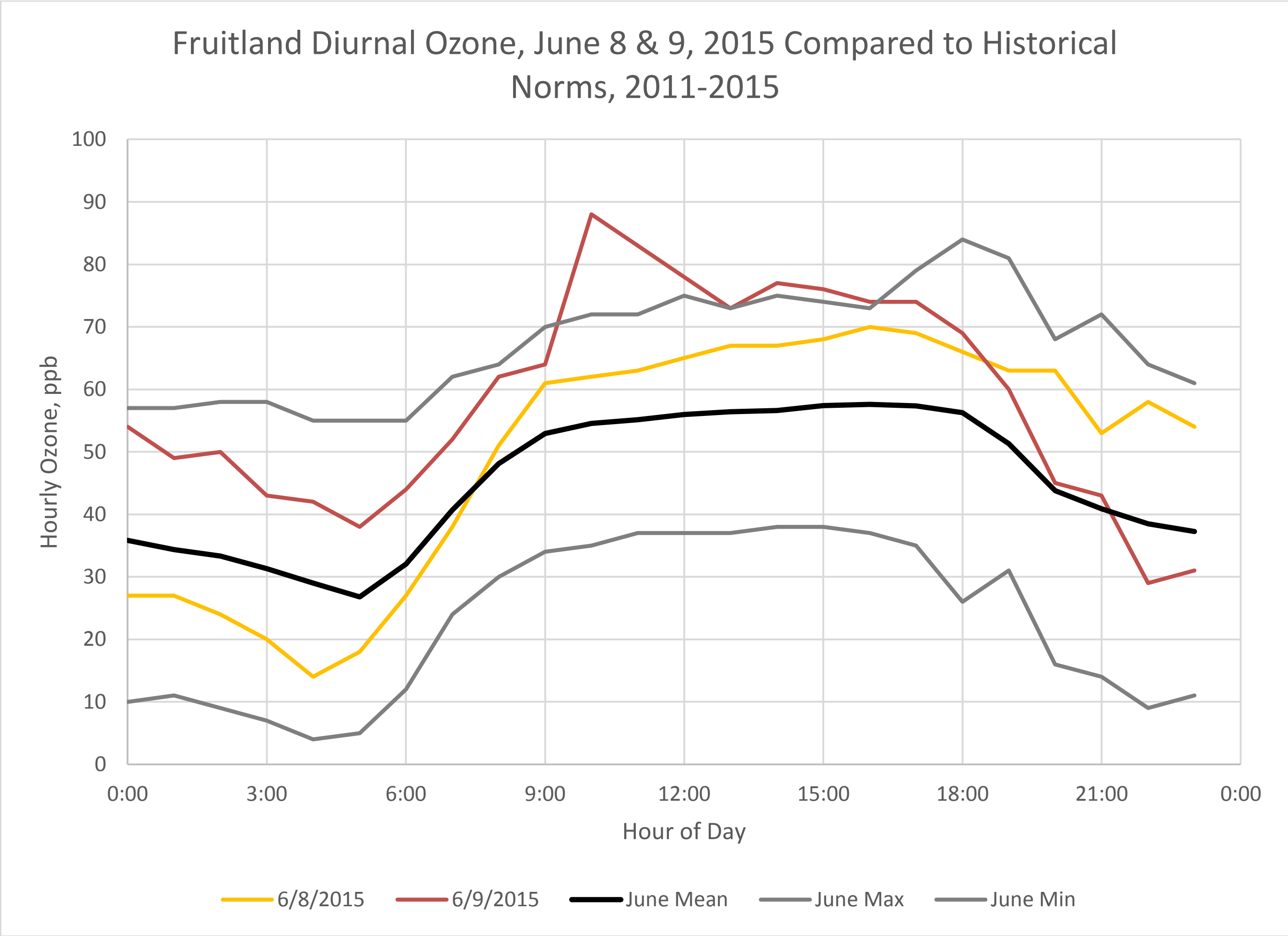

Figure 10 Fruitland Diurnal Ozone Compared to Historical Norms, 2011-2015

The diurnal profiles for the other Uinta Basin monitors do not show unusual shapes compare to June diurnal norms, but in several cases show hourly ozone concentration for some morning hours higher than seen on any other June days (true for Myton, Figure 11; Whiterocks, Figure 12; Ouray, Figure 13; and Redwash, Figure 14). The diurnal profiles for Dinosaur National Monument (Figure 15) and Rangely, Colorado (Figure 16) showed highest ever April-June ozone only for a single hour of the afternoon of June 8, consistent with the ranking of June 8 and 9, 2015 8-hour ozone as 3^{rd} and 4^{th} highest amongst all April-June data at Dinosaur National Monument, and 2^{nd} and 3^{rd} highest at Rangely, Colorado.

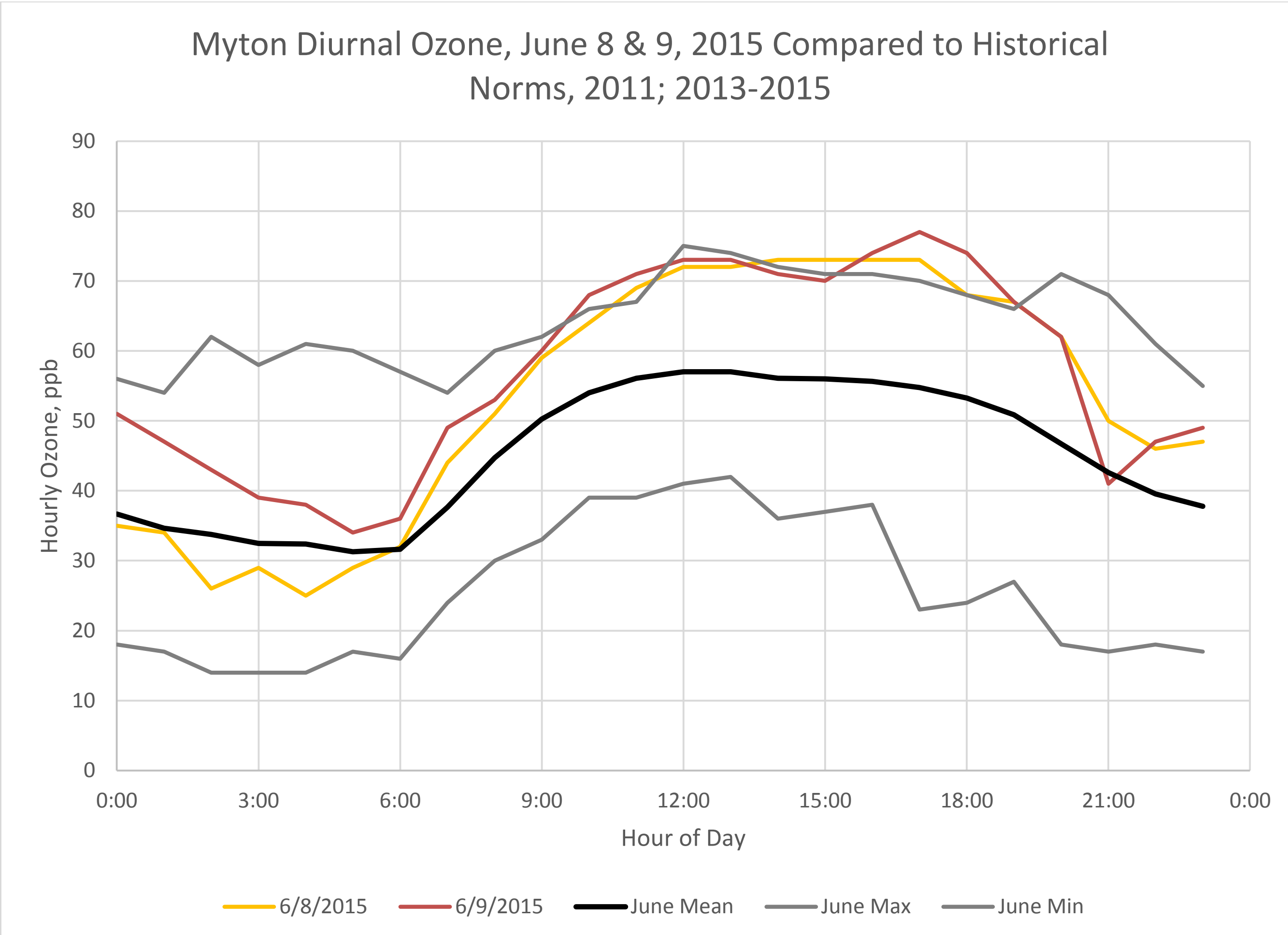

Figure 11 Myton Diurnal Ozone Compared to Historical Norms, 2011; 2013-2015

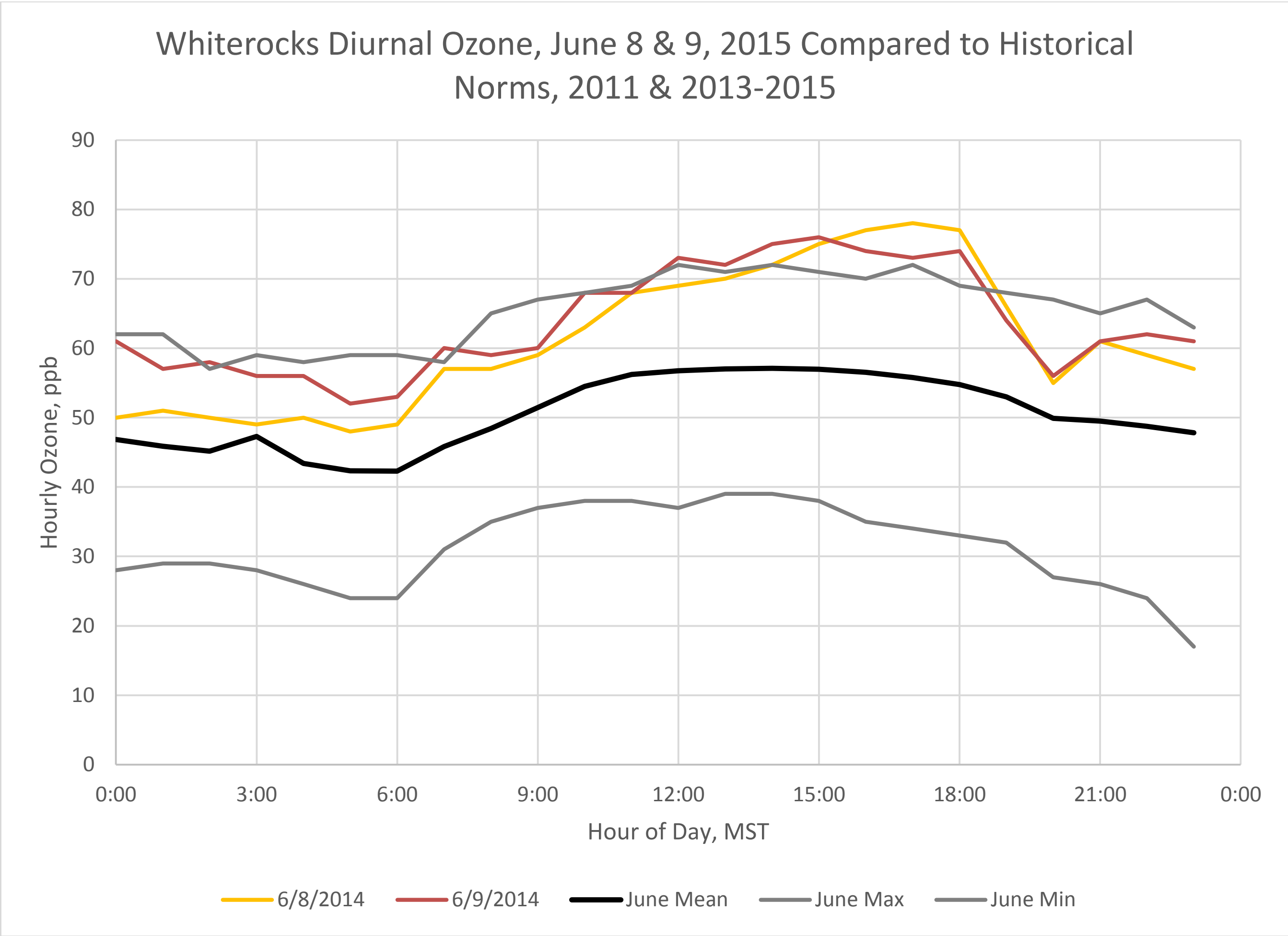

Figure 12 Whiterocks Diurnal Ozone Compared to Historical Norms, 2011; 2013-2015

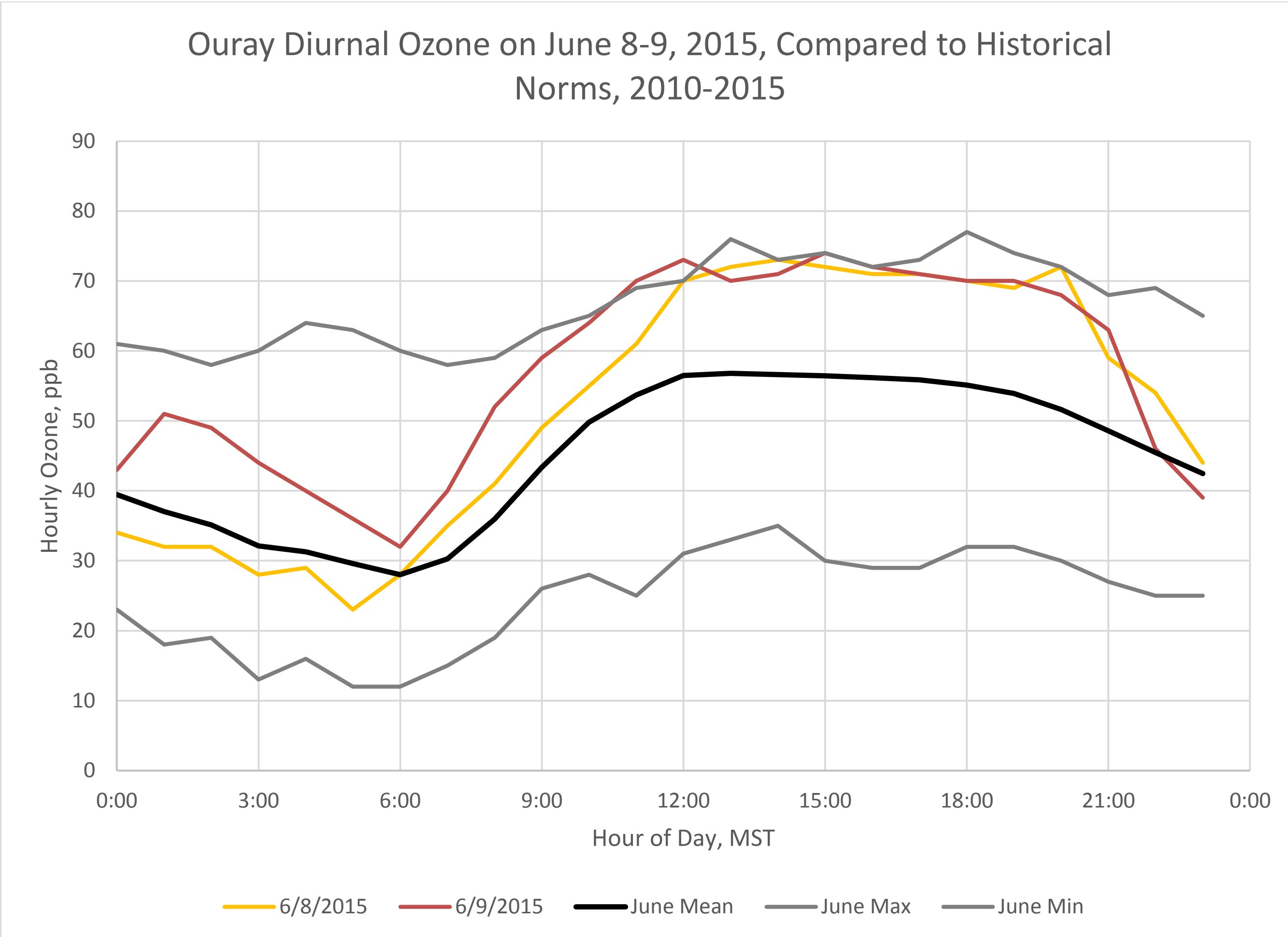

Figure 13 Ouray Diurnal Ozone Compared to Historical Norms, 2010-2015

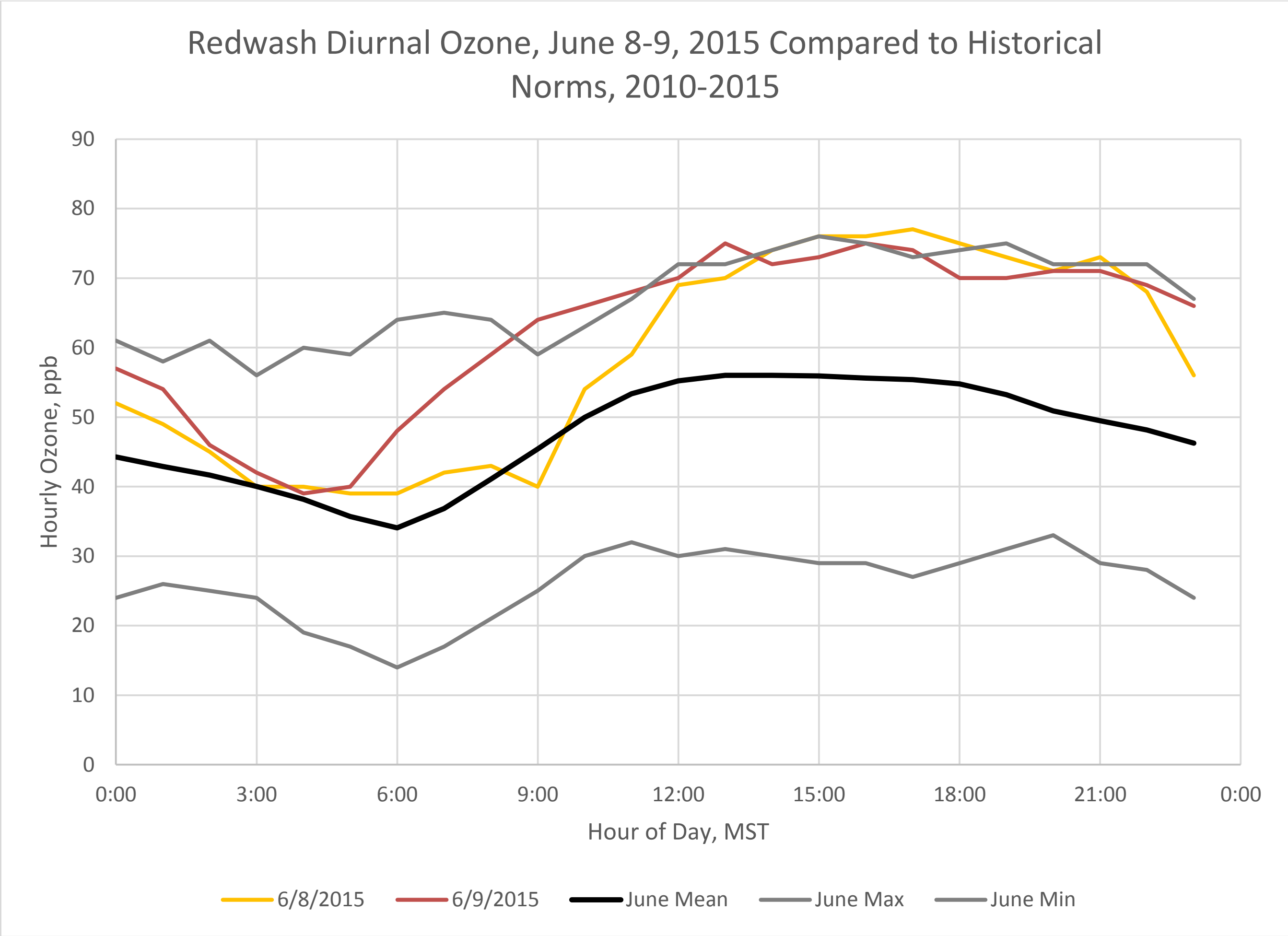

Figure 14 Redwash Diurnal Ozone Compared to Historical Norms, 2010-2015

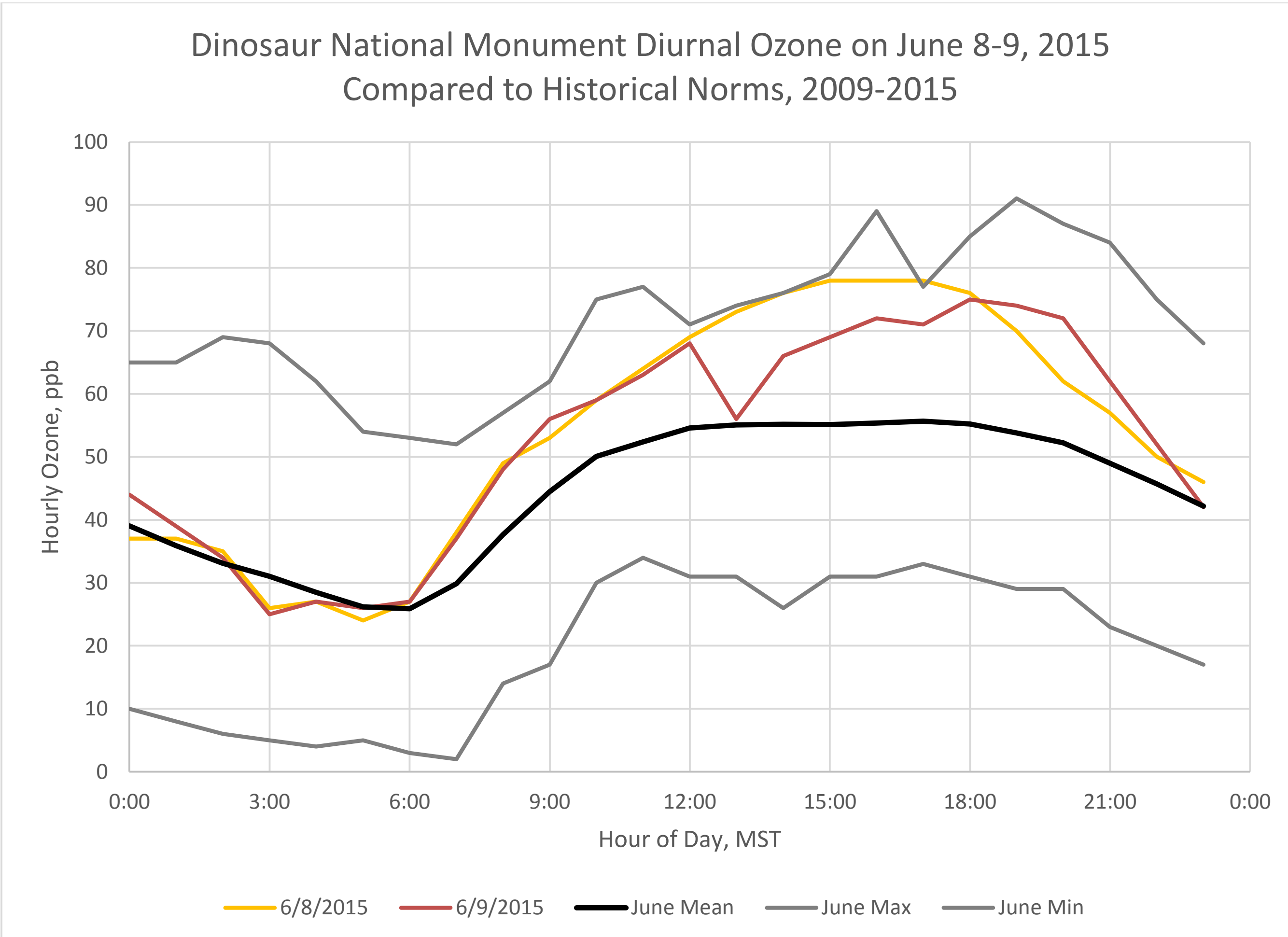

Figure 15 Dinosaur National Monument Diurnal Ozone Compared to Historical Norms, 2009-2015

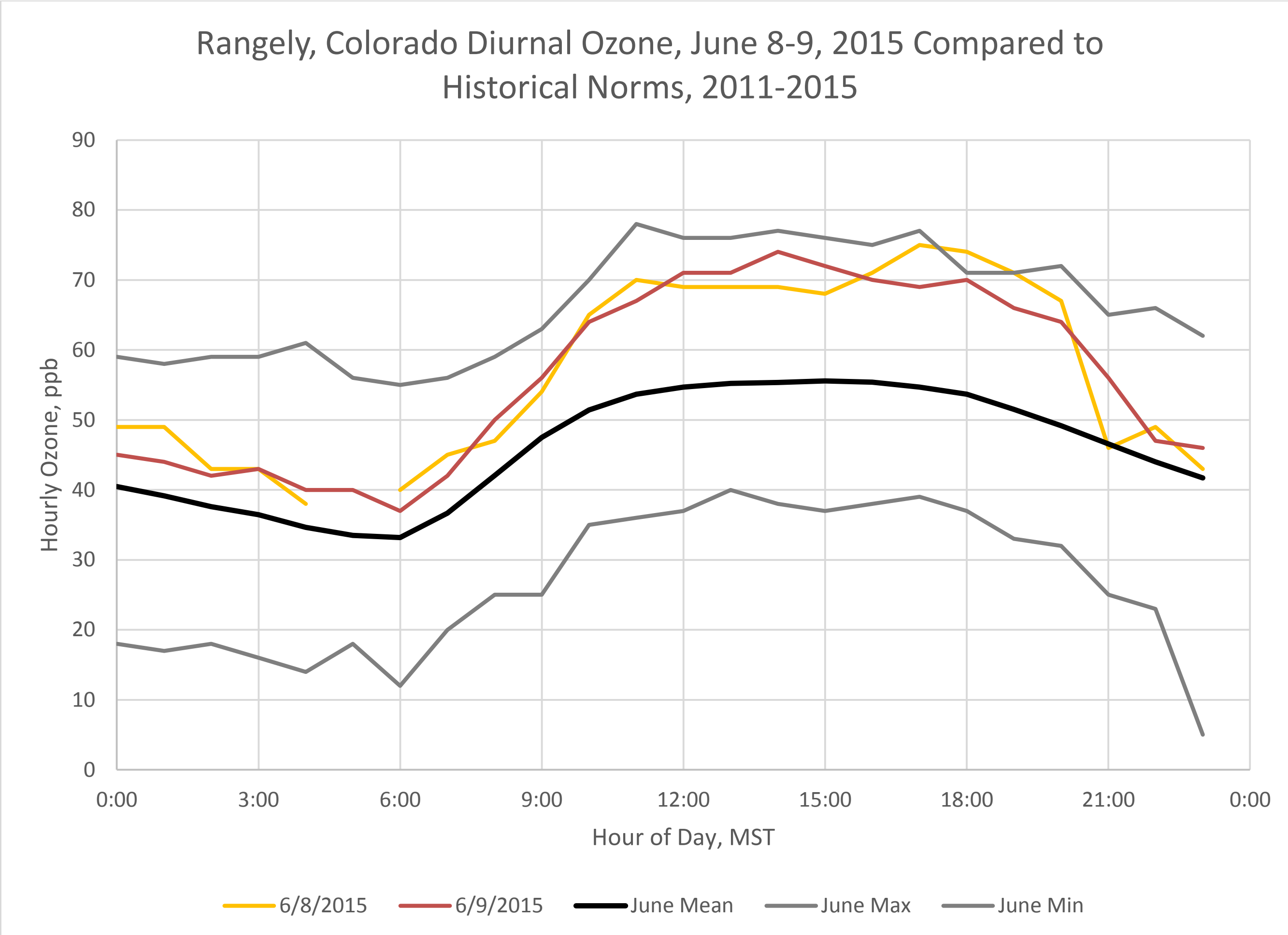

Figure 16 Rangely, Colorado Diurnal Ozone Compared to Historical Norms, 2011-2015

B. METEOROLOGY

On June 3 and 4, 2015 a strong upper level trough formed over the Pacific Coast, as shown in Figure 17. A surface low over southern Nevada and the Mojave Desert of California coincided with the upper level low. Between June 3 and June 9, the north end of the trough moved east across the U.S. – Canada border, while the low pressure at the southern end of the trough remained roughly stationary over southern California and Nevada. By June 7 and 8, the system consisted of an upper level trough over the upper midwest U. S. with an associated elongated trough extending from the upper midwest south west to California, as shown in Figure 18. Surface level winds and pressure reflected the upper level trough in the midwest U. S., but surface conditions west of the Rocky Mountains did not reflect the elongated trough found at high elevation.

Surface winds on June 8 and 9, 2015 were generally light and variable, with high temperatures over the eastern Great Basin and Uinta basin generally in the mid-80s, as shown in Figure 19. Time series of surface winds are shown in Figure 20 for a citizen site in Strawberry, Utah (8 miles east of the Fruitland monitor), the Fruitland monitor (note data missing from 9:00 pm to midnight both days), and the Ouray monitor, 50 miles east of Fruitland.

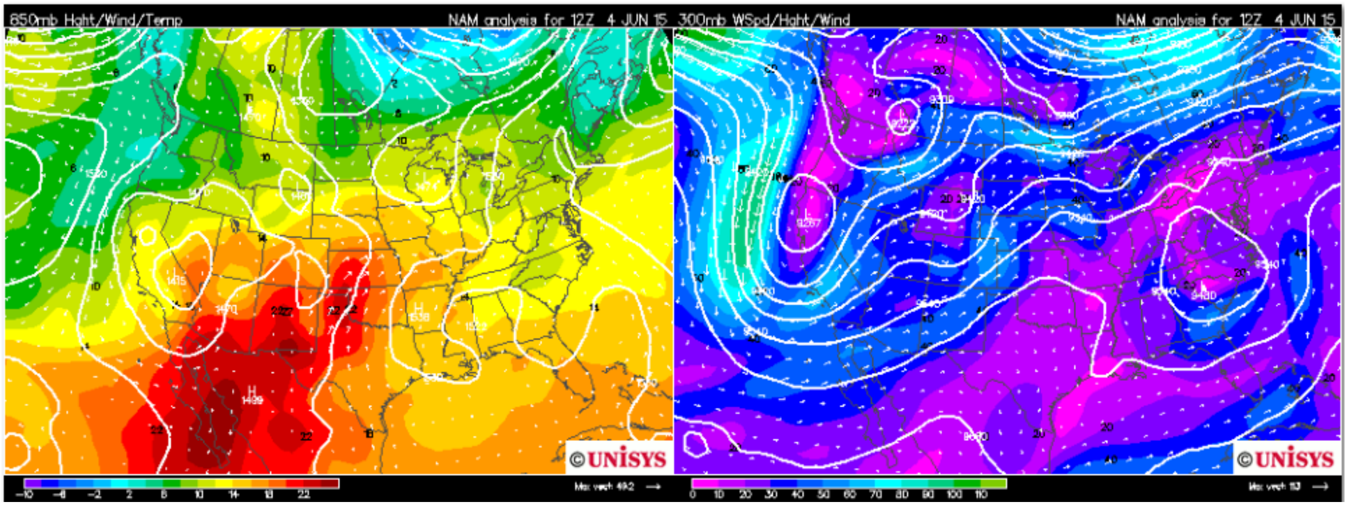

Figure 17 850 mb Height, Winds and Temperature (left) and 300 mb Height, Wind Speed and Wind Direction (right), June 4, 2015, 5:00 am MST

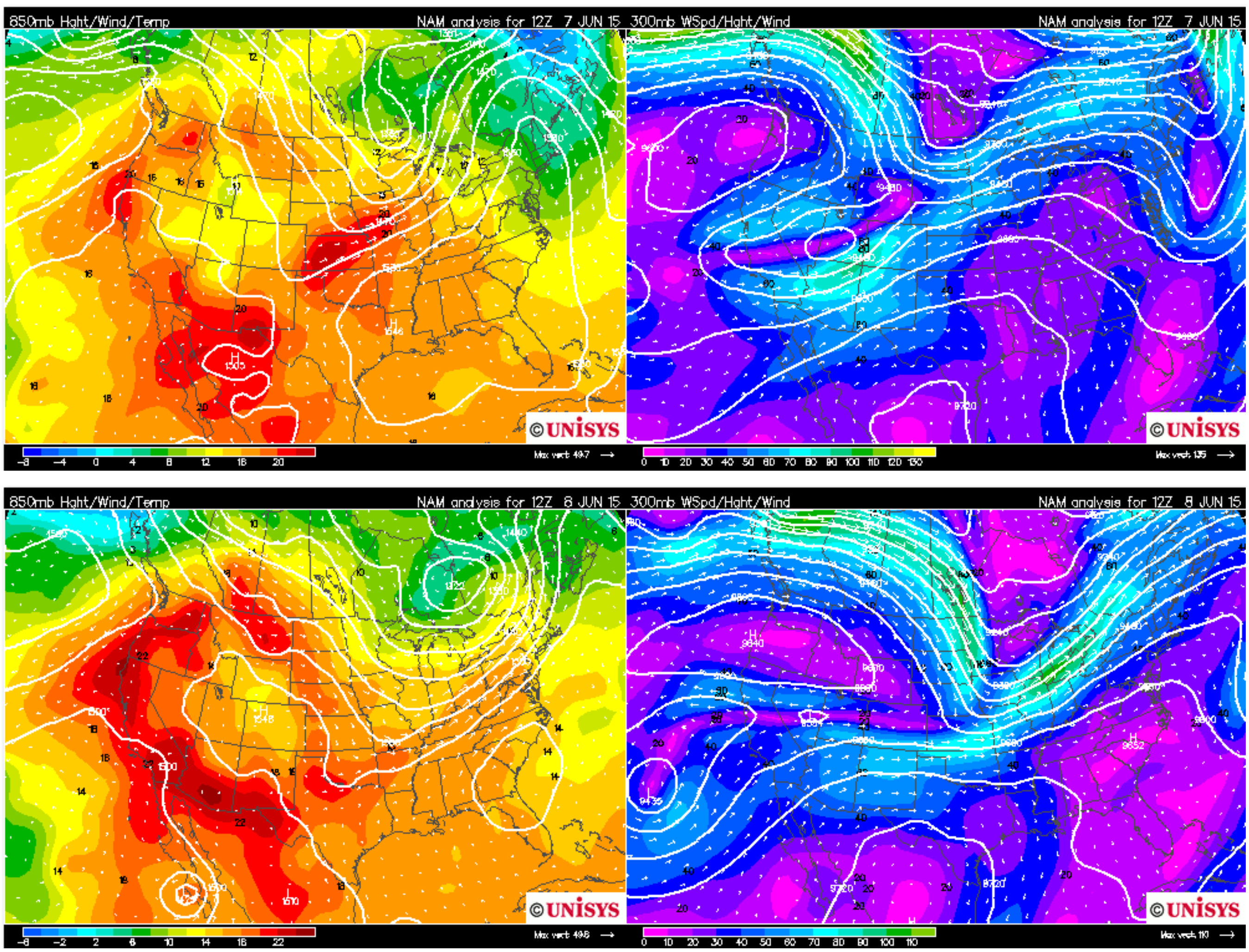

Figure 18 850 mb Height, Winds and Temperature (left) and 300 mb Height, Wind Speed and Wind Direction (right), June 7, 2015, 5:00 am MST (top) and June 8, 2015, 5:00 am MST (bottom)

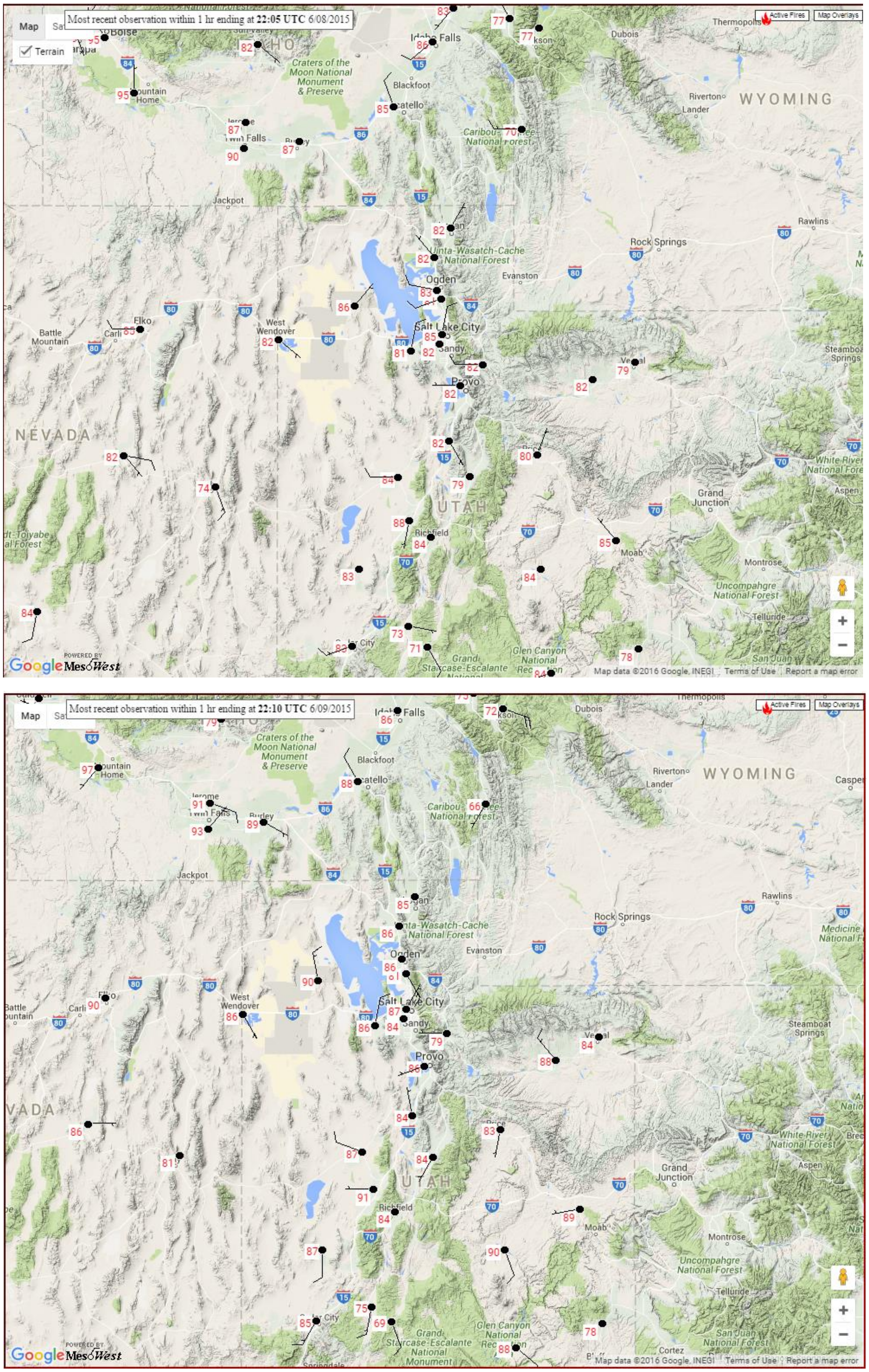

Figure 19 Surface Winds and Temperatures, 2:00 pm MST, June 8, 2015 (top), June 9, 2015 (bottom) (from http://mesowest.utah.edu/)

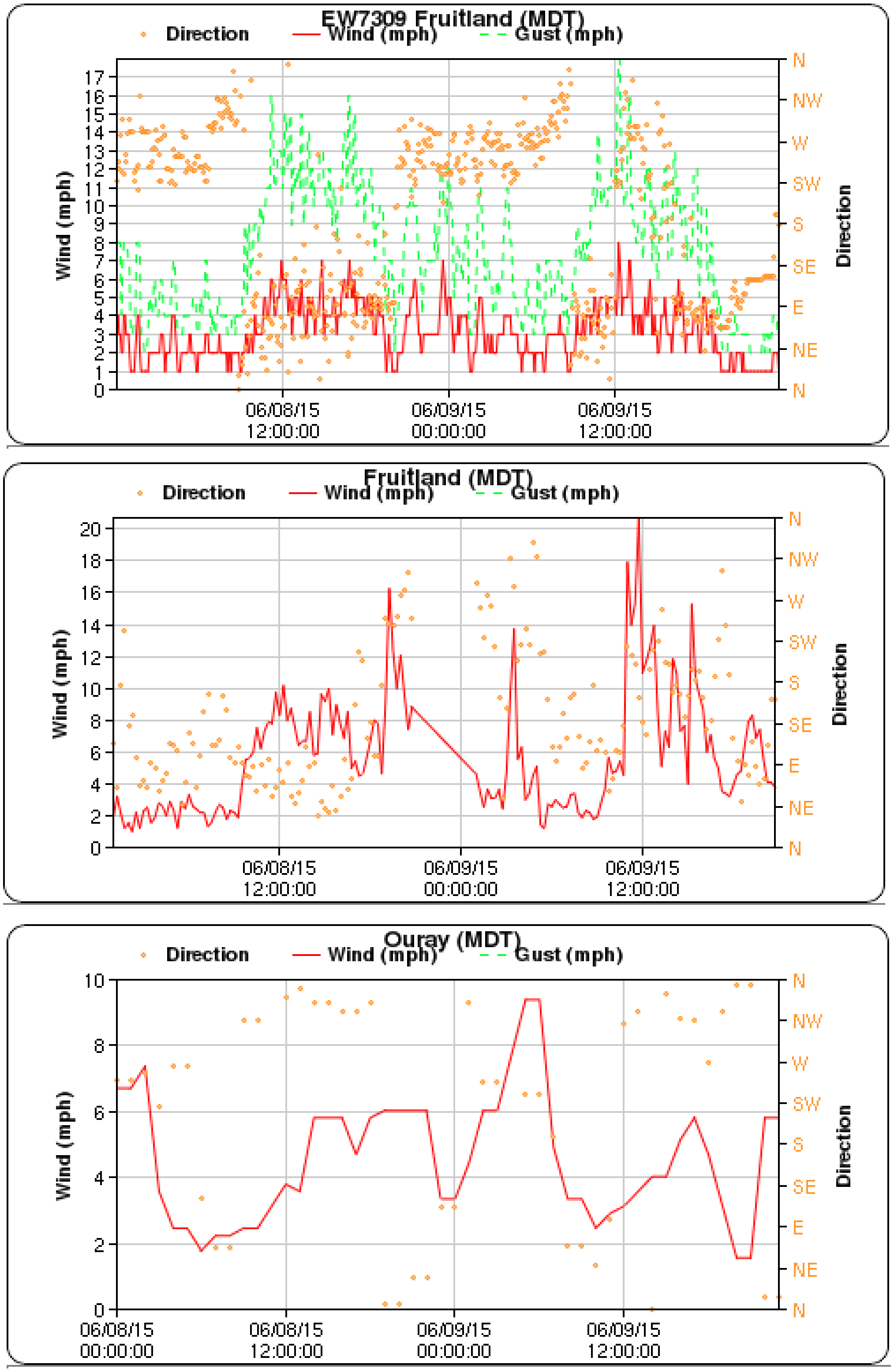

Figure 20 Surface Winds, June 8-9, 2015; Strawberry, UT (top); Fruitland Monitor (middle); Ouray Monitor (bottom) (from http://mesowest.utah.edu/)

To evaluate whether the meteorology on June 8 and 9, 2015 were unusual compared to prior high ozone days, scatterplots of daily maximum 8-hour ozone vs. daily maximum temperature were constructed for days with 8-hour ozone of 55 ppb or greater (55 ppb is the lower end of the moderate AQI category). The data were segregated by season, with winter days (December-March 15) in blue, spring days (March 15 to June 15) in green, and summer days (June 16 through September) in gold. In addition, any days June through September where the NOAA Hazard Mapping System (HMS) showed visible smoke plumes over the Uinta Basin were also segregated, and are shown in brown. HMS smoke plume data is available through AIRNowTech Navigator (https://airnowtech.org/navigator/index.cfm) beginning July 21, 2011, so these plots represent data from July 21, 2011 through the most recent data in AQS (generally March to May, 2016). June 8 and 9, 2015 are shown as red triangles.

Figure 21 shows the scatterplot for Ouray. Winter ozone days are enclosed in the blue polygon; daily maximum 8-hour ozone in winter ranges up to 141 ppb, while maximum temperature on winter ozone days was generally below 40 °F. A few winter days in March of 2013 saw temperatures as high as 55 °F as winter snow was melting. Springtime was historically as high as 72 ppb at Ouray (April 28, 2012), with temperature on elevated springtime ozone days between 38 °F and 94 °F. Summer elevated ozone days generally had temperatures between 64 and 100 °F, with ozone up to 67 ppb in the absence of smoke plumes. Ozone concurrent with smoke plumes generally occurred with temperatures between 78 and 99 °F, with ozone as high as 74 ppb. June 8 and 9, 2015 would be classified as springtime smoke free days, and show ozone several ppb higher than historically seen in spring with the exception of April 28, 2012.

Table 4 summarizes the ozone and temperature extremes of the seasonal categories for the Uinta Basin monitors shown in Figures 21-26. All the scatterplots show June 8 and 9, 2015 as outliers when compared to historical data.

Table 4 Temperature and Ozone Observation Ranges by Season and Smoke Presence

Monitor	Winter O_3 Temp. Range	Winter Peak O_3 (ppb)	Spring O_3 Temp. Range	Spring Peak O_3 (ppb)	Summer O_3 Temp. Range	Summer Peak O_3 (ppb)	Smoke Plume O_3 Temp. Range	Smoke Plume Peak O_3 (ppb)
Ouray	-2 to 55	141	38 to 94	72	64 to 100	67	78 to 99	74
Redwash	0 to 42	120	39 to 91	67	67 to 98	69	78 to 97	73
Myton	6 to 47	117	43 to 90	67	74 to 99	66	82 to 96	71
Whiterocks	12 to 43	107	45 to 85	71	63 to 93	68	78 to 91	70
Dinosaur NM	0 to 47	126	47 to 96	71	69 to 100	69	76 to 99	83
Rangely, Colorado	15 to 47	106	47 to 89	71	68 to 96	65	83 to 96	71

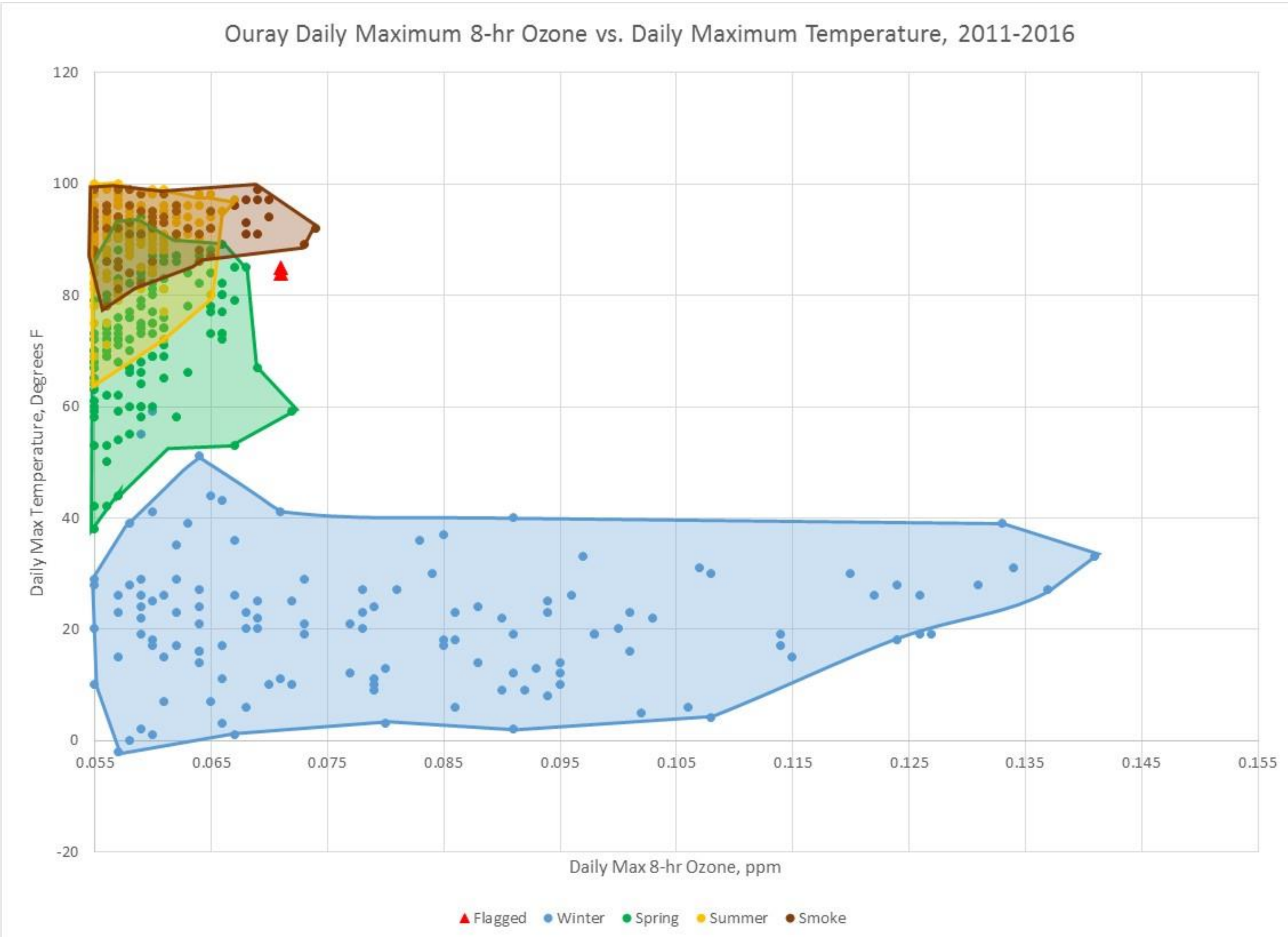

Figure 21 Ouray Daily Max 8-hr Ozone and Temperature, Days Over 55 ppb, July 2011-2016

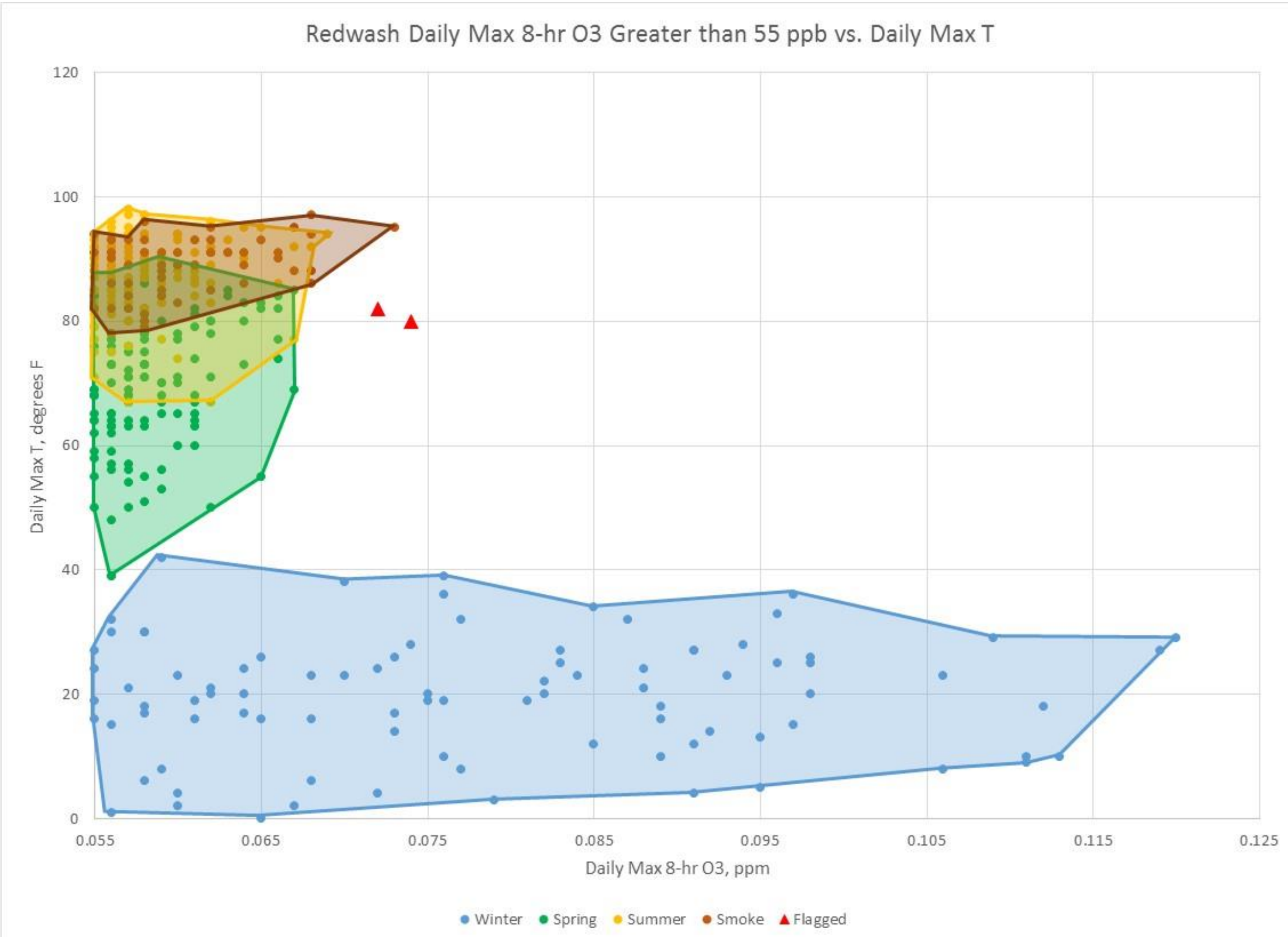

Figure 22 Redwash Daily Max 8-hr Ozone and Temperature, Days Over 55 ppb, July 2011-2016

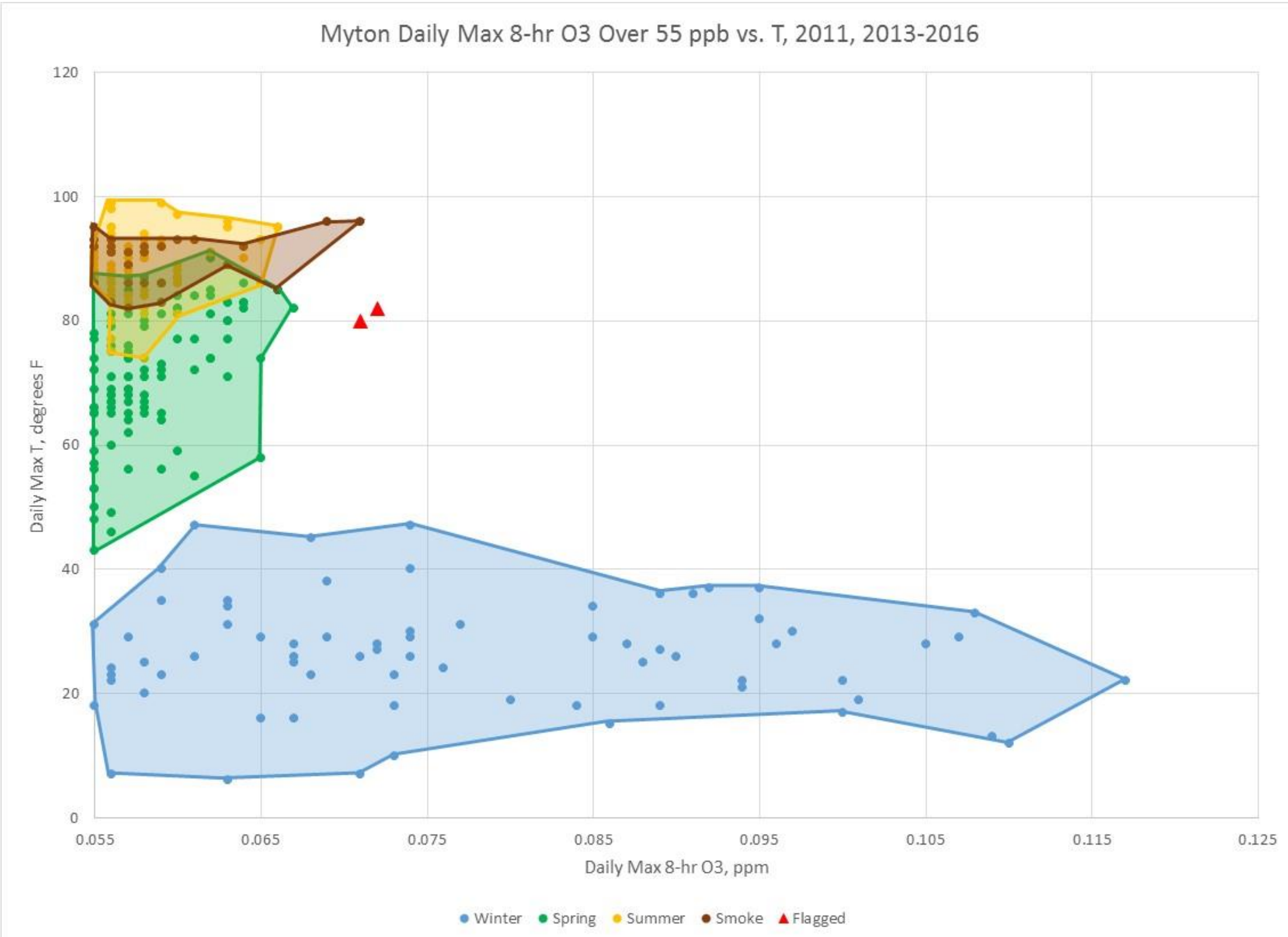

Figure 23 Myton Daily Max 8-hr Ozone and Temperature, Days Over 55 ppb, July 2011, 2013-2016

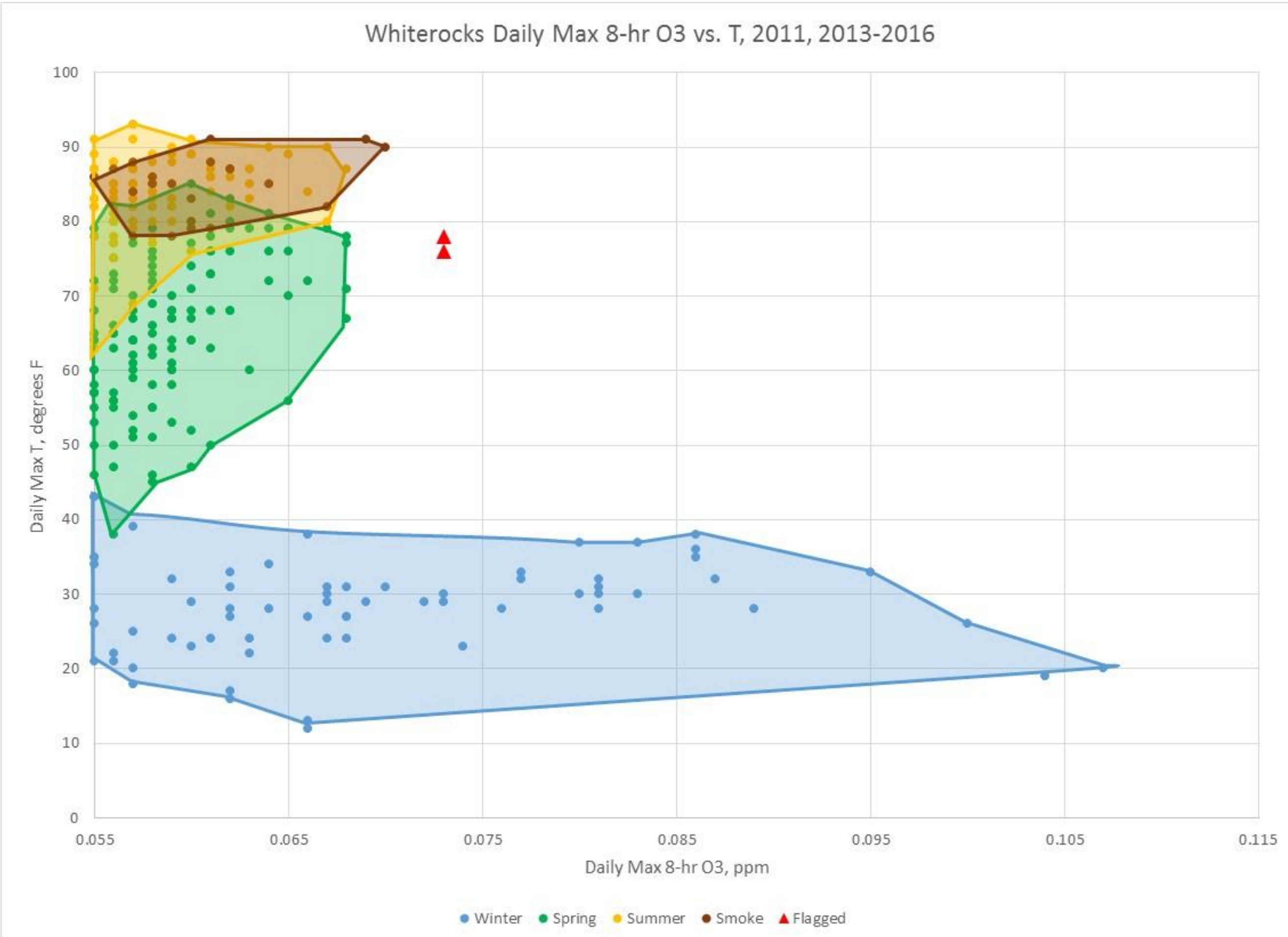

Figure 24 Whiterocks Daily Max 8-hr Ozone and Temperature, Days Over 55 ppb, July 2011, 2013-2016

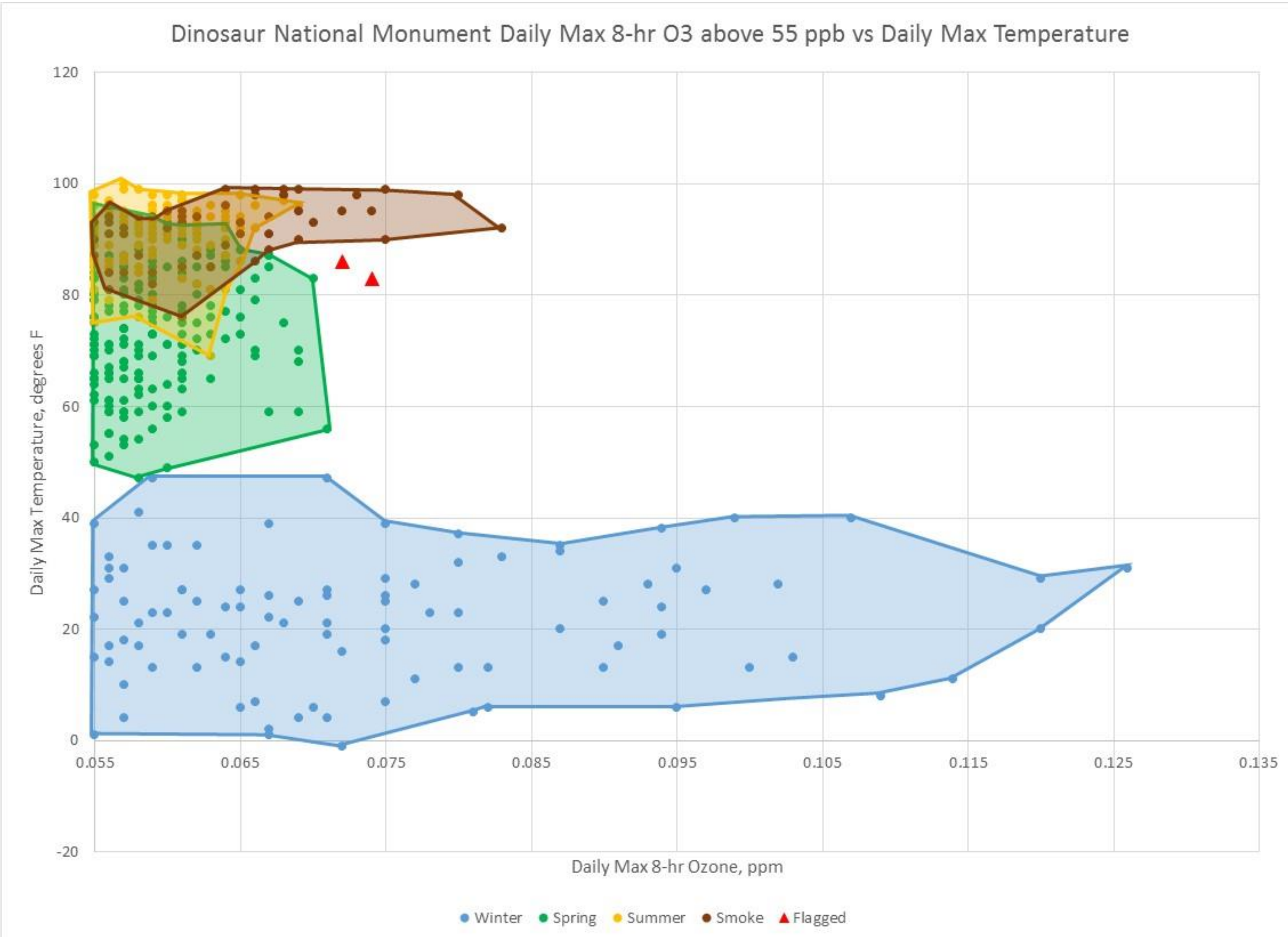

Figure 25 Dinosaur National Monument Daily Max 8-hr Ozone and Temperature, Days Over 55 ppb, July 2011-2016

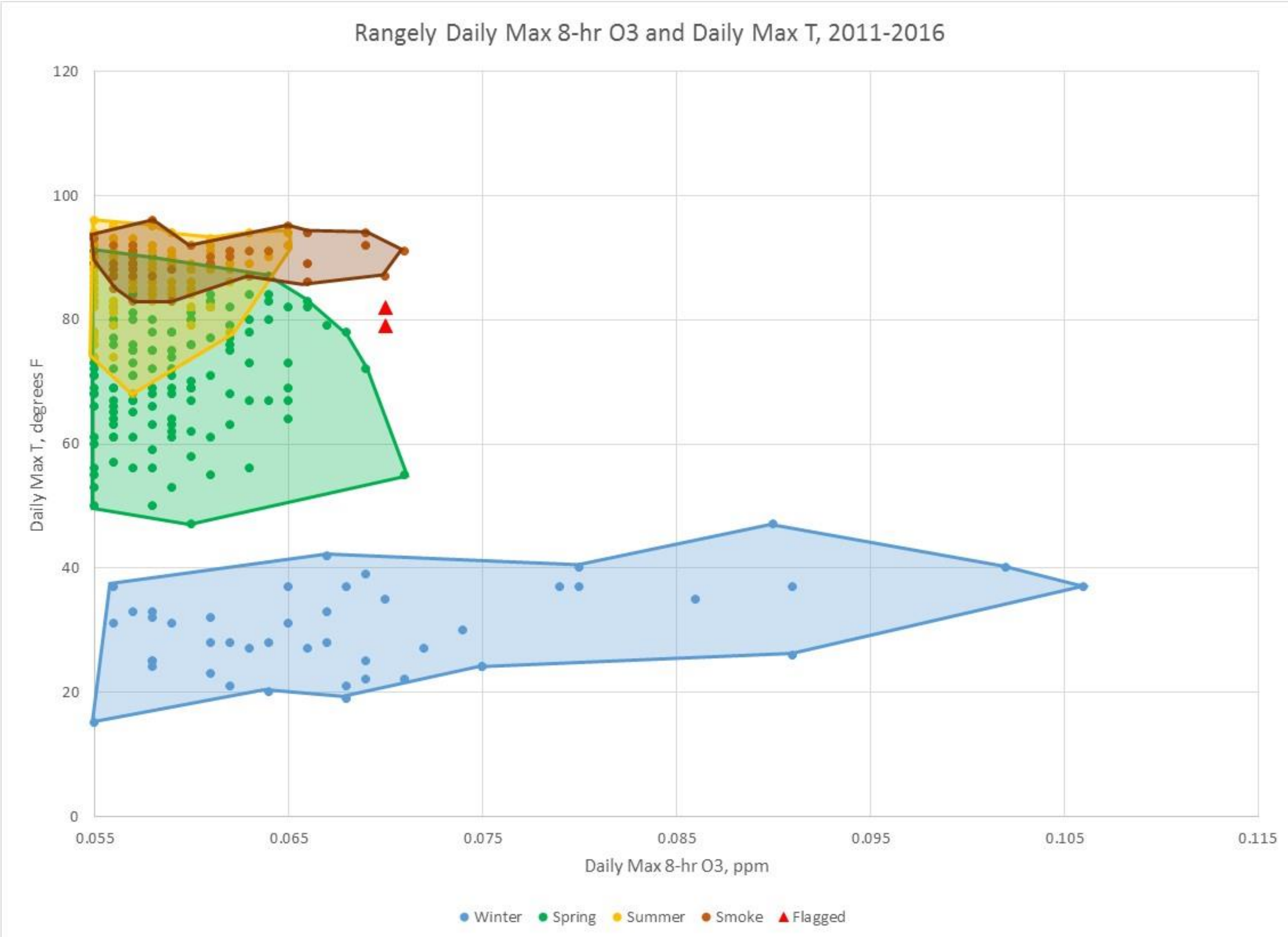

Figure 26 Rangely, Colorado Daily Max 8-hr Ozone and Temperature, Days Over 55 ppb, July 2011-2016

C. EVIDENCE OF STRATOSPHERIC INTRUSION

NOAA Geostationary Operational Environmental Satellite (GOES) ozone sounder images from June 4, 2015 show enhanced total column ozone along the western edge of the upper level trough forming along the U. S. Pacific coast (seen in Figure 17), as shown in Figure 27. Enhance total column ozone is observed in regions of folds in the tropopause, which brings stratospheric air (and stratospheric ozone) down into the upper troposphere.

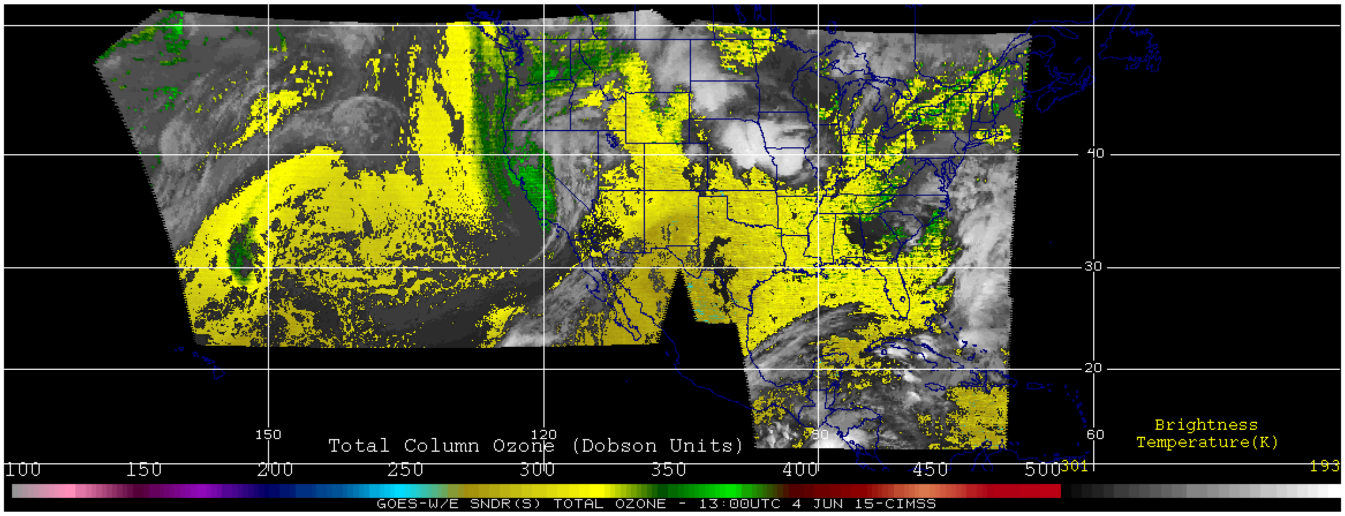

Figure 27 GOES Total Column Ozone, 6:00 am MST

A similar sounding on June 7 at 5:00 am MST shows an area of enhance total column ozone coinciding with the elongated trough extending from western South Dakota to California, south of San Francisco, as shown in Figure 28.

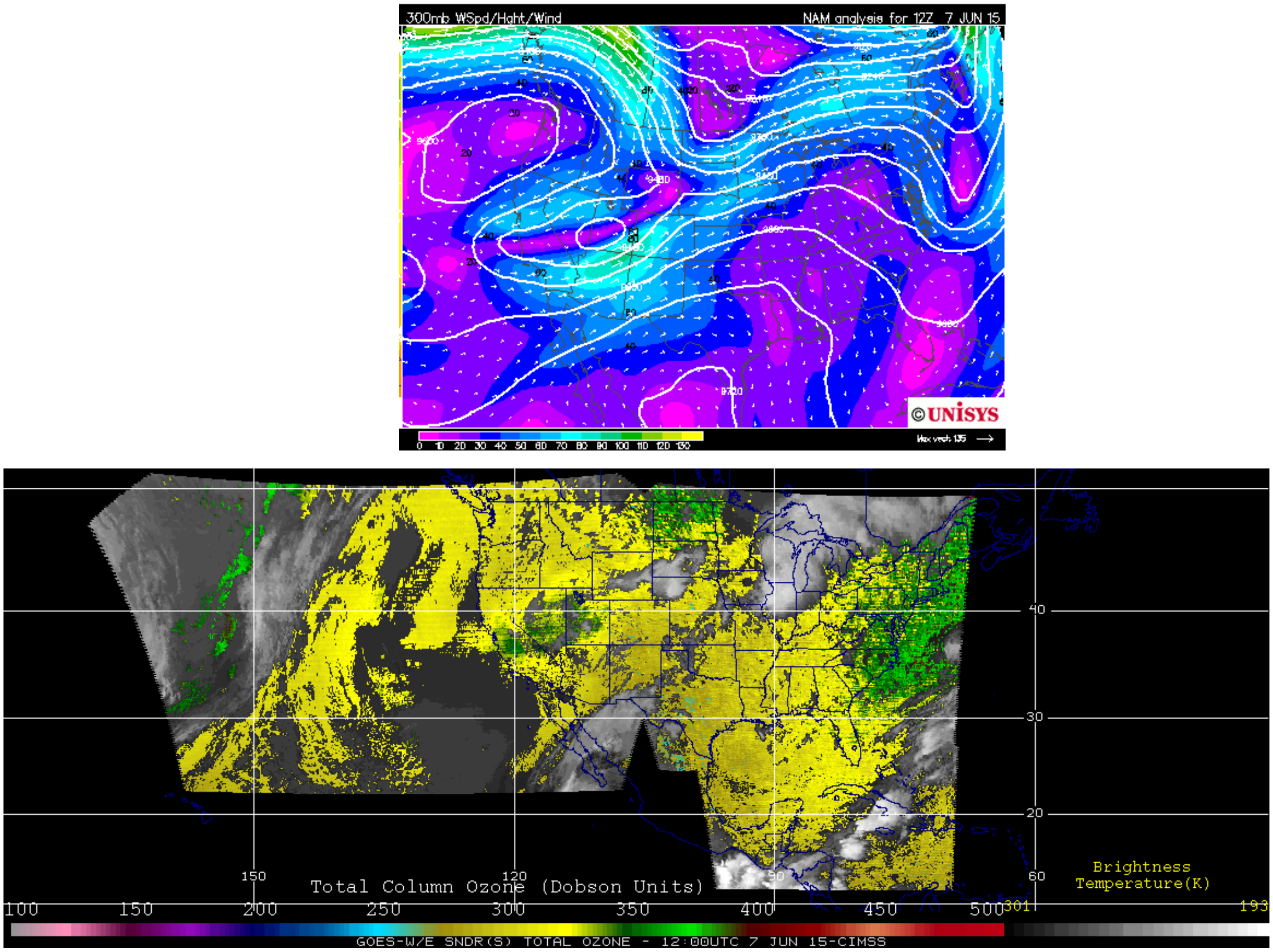

Figure 28 300 mb Height, Wind Speed and Wind Direction (top), and GOES Total Column Ozone, June 7, 2015, 5:00 am MST

The area of enhanced total column ozone has strengthened and moved into Utah in the sounding of 5:00 pm MST on June 7, still coinciding with the elongated trough, as shown in Figure 29.

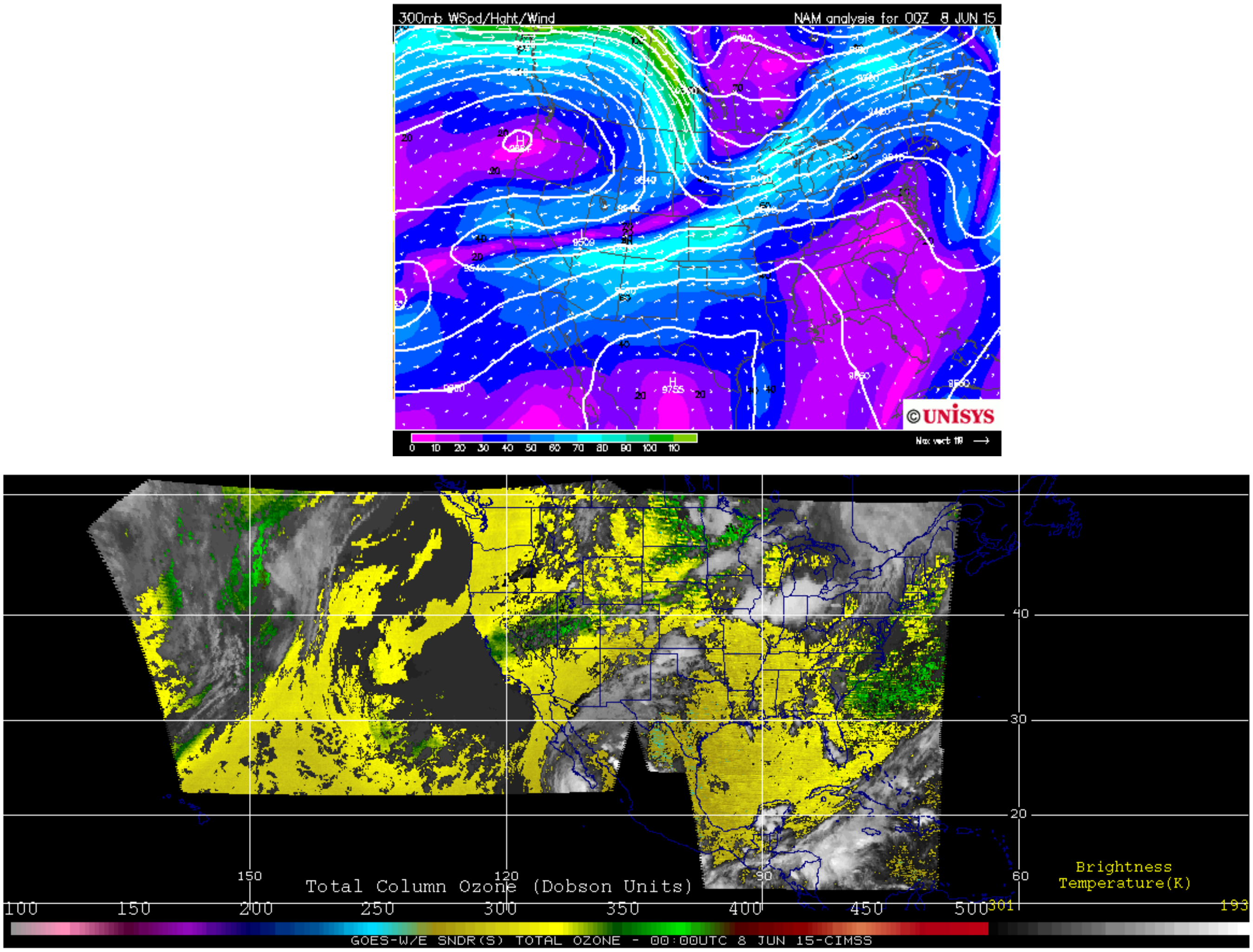

Figure 29 300 mb Height, Wind Speed and Wind Direction (top), and GOES Total Column Ozone, June 7, 2015, 5:00 apm MST

Dr. Huy Tran of the Utah State University Bingham Research Center has plotted NOAA/NWS North American Mesoscale Forecast System (NAM) isentropic potential vorticity (IPV) over the Uinta Basin for the period from May 20 through June 15.[2] IPV was described in an exceptional event demonstration prepared by the Wyoming Department of Environmental Quality as "a proxy for atmospheric spin and is a conservative property with values of up to two orders of magnitude [100 times] greater for stratospheric air than that of tropospheric air".[3] The IPV plot shown in Figure 30 shows the tropopause generally between 10,000 and 15,000 meters (32,808 to 49,213 feet) in the period from May 20 through June 14. Significant excursions of the tropopause below 10,000 meters occur between May 22 through

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[2] Investigation of Possible Ozone Exceptional Events in June 2015 in the Uintah Basin, Tran, Huy, Seth Lyman, Trang Tran, Marc Mansfield, Brigham Entrepreneurship & Energy Research Center, Utah State University, April 2016.

[3] Exceptional Event Demonstration Package for the Environmental Protection Agency, Big Piney and Boulder, Wyoming Ozone Standard Exceedances June 14, 2012, Wyoming DEQ, August 2013, citing Shapiro, M. A. "Turbulent Mixing within Tropopause Folds as a Mechanism of Chemical Constituents between the Stratosphere and Troposphere." Journal of the Atmospheric Sciences (American Meteorological Society) 37 (1980): 994-1004.

25 (approximately 7,500 meters, or 24,600 feet on May 23) and between May 28 and May 30 (approximately 8,000 meters, or 26,250 feet on May 28). The most significant tropopause lowering of the period then occurs on between June 5 and June 10 (circled in Figure 30), with a large mass of stratospheric air with IPV values between 8 and 10 IPV units at around 10,000 meters on May 7 and 8. On May 9, a large filament of stratospheric air has descended to as low as 5,500 meters, while the tropopause has reached its high point of the period at approximately 19,000 meters; this indicates a fold in the tropopause lies over the Uinta basin.

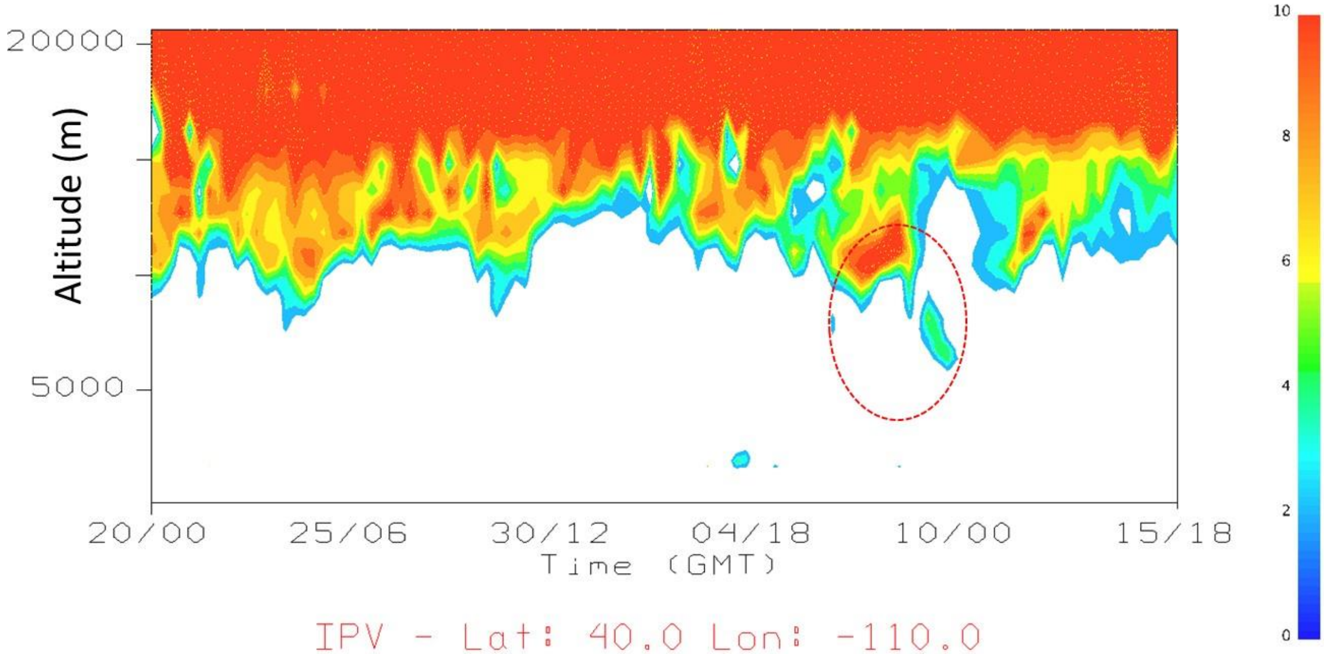


Figure 30 NAM IPV Plot Showing Tropopause Height May 20-June 15, 2015, and a Tropopause Fold Over the Uinta Basin of Utah on June 9, 2015 (circled)[4]

Dr. Tran also used NAM to generate a vertical profile of relative humidity plot above the Uinta Basin in the same period, shown in Figure 31; NAM shows a lobe of low humidity air coincident with the IPV lobe indicating the Tropopause fold on June 9, 2015. Stratospheric air, in addition to having high IPV and ozone, has low relative humidity when compared to tropospheric air.

[4] Investigation of Possible Ozone Exceptional Events in June 2015 in the Uintah Basin, Tran, Huy, et al.

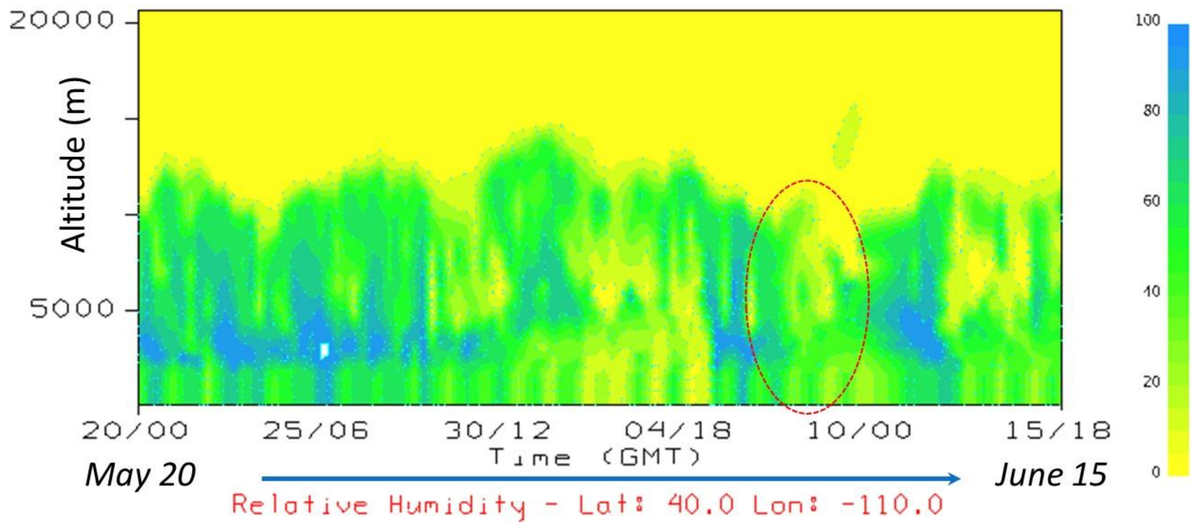


Figure 31 NAM Relative Humidity Plot Showing Approximate Tropopause Height, and a Tropopause Fold Over the Uinta Basin of Utah on June 9, 2015[5]

In addition to NAM vertical profiles, Dr. Tran used the GEOS-Chem global atmospheric chemistry model to estimate the vertical profile of ozone over the Uinta Basin for the period from June 1, 2015 through June 12, 2015. Figure 32 shows the GEOS-Chem ozone profile over the Ouray monitor. Lobes of stratospheric ozone with concentrations above 100 ppb are shown (circled) descending well into the troposphere on June 8 and 9 (hours 168-216) which correspond well with the IPV and humidity lobes from NAM. Corresponding elevations in ground level ozone is seen below the intrusion lobes. The GEOS-Chem predictions are used here qualitatively to support the conclusion that stratospheric air reach the ground and impacted the Ute Indian Tribe monitors, but the GEOS-Chem results are not expected to accurately predict the actual concentrations measured by the monitors.

[5] Ibid.

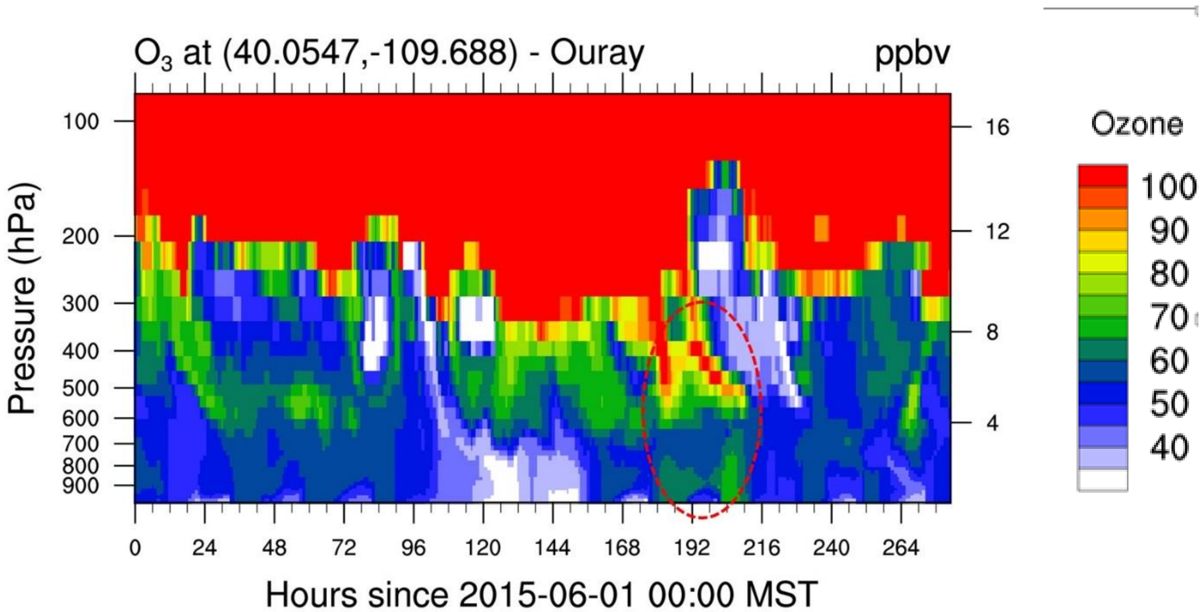


Figure 32 GEOS-Chem Plot of Vertical Ozone Above the Ouray Monitor, June 1-12, 2015[6]

Similarly in Figure 33, GEOS-Chem shows ozone above the Fruitland monitor. The lobe of stratospheric air with ozone over 100 ppb is larger and deeper over Fruitland, and GEOS-Chem shows the stratospheric lobes dispersing vertically all the way to surface. The fold in the tropopause is directly visible in the Fruitland GEOS-Chem plot, with low concentration tropospheric air ascending above the high ozone stratospheric intrusion air from about hour 192 (6/9/15 00:00 MST) until about hour 210 (6/9/2015 18:00 MST).

[6] Ibid.

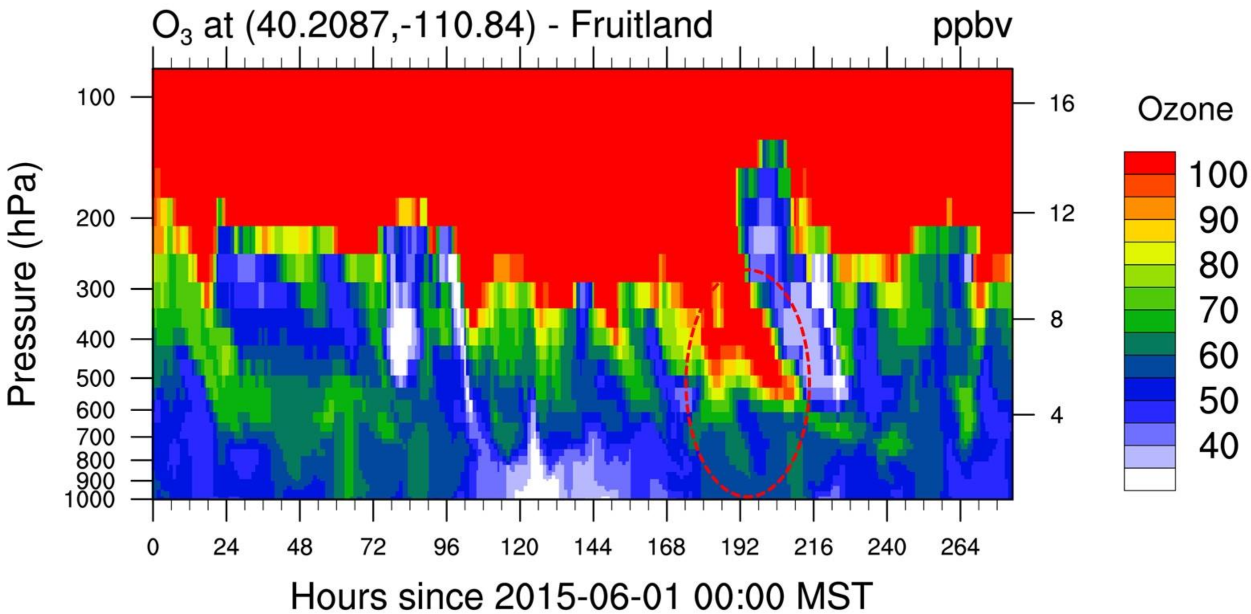


Figure 33 GEOS-Chem Plot of Vertical Ozone Above the Fruitland Monitor, June 1-12, 2015

The NASA Giovanni satellite data retrieval and mapping service was used to map total column ozone observations on June 7 (in UTC, so time averaged from 5:00 pm June 6 MST to 5:00 pm June 7 MST) and CO on June 8 (UTC), as shown in the left hand map of Figure 34. The Giovanni ozone map is similar to the total column ozone shown in Figure 29. Because the tropopause isolates the stratosphere from the troposphere, and therefore from ground level CO emissions, stratospheric air is low in CO when compared to tropospheric air. Tropospheric air with low CO concentrations due to stratospheric intrusion can be more difficult to identify in satellite data than are ozone enhancements. CO concentrations in the continental background troposphere can already be relatively low, so that additional lowering by intrusion of stratospheric air may not stand out in total column measurements as clearly as does total column ozone. Relatively high total column CO can still be observed in some total column observations that include stratospheric intrusions. Total column CO is shown in the right hand map of Figure 34, with a low CO region over northwest Nevada roughly coincident with elevated total column ozone in left hand map, and also over the high elevation region of the Rocky Mountains, not associated with elevated total column ozone.

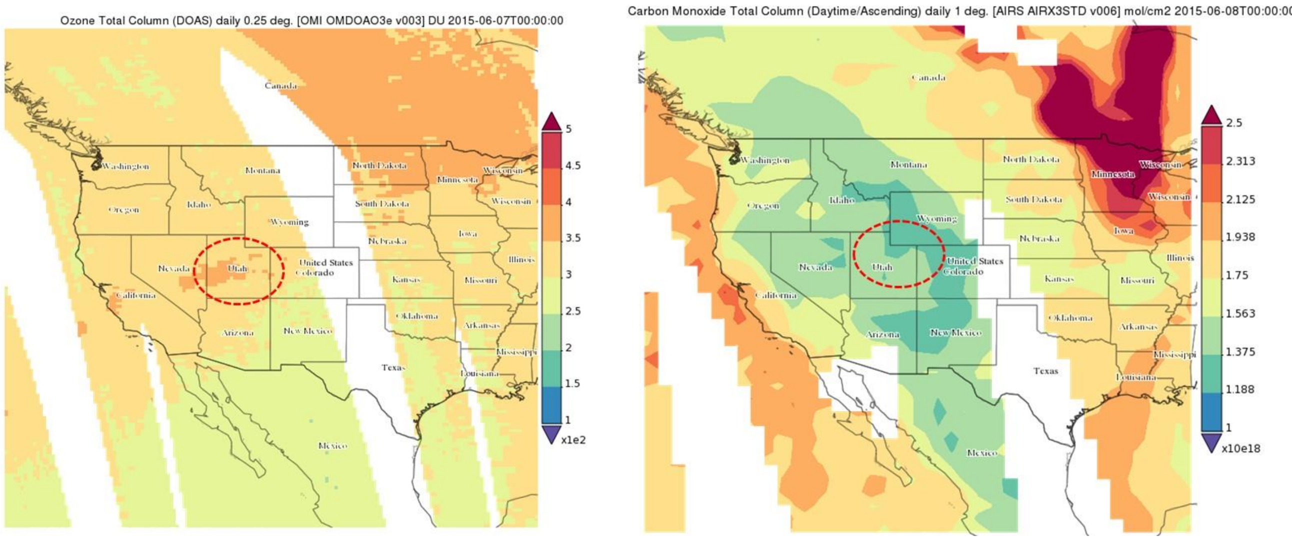
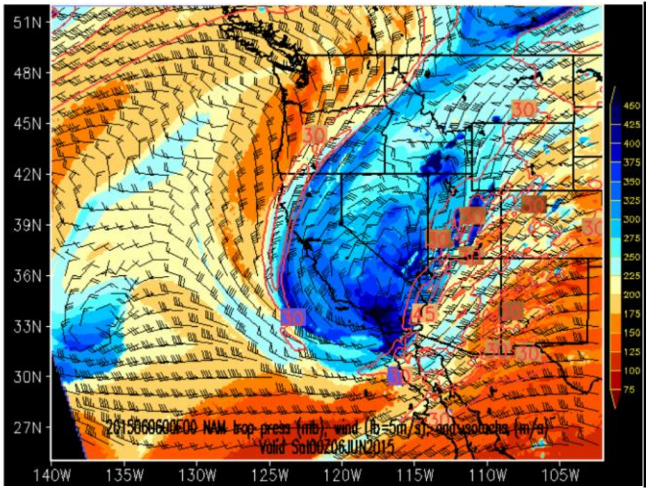


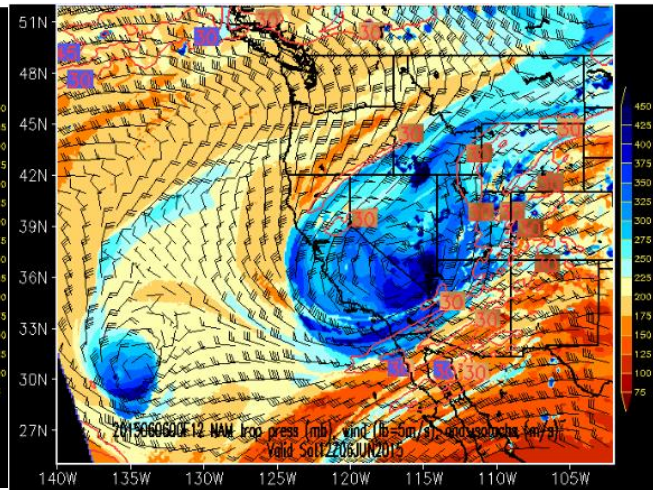
Figure 34 Giovanni Map of Total Column Ozone (left) on June 7, 2015, and Total Column CO on June 8, 2015; Utah Intrusion Area Circled in Red

In addition to the NAM IPV and humidity charts generated by Dr. Huy Tran of Utah State University, the University of Utah Horel Research Group archives tropopause height as given in NAM forecast runs by NOAA/NWS. Figures 35 and 36 show tropopause height over the southwest U. S. each 12 hours between 5:00 pm June 5 and 5:00 am June 10. The tropopause height maps show an area with the tropopause at or below 450 mb (dark blue and black areas, approximately 21,000 feet altitude) associated with the upper level low over southern California shown in Figure 17 (top left of Figure 29). The area of lowered tropopause moves eastward and northward over time as the upper level low stretches into the elongated trough of Figures 28 and 29. By June 8 and 9, 2015 the area of lowered tropopause stretches across northern Nevada and Utah, including the Uinta Basin.

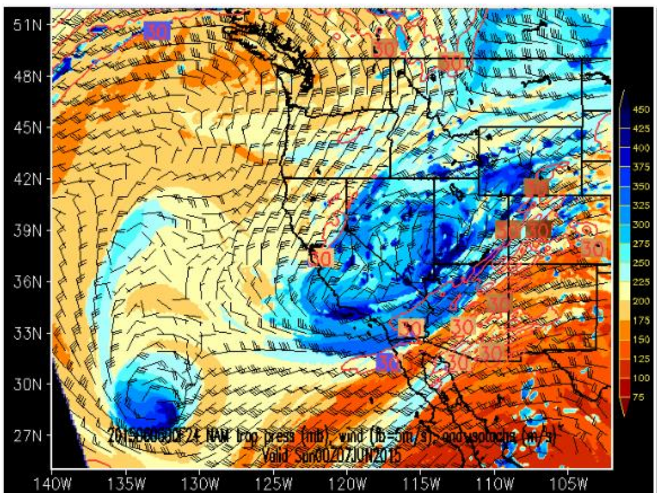
NAM Run of 0Z 6/6/2015; Valid 0Z 6/6/2015



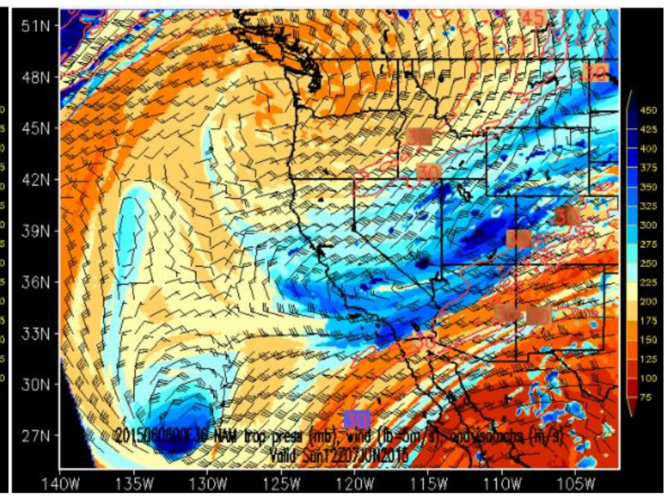
NAM Run of 0Z 6/6/2015; Valid 12Z 6/6/2015



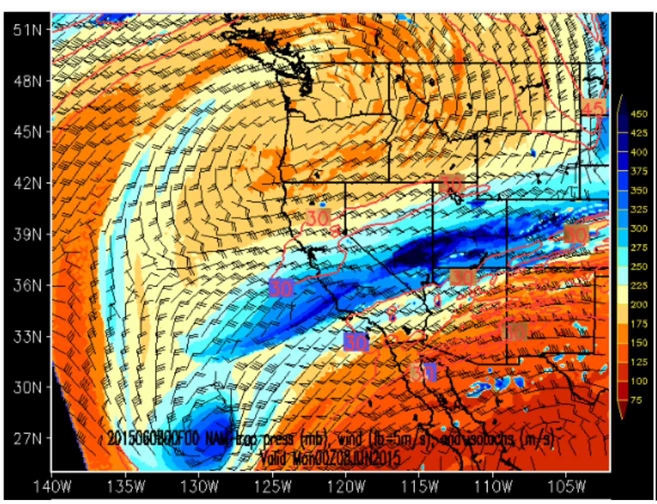
NAM Run of 0Z 6/6/2015; Valid 0Z 6/7/2015



NAM Run of 0Z 6/6/2015; Valid 12Z 6/6/2015



NAM Run of 0Z 6/8/2015; Valid 0Z 6/7/2015



NAM Run of 0Z 6/8/2015; Valid 12Z 6/6/2015

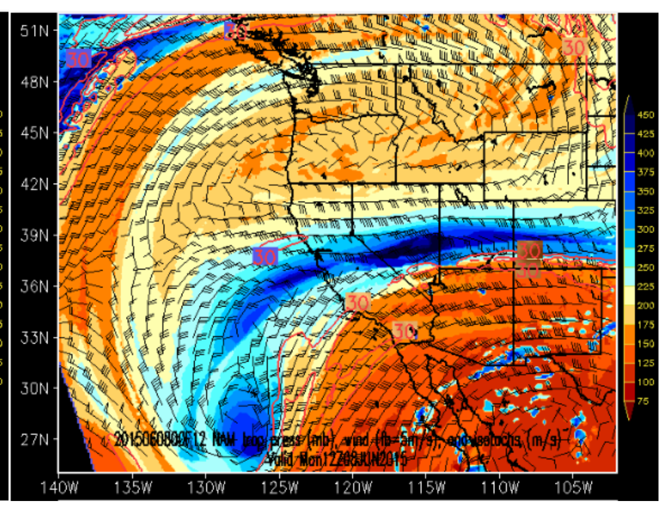
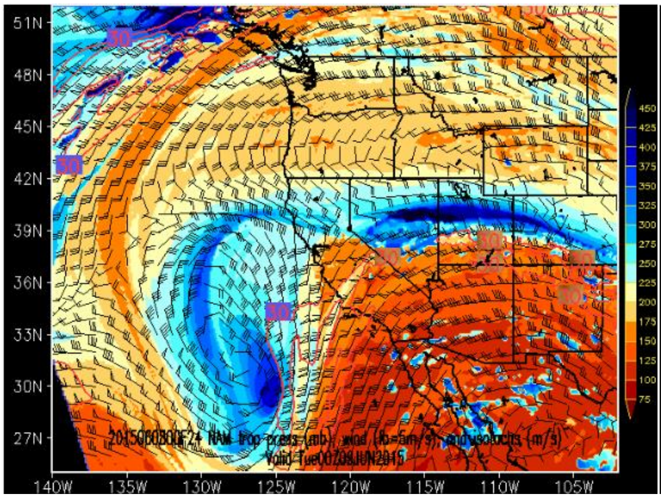
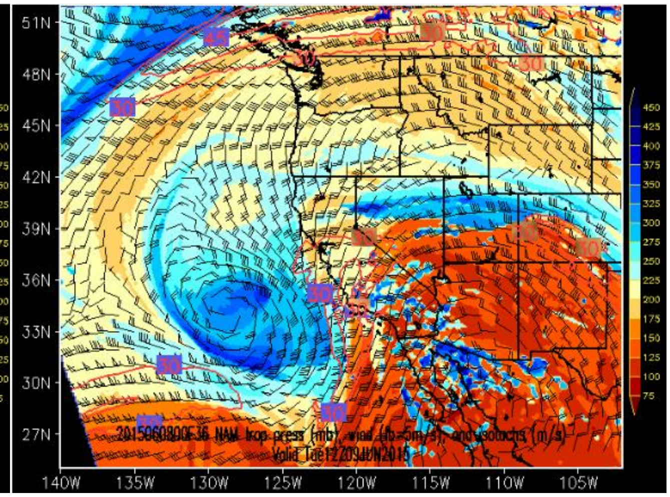


Figure 35 NAM Forecast Tropopause Heights, June 5, 2015 5:00 pm, -June 8, 2015, 5:00 am MST

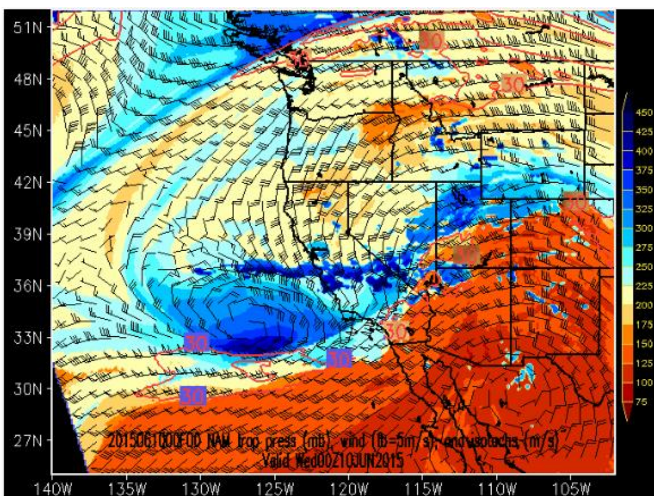
NAM Run of 0Z 6/8/2015; Valid 0Z 6/9/2015



NAM Run of 0Z 6/8/2015; Valid 12Z 6/9/2015



NAM Run of 0Z 6/10/2015; Valid 0Z 6/10/2015



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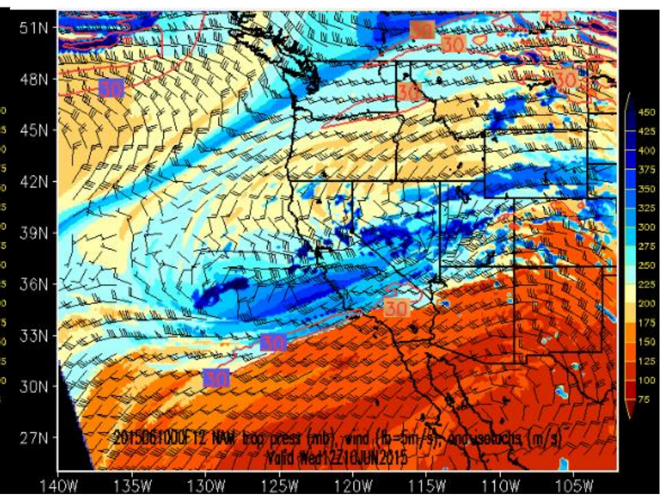

Figure 36 NAM Forecast Tropopause Heights, June 8, 2015 5:00 pm, -June 10, 2015, 5:00 am MST

Simultaneous with the map at the upper left in Figure 36, images of vertical distribution of ozone have been developed using the NOAA Realtime Air Quality Modeling System (RAQMS) have been provided by Dr. Brad Pierce of NOAA.[7] Figures 37, 38, 39 and 40 show RAQMS ozone concentration maps at 5 km (16,400 feet), 3 km (9,840 feet), 1 km (3,280 feet) and 0 m above ground level at 5:00 pm MST June 8, 2015.

[7] E-mail communication, Brad Pierce to Richard Payton, "RAQMS Evaluation of June 8 & 9, 2015"; received July 19, 2016.

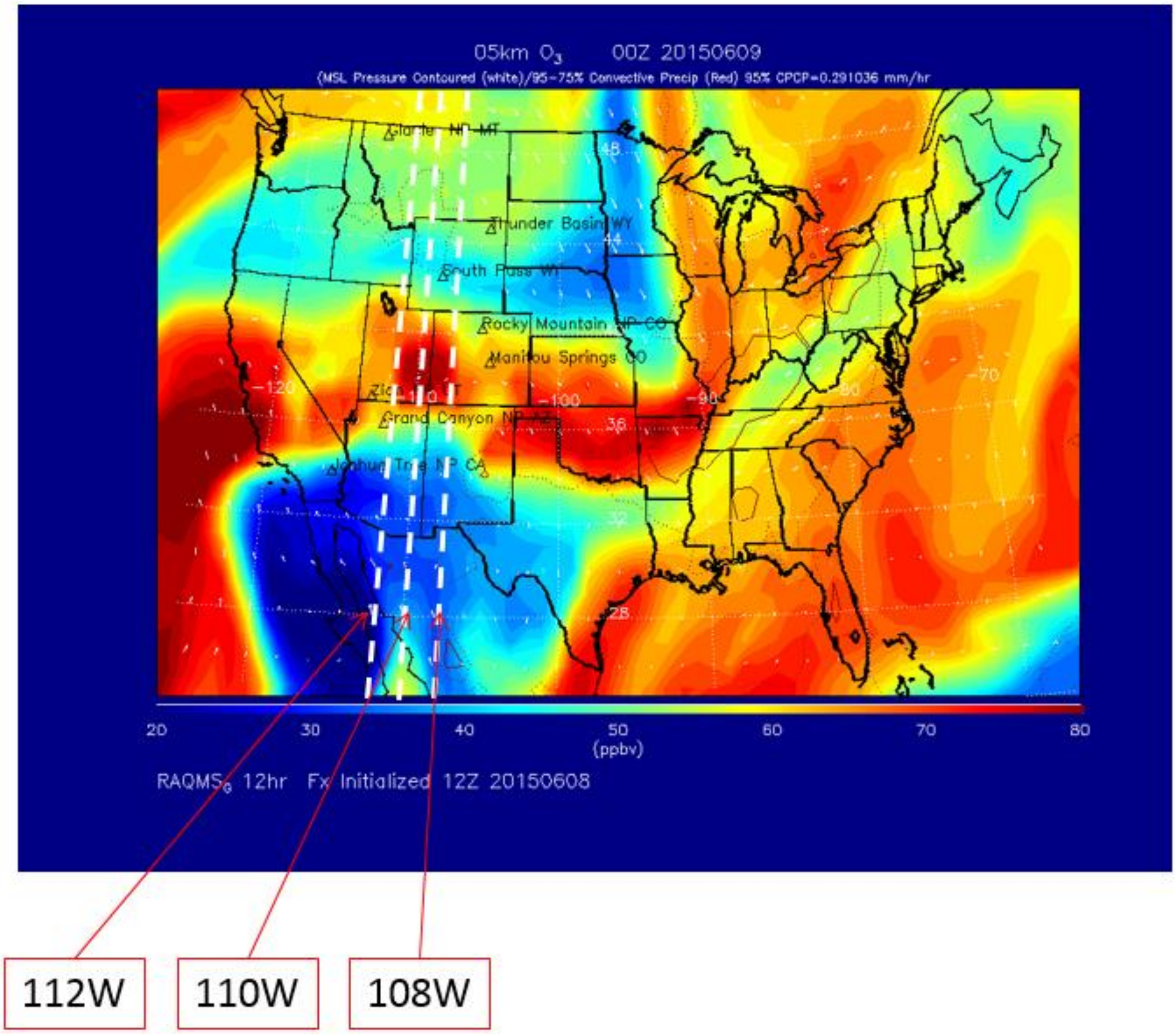

Figure 37 RAQMS Ozone Concentration at 5 km Altitude (16,400 feet) AGL at 5:00 pm MST, June 8, 2015

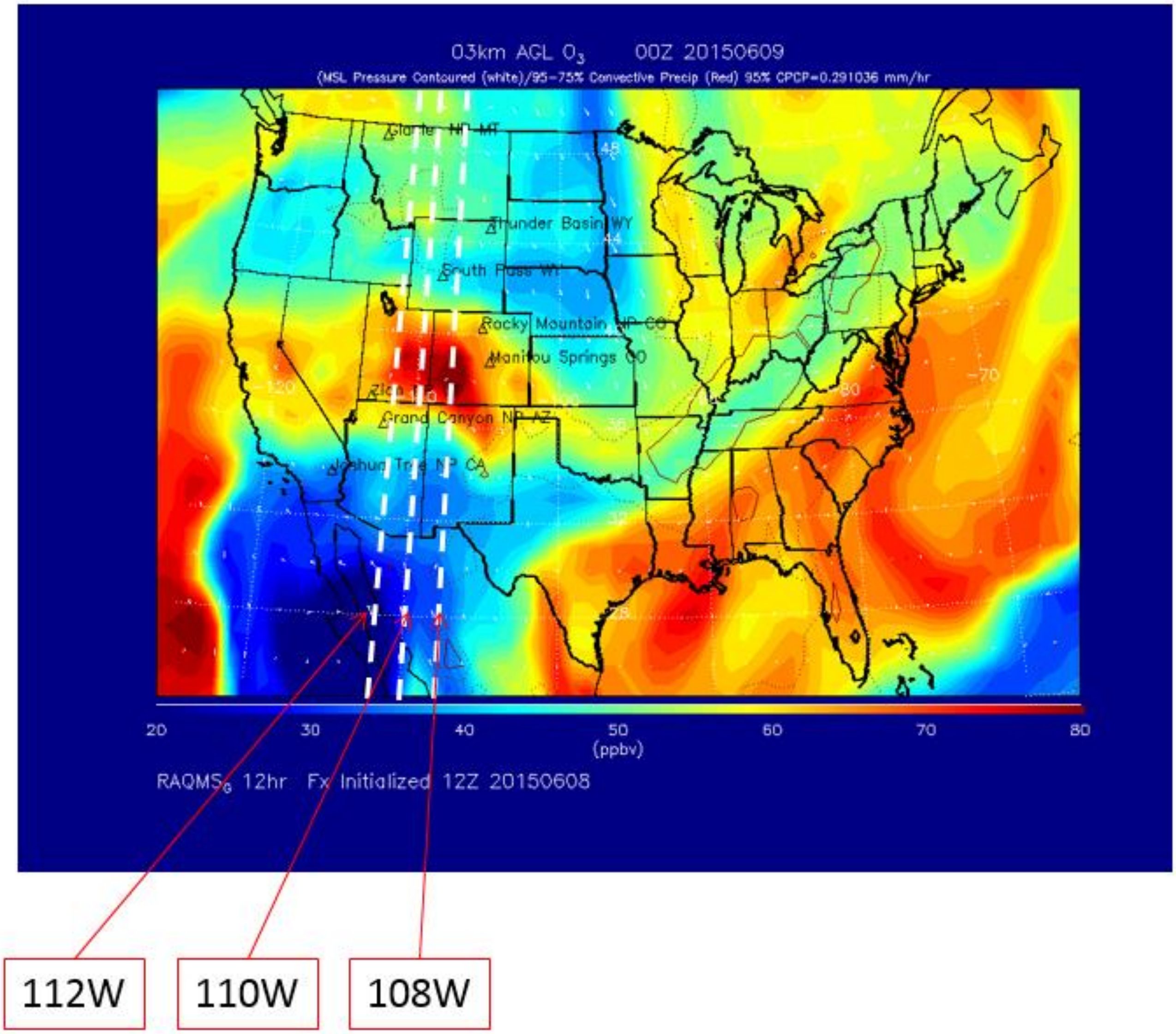

Figure 38 RAQMS Ozone Concentration at 3 km Altitude (9,840 feet) AGL at 5:00 pm MST, June 8, 2015

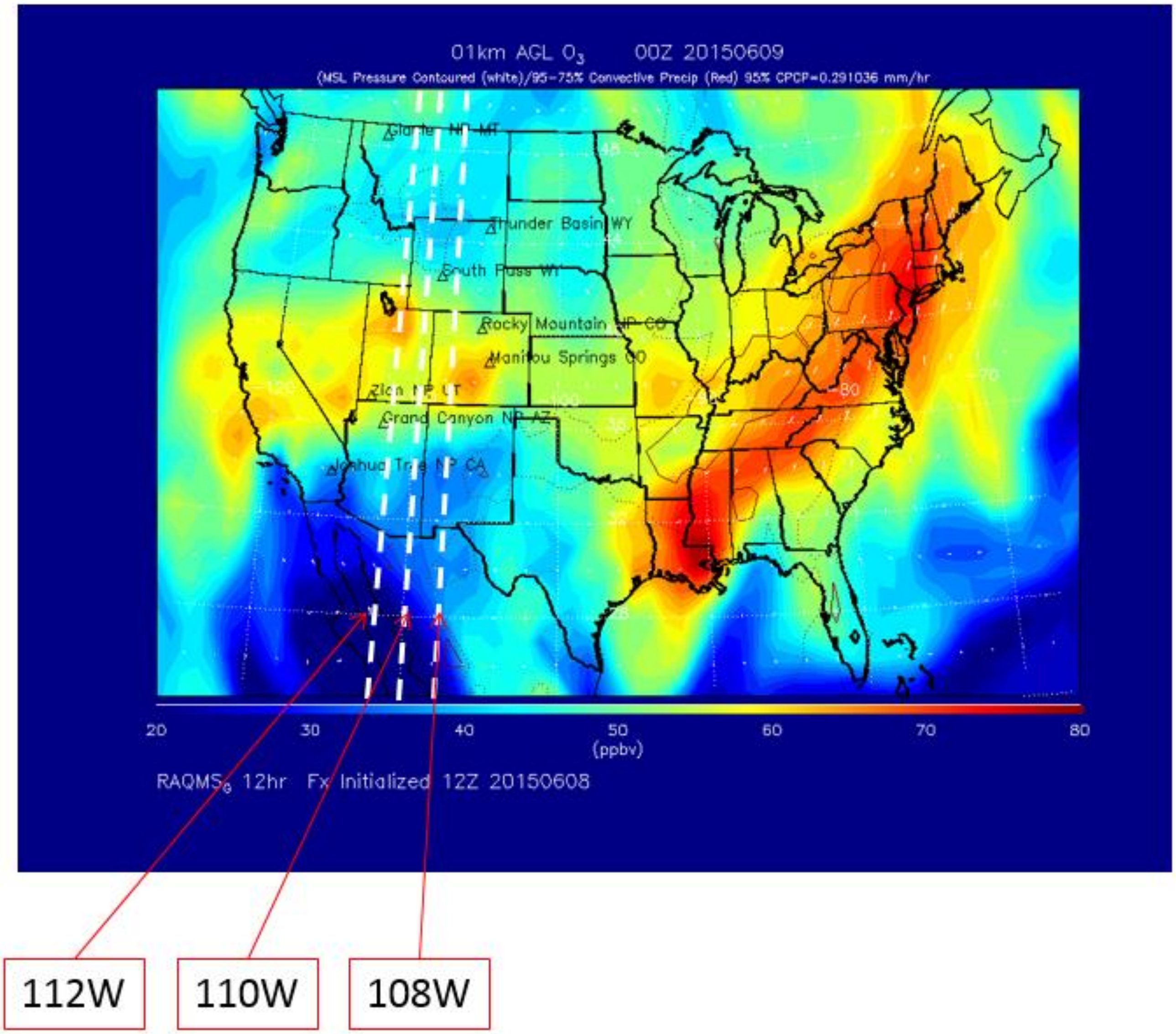

Figure 39 RAQMS Ozone Concentration at 1 km Altitude (3,280 feet) AGL at 5:00 pm MST, June 8, 2015

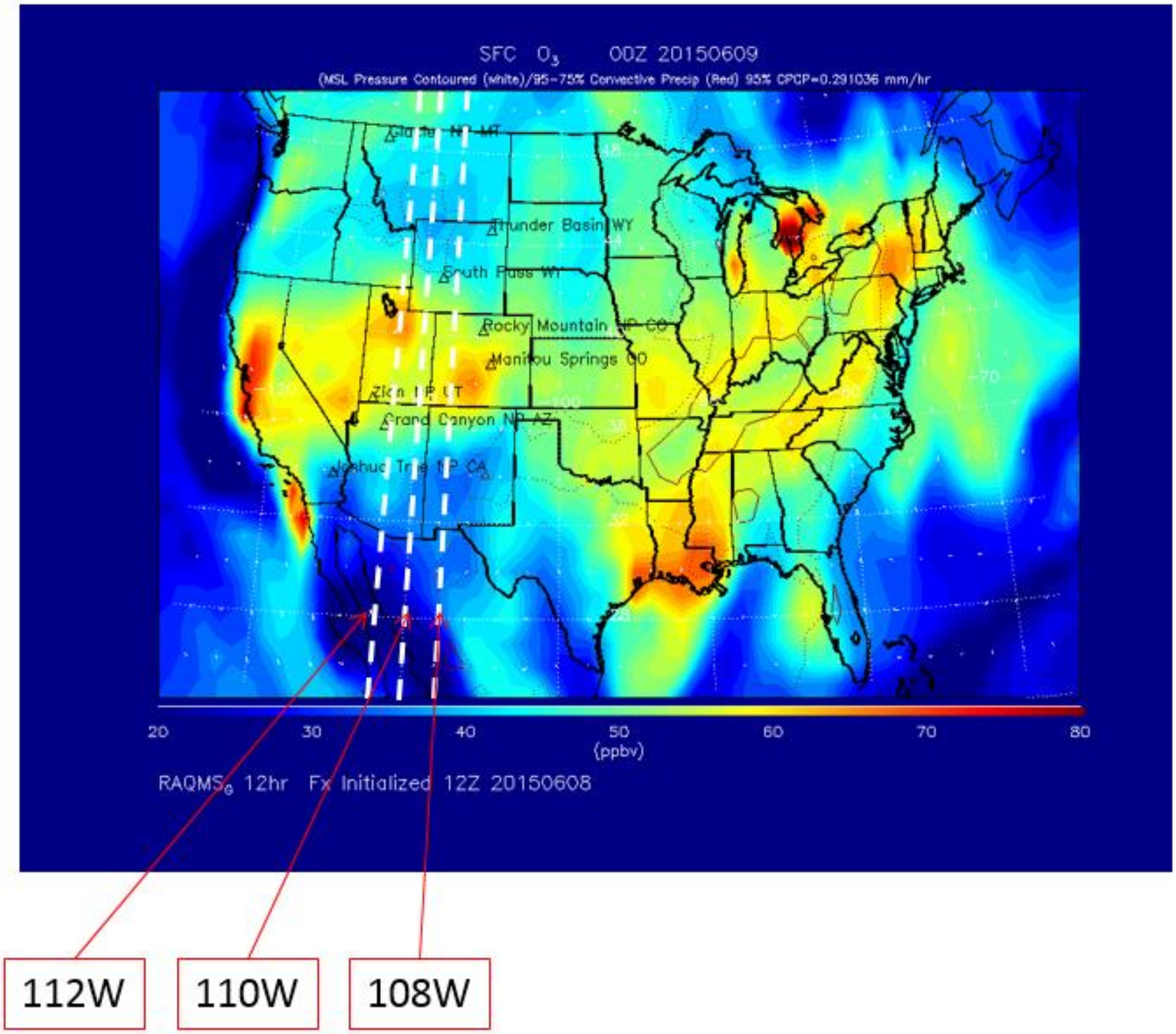

Figure 40 RAQMS Ozone Concentration at Surface at 5:00 pm MST, June 8, 2015

The three dashed lines at 108, 110 and 112 degrees west longitude show transects used to generated RAQMS vertical profiles of ozone shown in Figure 41. The Uinta Basin extends from approximately 108.75 to 111 degrees west longitude, and from approximately 39.3 to 40.6 degrees north latitude. The white dashed line in Figure 41 at 40 degrees north represents the approximate center of the basin, with the transect at 108 degrees west lying just east of the basin (passing through Meeker, Colorado) and the transect at 112 west passes through Salt Lake City, just west of the basin and the Wasatch mountains. The three transects show the region of lowered tropopause height from Figure 36, with stratospheric ozone of 80 ppb or higher down to 5 km altitude (16,400 feet), and 70 ppb or higher down to 4 km (13,000 feet) above sea level.

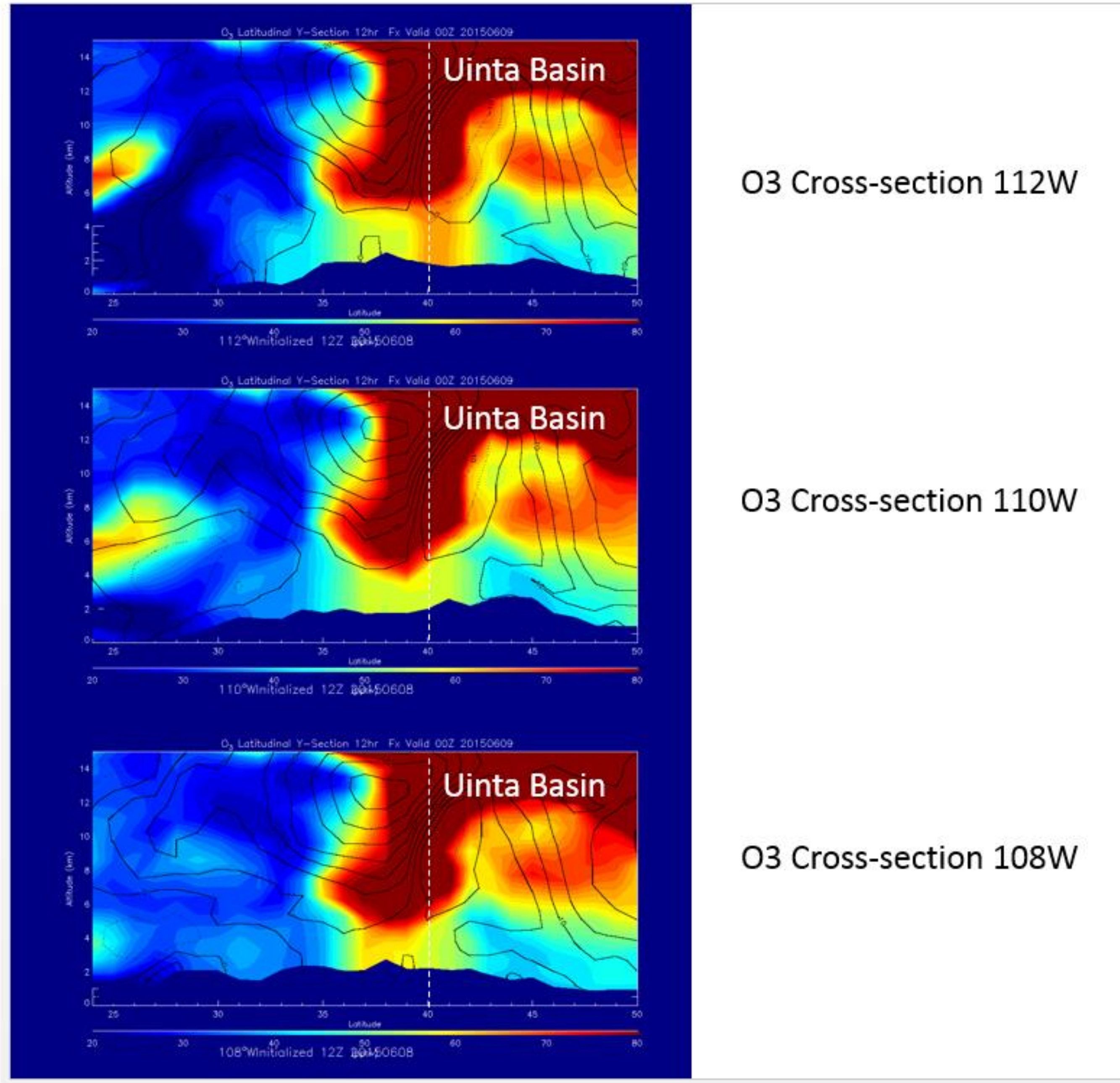

Figure 41 RAQMS Ozone Vertical Profiles, 5:00 pm MST, June 8, 2015, 108, 110 and 112 °W

Figure 42 shows RAQMS estimates of local oxidant production rates. Elevated oxidant production due to local photochemistry are seen for Salt Lake City (41 °N, 112 °W) and Phoenix, AZ (33 °N, 112 °W), southwest Wyoming (41 °N, 108 °W) and the four corners region (36 °N, 108 °W), but a minima in local photochemical oxidant production is shown in the Uinta Basin (40 °N, 110 °W). The RAQMS result suggest that local photochemistry played little or no role in the elevated ozone in the Uinta Basin on June 8 2015.

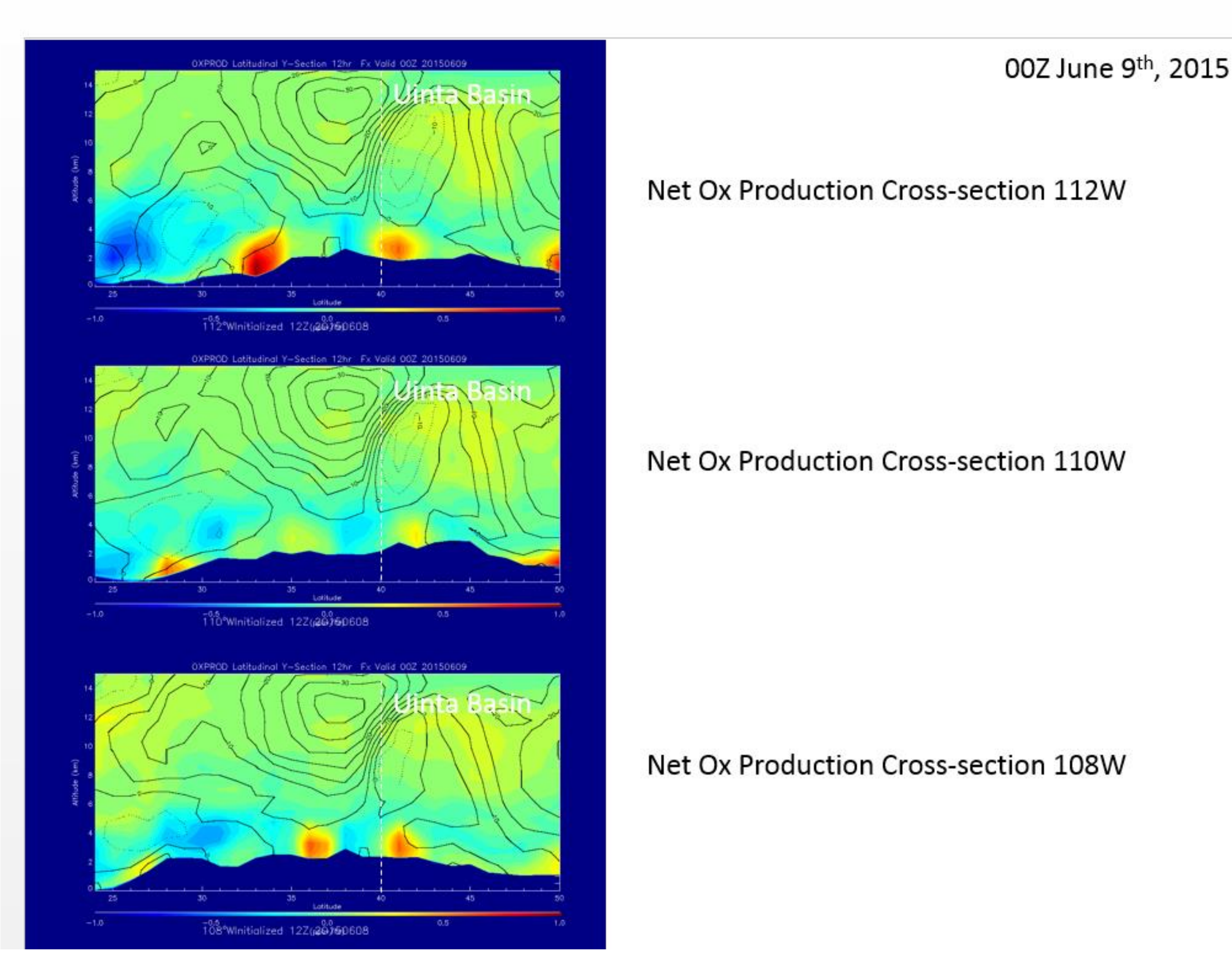

Figure 42 RAQMS Predicted Local Photochemical Oxidant Production Rates, 5:00 pm MST, June 8, 2015

NOAA launches upper atmosphere balloons twice daily from 92 locations in North America. Balloons are launched so as to make measurements of stratospheric temperature, relative humidity, winds and pressure at midnight and noon GMT each day. For mountain time zone locations, balloons are launched shortly after 4:00 am and 4:00 pm MST so that the reach the stratosphere at approximately 5:00 MST. Soundings were examined from the following sites to look for evidence within the relative humidity data for the stratospheric intrusion impacting the Uinta Basin monitors: Salt Lake City, Utah; Las Vegas and Elko, Nevada; Riverton, Wyoming; Grand Junction, Colorado; Flagstaff, Arizona; and Albuquerque, New Mexico. Of these sites, Flagstaff, Arizona and Grand Junction, Colorado were the sites showing the greatest evidence of dry air layers deep with the troposphere which could have had stratospheric origin. Soundings from Grand Junction are shown in Figure 43, and from Albuquerque in Figure 44. Dry air layers are circled in red.

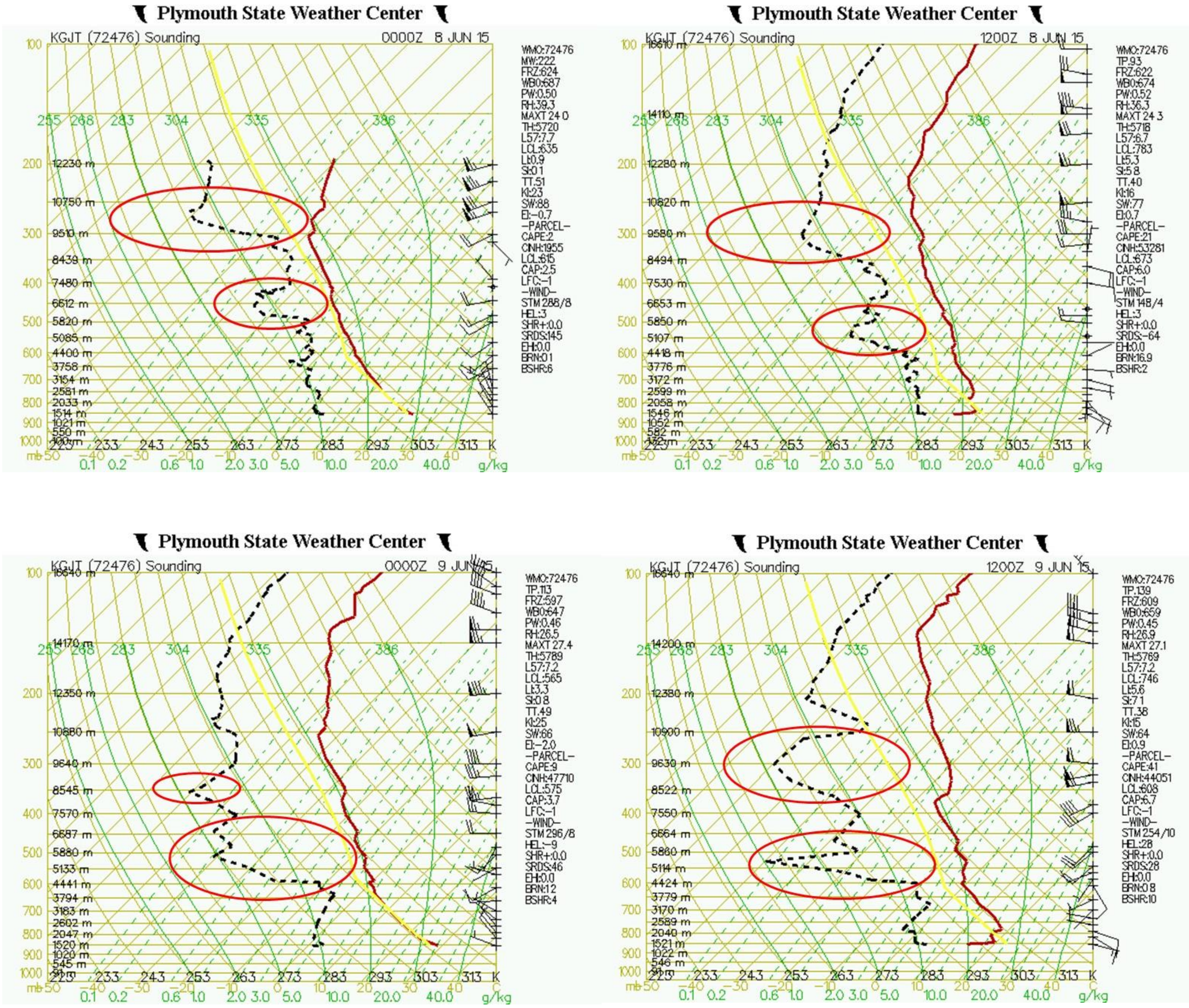

Figure 43 Upper Air Soundings for Grand Junction, Colorado; Relative Humidity in Dashed Black, Low Humidity Layers Circled in Red. June 7, 5:00 pm MST, upper left; June 8, 5:00 am MST, upper right; June 8, 5:00 pm, lower left; June 9, 5:00 am MST, lower right[8]

[8] Plymouth State University Weather Center, WXP Archive, http://vortex.plymouth.edu/myo/upa/raobplt-a.html. Files accessed May 3, 2016.

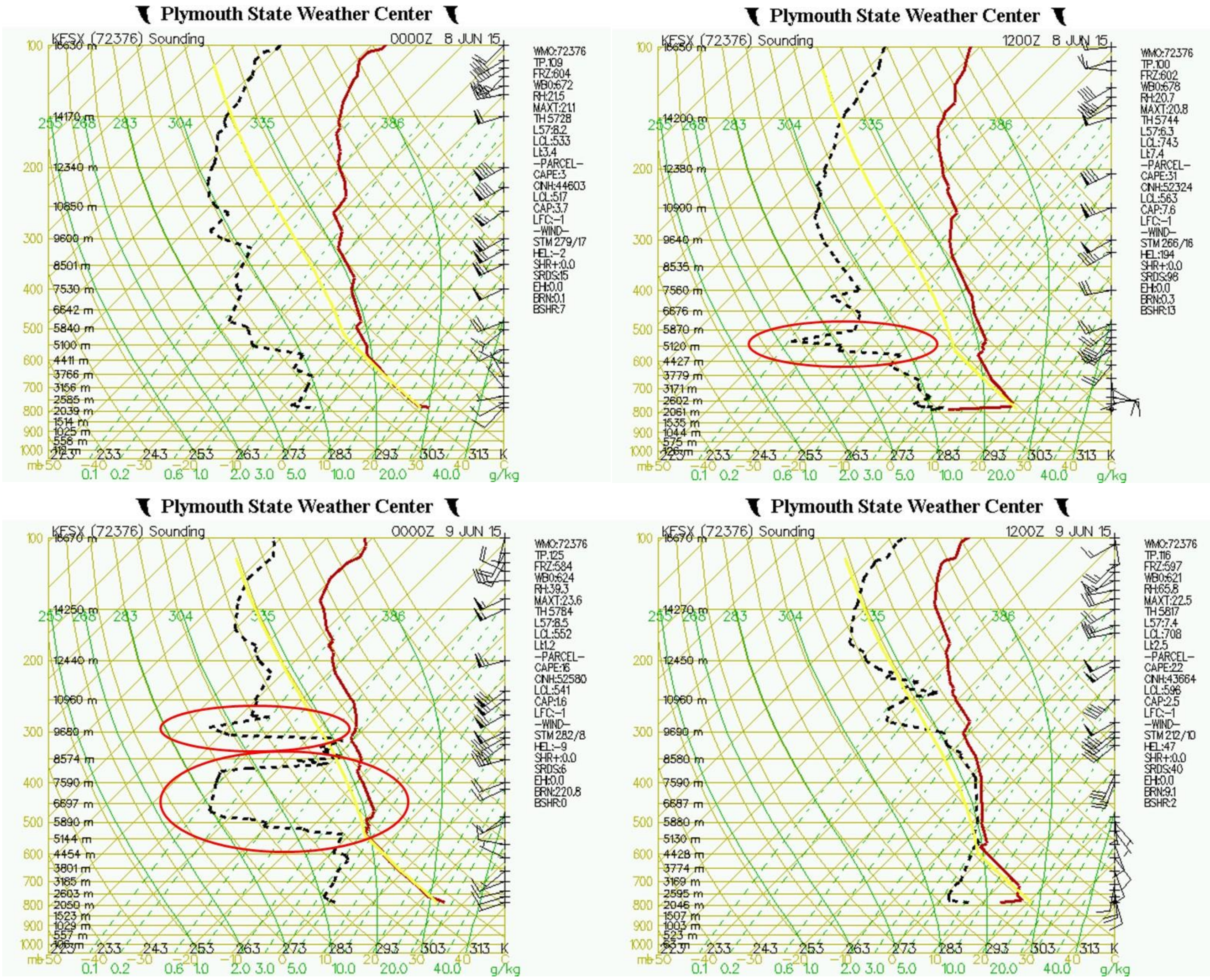

Figure 44 Upper Air Soundings for Flagstaff, Arizona; Relative Humidity in Dashed Black, Low Humidity Layers Circled in Red. June 7, 5:00 pm MST, upper left; June 8, 5:00 am MST, upper right; June 8, 5:00 pm, lower left; June 9, 5:00 am MST, lower right

D. CLEAR CAUSAL RELATIONSHIP CONCLUSION

Based on the evidence, including comparisons and analyses, provided in section 3 of this demonstration, the Ute Indian Tribe of the Uintah and Ouray Reservation has established that a clear causal relationship exists between the stratospheric intrusion event, which occurred on June 8 and 9, 2015 in the Uinta Basin, and the monitored ozone exceedance on those days. The clear causal relationship evidence also demonstrates that the event affected air quality at the monitor, and that the event is associated with a measured concentration in excess of normal historical fluctuations, including background.

4. AFFECTS AIR QUALITY

Figure 2 showed that rural, remote high elevation ozone monitors in the Rocky Mountain west observed elevated ozone levels on June 3 and 4 and on June 7, 8 and 9, 2015. Figure 45 shows maps of measured ozone in the region for June 1 through June 10, showing the geographic extent of the elevated ozone, particularly on June 2, 3, 4, 8 and 9. Section 3 provided evidence that the elevated ozone observed was caused in part by stratospheric ozone affecting surface air quality.

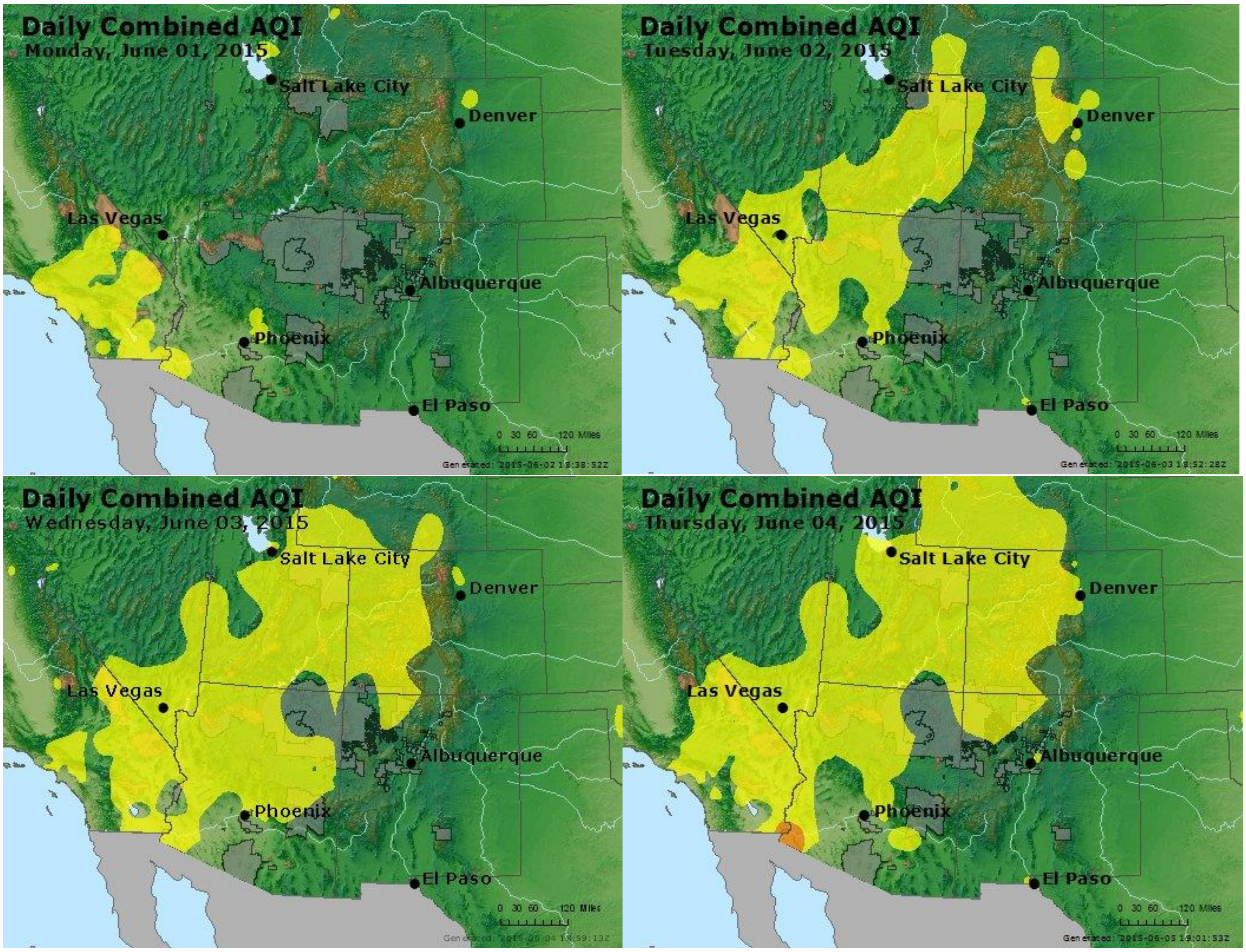

Figure 45 AIRNow Maps of June 1-10, Showing Elevated Ozone at Rural Sites on June 2, 3, 4, 8 and 9.

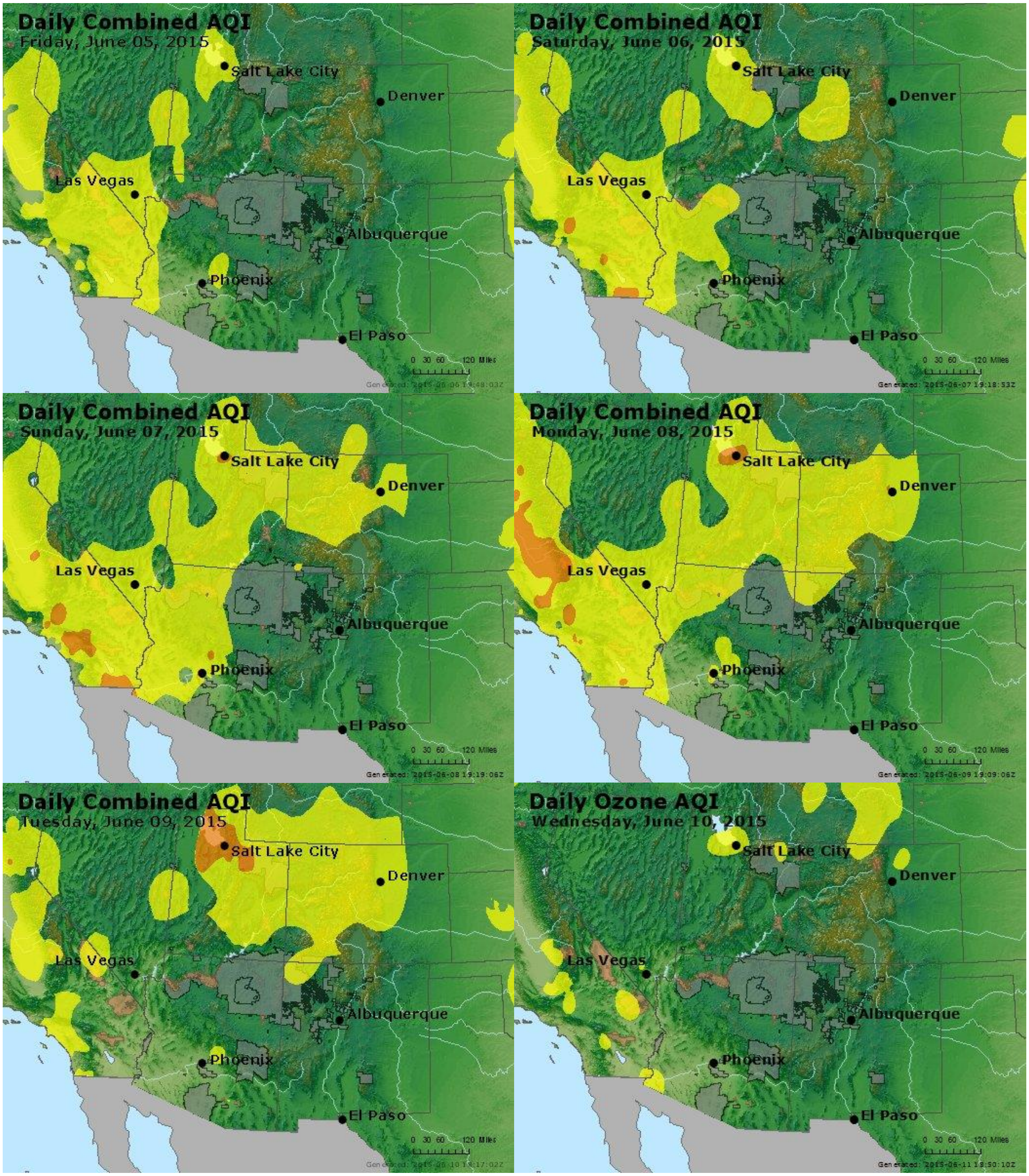

Figure 45 (concl.) AIRNow Maps of June 1-10, Showing Elevated Ozone at Rural Sites on June 2, 3, 4, 8 and 9.

5. NO EXCEEDANCE BUT FOR STRATOSPHERIC INTRUSION

Given the evidence of Section 3.A comparing the ozone data from June 8 and 9 to historical values, and concluding that June 8 and 9, 2015 represented the highest ever recorded ozone at the Fruitland monitor on June 9, and the 1st and 2nd highest spring ozone (April-June) at three of the four monitors impacted (Myton, Whiterocks and Redwash), and the evidence of Section 3.C showing that a stratospheric ozone intrusion was present on June 8 and 9 and affecting the surface level air quality measurements in the Uinta Basin, the ozone exceedances on June 8 and 9, 2015 in the Uinta Basin have a clear causal relationship to the stratospheric intrusion, and would not have occurred but for the intrusion.

6. NATURAL EVENT

The Exceptional Events Rule states a '[n]atural event means an event and its resulting emissions, which may recur, in which human activity plays little or no direct causal role.' Therefore, stratospheric intrusions that cause monitored ambient ozone exceedances or violations are considered to be natural exceptional events. The Ute Indian Tribe of the Uintah and Ouray Reservation has shown through the analyses provided in Section 3 of this demonstration that the subject stratospheric intrusion caused each of the identified exceedances. Through these analyses and the fact that stratospheric intrusions are purely natural, and that the event is associated with a measured concentration in excess of normal historical fluctuations, including background, the Ute Indian Tribe has satisfied the 'human activity that is unlikely to recur at a particular location or a natural event' element.

7. NOT REASONABLY CONTROLLABLE OR PREVENTABLE

The documentation provided in Section 3 of this demonstration shows that the subject stratospheric intrusion caused each of the identified exceedances. Through these analyses and the fact that stratospheric intrusions are purely natural events that cannot be prevented or controlled, the Ute Indian Tribe has satisfied the 'not reasonably controllable or preventable' criterion.

While stratospheric intrusion ozone cannot be controlled or prevented, anthropogenic emissions of ozone precursors within the Uinta Basin do have some controls. The Uinta Basin was designated an unclassifiable ozone area for the 2008 ozone NAAQS in 2012. Unclassifiable areas do not require development of attainment implementation plans. New and modified emission sources in the Uinta Basin are controlled, however, through federal and state regulations for the oil and gas industry.[9] Oil and gas production accounts for about 97% of the anthropogenic VOC emissions in the Basin. Approximately two thirds of the producing oil and gas wells are located in Indian Country. The EPA has issued New Source Performance Standards (NSPS) for the oil and gas industry to control VOCs, and now methane. These standards require "green completions" to capture emissions from oil and gas well installation, emission reductions from storage tanks and other production equipment, and leak detection and repair self-inspections.

The state of Utah has permitting requirements for new and modified emissions sources, both major and minor sources on lands under State jurisdiction. Minor sources are required to apply best available control technology (BACT). Major sources are required to demonstrate compliance with NAAQS

[9] 40 CFR Part 60, Subpart OOOO, Standards of Performance for Crude Oil and Natural Gas Production, Transmission and Distribution, applicable to emission sources that commenced construction, modification or reconstruction after August 23, 2011.

through modeling requirements of the PSD program. Federal standards have also been implemented for new and modified reciprocating internal combustion engines (RICE) and NSPS for compression ignition engines and spark ignition engines will regulate VOC and NOx emissions from these engines. Additionally, the State of Utah has established four rules to address existing sources. These rules require that equipment is operated in a manner that minimizes VOC emissions; existing high-bleed pneumatic controllers are required to be replace with low-bleed controllers; and flares shall have self-igniters and use of bottom filling or submerged filling when loading product into tanker trucks. Compliance with state and federal requirements is ensured with on-going inspections, audits and enforcements actions.

8. CONCLUSION

This exceptional event demonstration shows that the stratospheric ozone intrusion of June 8 and 9, 2015 satisfies the criteria set forth in 40 CFR §50.1(j) for the definition of an exceptional event. The portions of the demonstration relevant to the required demonstration elements stated in Section 1 are summarized in Table 5.

Table 5 Demonstration Chapters addressing Exceptional Event Requirements

EE Demonstration Element	Relevant Section
Affects Air Quality	Section 4
Not Reasonably Controllable or Preventable	Section 7
Natural Event	Section 6
Clear Causal Relationship	Section 3
In Excess of Normal Historical Fluctuations	Section 3.A
No Exceedance But For the Event	Section 5