Technical Support Document For the Lamar Exceptional Events Occurring on:

March 11, 2014
March 15, 2014
March 18, 2014
March 29, 2014
March 30, 2014
March 31, 2014
April 23, 2014
April 29, 2014
November 10, 2014

COLORADO
Department of Public Health & Environment

Prepared by the
Air Pollution Control Division
Colorado Department of Public Health and Environment

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Executive Summary

In 2005, Congress identified a need to account for events that result in exceedances of the National Ambient Air Quality Standards (NAAQS) that are exceptional in nature[1] (e.g., not expected to reoccur or caused by acts of nature beyond man-made controls). In response, EPA promulgated the Exceptional Events Rule (EER) to address exceptional events in 40 CFR Parts 50 and 51 on March 22, 2007 (72 FR 13560). On May 2, 2011, in an attempt to clarify this rule, EPA released draft guidance documents on the implementation of the EER to State, tribal and local air agencies for review. The EER allows for states and tribes to "flag" air quality monitoring data as an exceptional event and exclude those data from use in determinations with respect to exceedances or violations of the NAAQS, if EPA concurs with the demonstration submitted by the flagging agency.

Due to the semi-arid nature of parts of the state, Colorado is highly susceptible to windblown dust events. These events are often captured by various air quality monitoring equipment throughout the state, sometimes resulting in exceedances or violations of the 24-hour PM_{10} NAAQS. This document contains detailed information about the large regional windblown dust events that occurred in 2013. The Colorado Department of Public Health and Environment (CDPHE) Air Pollution Control Division (APCD) has prepared this report for the U.S. Environmental Protection Agency (EPA) to demonstrate that the elevated PM_{10} concentrations recorded in 2014 in Lamar, Colorado, were caused by natural events.

EPA's June 2012 draft Guidance on the Preparation of Demonstrations in Support of Requests to Exclude Ambient Air Quality Data Affected by High Winds under the Exceptional Events Rule states "the EPA will accept a threshold of a sustained wind of 25 mph for areas in the west provided the agencies support this as the level at which they expect stable surfaces (i.e., controlled anthropogenic and undisturbed natural surfaces) to be overwhelmed…". In addition, in both eastern and western Colorado it has been shown that wind speeds of 30 mph or greater and gusts of 40 mph or greater can cause blowing dust (see the Lamar Blowing Dust Climatology at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2). For these blowing dust events, it has been assumed that sustained winds of 30 mph and higher or wind gusts of 40 mph and higher can cause blowing dust in Colorado and the surrounding states.

The PM_{10} exceedances in Lamar throughout 2014 would not have occurred if not for the following: (a) dry soil conditions over source regions with 30-day precipitation totals below the threshold identified as a precondition for blowing dust; and (b) meteorological conditions that caused strong surface winds over the area of concern. These PM_{10} exceedances were due to exceptional events associated with regional windstorm-caused emissions from erodible soil sources outside the monitored areas. These sources are not reasonably controllable during significant windstorms under abnormally dry or moderate drought conditions.

APCD is requesting concurrence on exclusion of the PM_{10} values from the Lamar Municipal Building site (08-099-0002) on March 11, 2014, March 15, 2014, March 18, 2014, March 29, 2014, March 30, 2014, March 31, 2014, April 23, 2014, April 29, 2014 and November 10, 2014.

[1] Section 319 of the Clear Air Act (CAA), as amended by section 6013 of the Safe Accountable Flexible Efficient-Transportation Equity Act: A Legacy for Users (SAFE-TEA-LU of 2005, required EPA to propose the Federal Exceptional Events Rule (EER) no later than March 1, 2006.

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1.0 Exceptional Events Rule Requirements

In addition to the technical requirements that are contained within the EER, procedural requirements must also be met in order for EPA to concur with the flagged air quality monitoring data. This section of the report lays out the requirements of the EER and discusses how the APCD addressed those requirements.

1.1 Procedural Criteria

This section presents a review of the procedural requirements of the EER as required by 40 CFR 50.14 (Treatment of Air Quality Monitoring Data Influenced by Exceptional Events) and explains how APCD fulfills them.

The Federal EER requirements include public notification that an event was occurring, the placement of informational flags on data in EPA's Air Quality System (AQS), submission of initial event description, the documentation that the public comment process was followed, and the submittal of a demonstration supporting the exceptional events flag. APCD has addressed all of these procedural and documentation requirements.

Public notification that event was occurring (40 CFR 50.14(c)(1)(i))
APCD issued Blowing Dust Advisories for southeastern Colorado advising citizens of the potential for high wind/dust events on March 11, 2014, March 15, 2014, March 18, 2014, March 29, 2014, March 30, 2014, March 31, 2014, April 23, 2014, April 29, 2014 and November 10, 2014. These areas included the town of Lamar. The advisories that were issued on March 11, 2014, March 15, 2014, March 18, 2014, March 29, 2014, March 30, 2014, March 31, 2014, April 23, 2014, April 29, 2014 and November 10, 2014 can be viewed at: http://www.colorado.gov/airquality/report.aspx and are discussed further in Section 2.

Place informational flag on data in AQS (40 CFR 50.14(c)(2)(ii))
APCD and other applicable agencies in Colorado submit data into EPA's AQS. Data from both filter-based and continuous monitors operated in Colorado are submitted to AQS.

When APCD and/or the Primary Quality Assurance Organization operating monitors in Colorado suspects that data may be influenced by an exceptional event, APCD and/or the other operating agency expedites analysis of the filters collected from the potentially-affected filter-based air monitoring instruments, quality assures the results and submits the data into AQS. APCD and/or other operating agencies also submit data from continuous monitors into AQS after quality assurance is complete.

If APCD and/or the applicable operating agency have determined a potential exists that the sample value has been influenced by an exceptional event, a preliminary flag is submitted with the measurement when the data are uploaded to AQS. The data are not official until they are certified by May 1st of the year following the calendar year in which the data were collected (40 CFR 58.15(a)(2)). The presence of the flag with a date/time stamp can be confirmed in AQS.

Notify EPA of intent to flag through submission of initial event description by July 1 of calendar year following event (40 CFR 50.14(c)(2)(iii))
In early 2011, APCD and EPA Region 8 staff agreed that the notification of the intent to flag data as an exceptional event would be done by submitting data to AQS with the proper flags

and the initial event descriptions. This was deemed acceptable, since Region 8 staff routinely pull the data to review for completeness and other analyses.

On March 11, 2014, March 15, 2014, March 18, 2014, March 29, 2014, March 30, 2014, March 31, 2014, April 23, 2014, April 29, 2014, and November 10, 2014, sample values greater than 150 $\mu g/m^3$ were taken in Lamar, Colorado during the high wind events that occurred on those days. These occurred at the monitor located in Lamar at the Municipal building (SLAMS). This monitor is operated by APCD in partnership with local operators.

Document that the public comment process was followed for event documentation (40 CFR 50.14(c)(3)(iv))
APCD posted this report on the Air Pollution Control Division's webpage for public review. APCD opened a 30-day public comment period on March 31, 2015 and closed the comment period on April 30, 2015. A copy of the public notice certification (in cover letter), along with any comments received, will be submitted to EPA, consistent with the requirements of 40 CFR 50.14(c)(3)(iv).

> **NOTE: No comments were received during the public comment period. Some minor non-substantial grammatical and formatting corrections were made.**

Submit demonstration supporting exceptional event flag (40 CFR 50.14(a)(1-2))
At the close of the comment period, and after APCD has had the opportunity to consider any comments submitted on this document, APCD will submit this document, along with any comments received (if applicable), and APCD's responses to those comments to EPA Region VIII headquarters in Denver, Colorado. The deadline for the submittal of this demonstration package is March 31, 2017 or one year prior to a regulatory action.

1.2 Documentation Requirements

Section 50.14(c)(3)(iv) of the EER states that in order to justify excluding air quality monitoring data, evidence must be provided for the following elements:

a. The event satisfies the criteria set forth in 40 CFR 501(j) that:
   (1) the event affected air quality,
   (2) the event was not reasonably controllable or preventable, and
   (3) the event was caused by human activity unlikely to recur in a particular location or was a natural event;
b. There is a clear causal relationship between the measurement under consideration and the event;
c. The event is associated with a measured concentration in excess of normal historical fluctuations; and
d. There would have been no exceedance or violation but for the event.

2.0 Meteorological Analysis of the 2014 Blowing Dust Events and PM_{10} Exceedances – Conceptual Model and Wind Statistics

Several powerful storm systems caused exceedances of the 24-hour PM_{10} standard in Lamar, Colorado in 2014. Exceedances were recorded in Lamar at the Lamar Municipal Building monitor. Meteorological analysis for each event is discussed further below.

EPA's June 2012, Draft Guidance on the Preparation of Demonstrations in Support of Requests to Exclude Ambient Air Quality Data Affected by High Winds under the Exceptional Events Rule states, "the EPA will accept a threshold of a sustained wind of 25 mph for areas in the west provided the agencies support this as the level at which they expect stable surfaces (i.e., controlled anthropogenic and undisturbed natural surfaces) to be overwhelmed…". In addition, in Colorado it has been shown that wind speeds of 30 mph or greater and gusts of 40 mph or greater can cause blowing dust (see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2). For this blowing dust event, it has been assumed that sustained winds of 30 mph and higher or wind gusts of 40 mph and higher can cause blowing dust in Colorado.

2.1 March 11, 2014 Meteorological Analysis

On March 11 of 2014, a powerful late winter storm system caused an exceedance of the 24-hour PM_{10} standard in Lamar, Colorado, at the Municipal Building monitor with a concentration of 387 $\mu g/m^3$. This highly elevated reading and the location of the monitor is plotted on a map of the Greater Lamar area in Figure 1. The exceedance in Lamar was the result of intense surface winds in the wake of a passing cold front. These surface features were associated with a strong upper-level trough that was moving across the western United States. The surface winds were predominantly out of a north to northeasterly direction which moved over dry soils in eastern Colorado, producing significant blowing dust.

High PM10 Natural Event in Colorado (March 11, 2014)

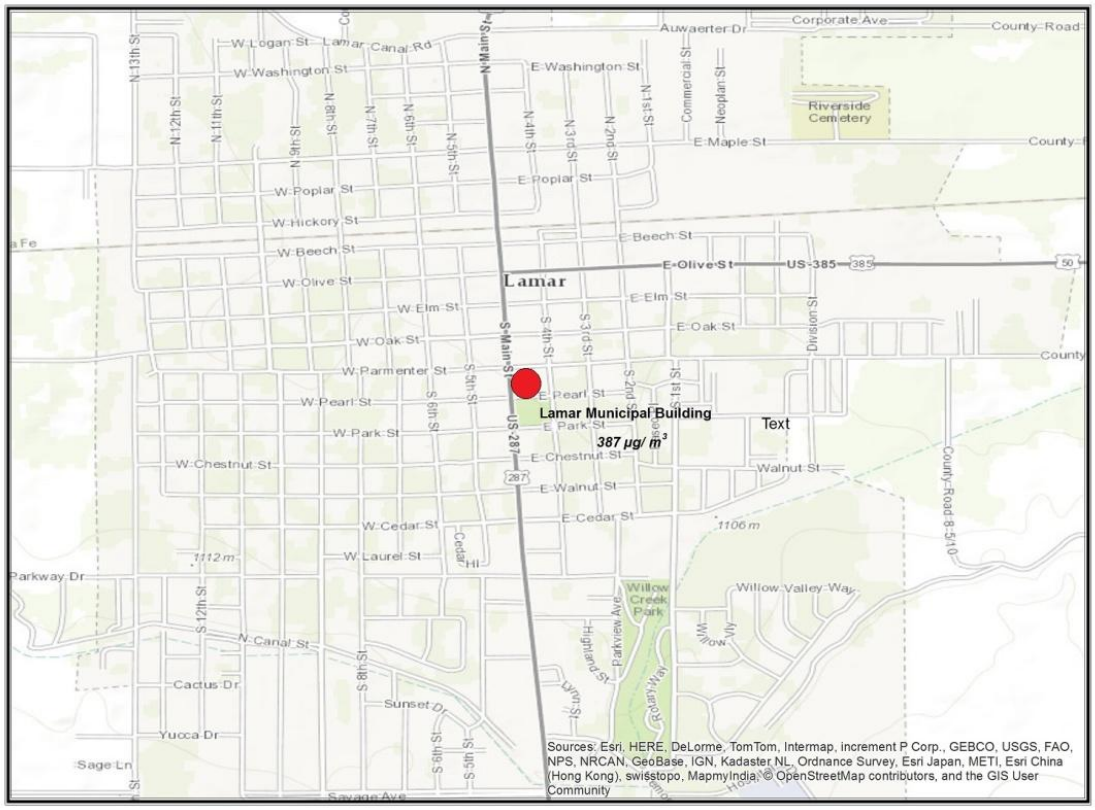


Figure 1: 24-hour PM_{10} concentration for the Lamar Municipal Building monitor, March 11, 2014.
(Source: http://webapps.datafed.net/datafed.aspx?dataset=AQS_D&parameter=pm10)

The upper-level trough associated with this storm system is shown on the 700 mb and 500 mb height analysis maps at 5:00 AM MST, March 11, 2014 in Figure 2 and Figure 3, respectively. The 700 mb level is located roughly 3 kilometers above mean sea level (MSL) while the 500 mb level is approximately 6 kilometers above MSL. These two charts show that a deep trough of low pressure was present at both the 700 and 500 mb level just a few hours before the blowing dust event of March 11, 2014 and that it was moving over the southwestern United States. This is a typical upper-air pattern for blowing dust events in Colorado (see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2).

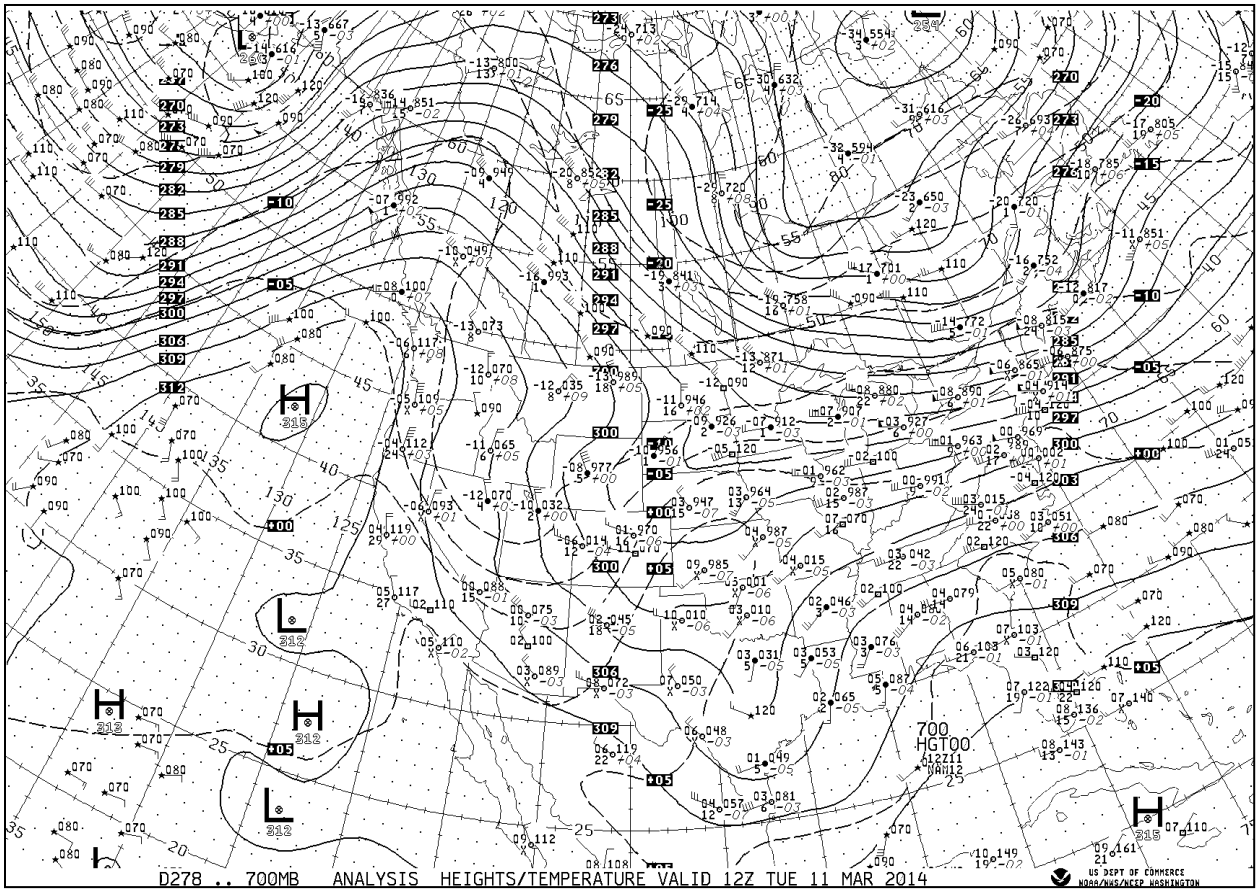


Figure 2: 700 mb (about 3 kilometers above mean sea level) analysis for 12Z March 11, 2014, or 5:00 AM MST March 11, 2014.
(Source: http://nomads.ncdc.noaa.gov/ncep/NCEP)

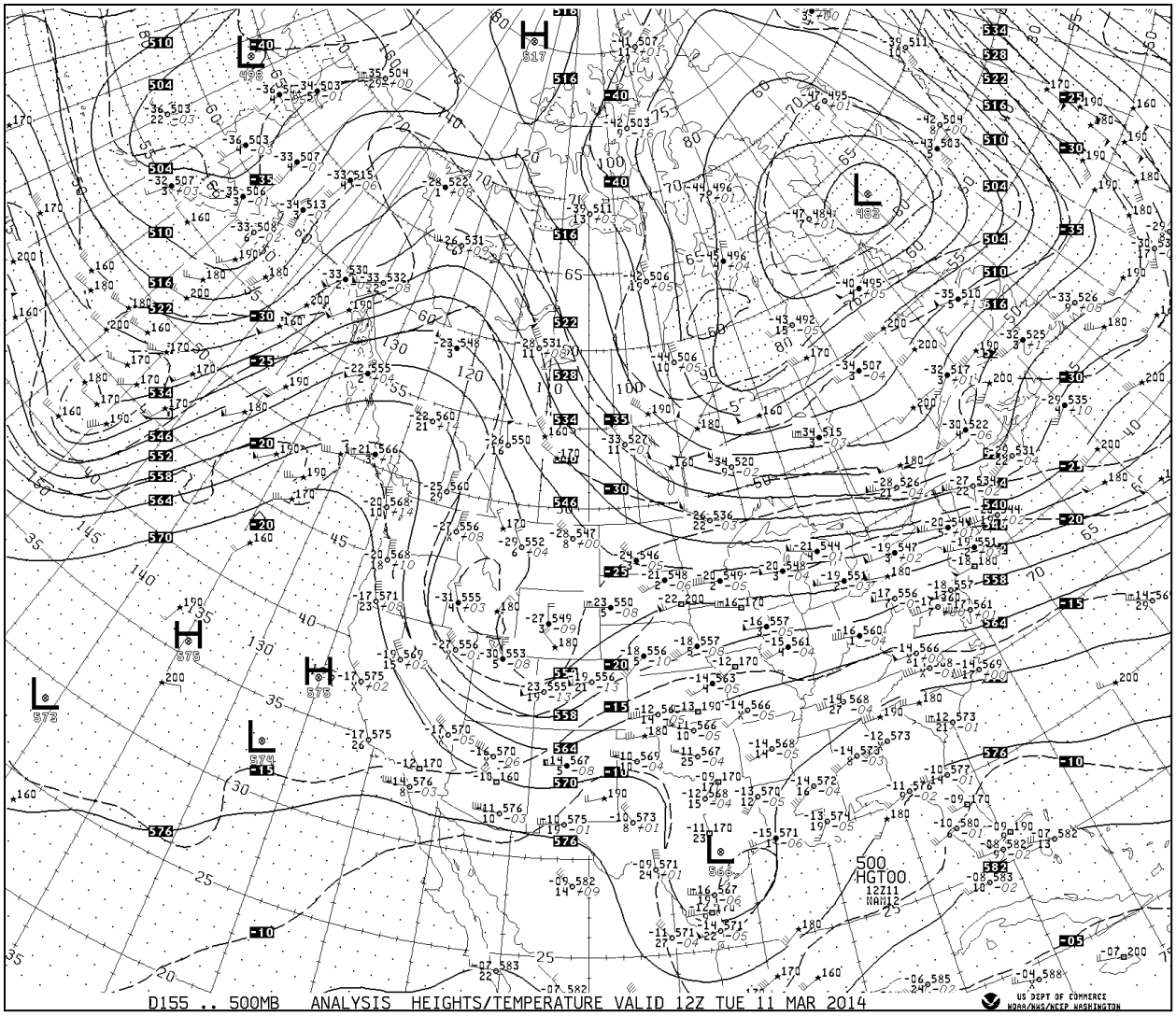


Figure 3: 500 mb (about 6 kilometers above mean sea level) analysis for 12Z March 11, 2014, or 5:00 AM MST March 11, 2014.
(Source: http://nomads.ncdc.noaa.gov/ncep/NCEP)

The surface weather associated with the storm system of March 11, 2014 is presented in Figure 4 and Figure 5. Significant surface features at 5:00 AM MST, March 11 (Figure 4) included a strong cold front that was moving southward through eastern Colorado. By 11:00 AM MST (Figure 5) the cold front had cleared eastern Colorado, leaving behind a significant amount of "bunching" of isobars. This indicates that a strong pressure gradient was in place. Wind speed is directly proportional to the pressure gradient, so a higher pressure gradient will produce stronger winds (see the following link for additional information on pressure gradient and its relationship to wind speed from the National Oceanic and Atmospheric Administration (NOAA): http://www.srh.noaa.gov/jetstream/synoptic/wind.htm). The strong pressure gradient was in response to a building ridge of high pressure in central Montana interacting with an intense area of low pressure in northeast New Mexico.

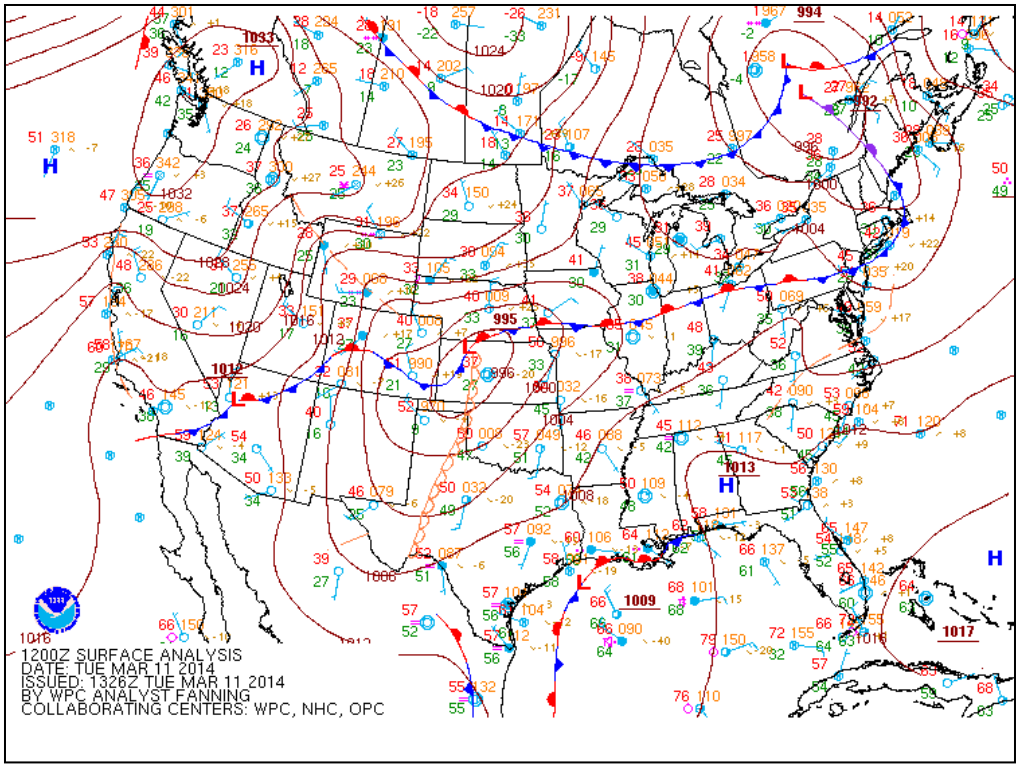


Figure 4: Surface Analysis for 12Z March 11, 2014, or 5:00 AM MST March 11, 2014. (Source: http://nomads.ncdc.noaa.gov/ncep/NCEP)

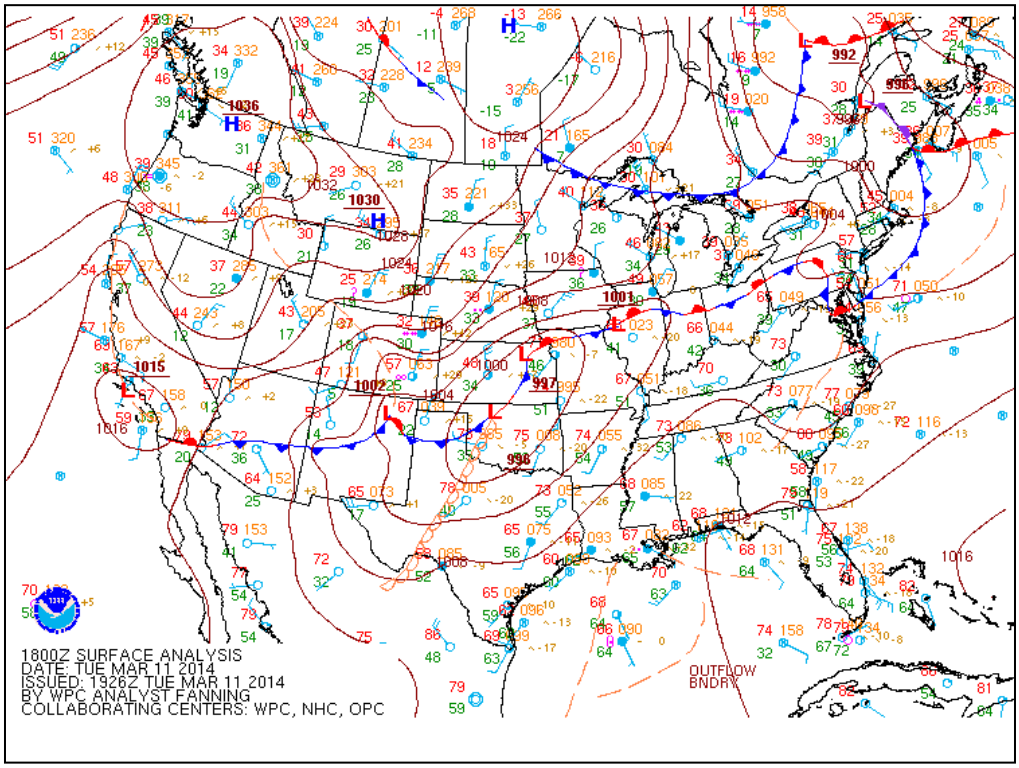


Figure 5: Surface Analysis for 18Z March 11, 2014, or 11:00 AM MST March 11, 2014. (Source: http://nomads.ncdc.noaa.gov/ncep/NCEP)

In order to fully evaluate the synoptic meteorological scenario of March 11, 2014, a regional surface weather map is provided showing individual station observations during the height of the event in question. Figure 6 presents weather observations for eastern Colorado and adjacent states at 1:43 PM MST, March 11. The station observation for Lamar (LAA) shows winds sustained at 30 knots (35 mph), gusts to 40 knots (46 mph), and a reduced visibility of 1 statute mile with the weather symbol of infinity (∞). The infinity sign is the weather symbol for haze. Haze is often reported during dust storms, and in dry and windy conditions haze typically refers to blowing dust (see the following link for the description of haze published by the National Oceanic and Atmospheric Administration (NOAA): http://www.crh.noaa.gov/lmk/?n=general_glossary). Also note that to the west of Lamar in nearby La Junta (LHX) and Pueblo (PUB), similar weather conditions were reported with high winds, haze and poor visibility. Additionally, to the east of Lamar in Garden City, KS (GCK) high winds and poor visibility were also observed with the weather symbol of the dollar sign ($). The dollar sign in meteorological observations is defined as "dust or sand raised by the wind at the time of the observation" (source: http://oceanservice.noaa.gov/education/yos/resource/JetStream/synoptic/ww_symbols.htm). This collection of weather observations indicates that a regional blowing dust event was indeed occurring on March 11, 2014.

Hourly surface observations, in table form, from Lamar and other regional weather stations provide supporting evidence that there was an extended period of high winds and haze (blowing dust) across the High Plains. Table 1 lists observations for the PM_{10} exceedance location of Lamar while La Junta, Pueblo and Garden City observations can be found in Table 2 through Table 4, respectively. Observations that are climatologically consistent with blowing dust conditions (see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2) are highlighted in yellow. Collectively, these four sites experienced many hours of reduced visibility along with sustained wind speeds and gusts at or above the thresholds for blowing dust.

Surface weather maps and hourly observations show that a regional dust storm occurred under north to northeasterly flow in the wake of a cold front. This data provides clear evidence of blowing dust and winds above the threshold speeds for blowing dust on March 11, 2014.

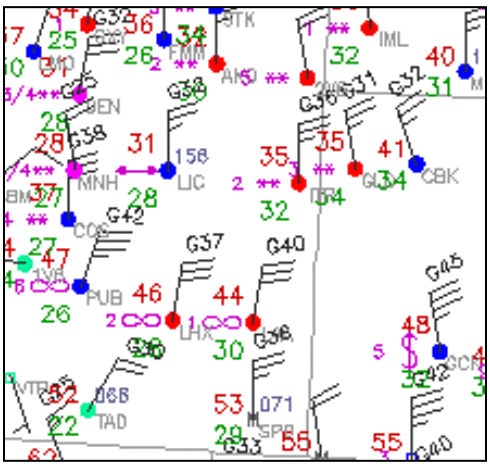


Figure 6: High Plains regional surface analysis for 1:43 PM MST, March 11, 2014. (Source: http://www.mmm.ucar.edu/imagearchive/)

Table 1: Weather observations for Lamar, Colorado, on March 11, 2014 (Source: http://mesowest.utah.edu/)

Time MST March 11, 2014	Temperature Degrees F	Relative Humidity in %	Wind Speed in mph	Wind Gust in mph	Wind Direction in Degrees	Weather	Visibility in miles
0:53	46	49	9		260		10
1:53	48	42	10		220		10
2:53	44	51	14		320		10
3:53	42	53	8		300		10
4:53	50	33	17	23	350		10
5:53	49	37	17		360		10
6:53	48	42	17		350		10
7:53	50	42	16		350		10
8:53	56	31	37	48	360		7
9:53	58	30	37	47	360		7
10:02	57	33	38	46	10	haze	6
10:53	53	46	39	47	360	haze	3
11:53	54	40	36	48	10	haze	4
12:29	51	46	38	48	20	haze	3
12:53	49	50	33	46	20	haze	2
13:00	47	53	37	48	10	haze	1
13:25	44	57	33	46	10	haze	2
13:53	44	55	36	46	10	haze	2
14:04	44	55	29	43	20	haze	3
14:14	44	53	32	41	20	haze	4
14:33	44	53	32	43	20	haze	5
14:53	43	55	30	39	10	haze	4
15:39	42	53	30	38	10	haze	2
15:53	42	53	35	46	10	haze	3
16:10	41	57	32	44	10	haze	5
16:53	39	59	32	45	20	haze	4
17:53	38	62	24	32	20		8
18:42	38	64	21	30	10		10
18:53	38	64	23	32	10		10
19:11	37	64	17	28	10		10
19:53	36	67	16		360		10
20:53	35	66	12		340		10

Table 2: Weather observations for La Junta, Colorado, on March 11, 2014 (Source: http://mesowest.utah.edu/)

Time MST March 11, 2014	Temperature Degrees F	Relative Humidity in %	Wind Speed in mph	Wind Gust in mph	Wind Direction in Degrees	Weather	Visibility in miles
5:01	51	30	13		340		10
5:53	47	40	12		330		10
6:53	48	40	9		330		10
7:53	50	41	10		320		10
8:53	56	29	31	39	10	haze	5
9:53	58	26	32	39	10		10
10:47	57	28	33	44	10	haze	2.5
10:48	57	29	31	44	10	haze	2.5
11:03	55	35	37	46	10	haze	1.25
11:15	55	35	35	48	10	haze	2
11:41	54	38	41	48	20	haze	1
11:48	54	38	39	51	10	haze	0.5
11:53	54	37	36	48	10	haze	0.75
12:01	55	37	32	46	10	haze	1.25
12:37	50	44	39	48	10	haze	1
12:43	50	44	36	44	10	haze	2
12:53	48	47	33	45	20	haze	2.5
13:07	47	49	30	43	360	haze	1.75
13:12	47	48	32	45	10	haze	3
13:19	46	49	35	43	10	haze	2.5
13:41	45	53	33	39	20	haze	4
13:53	45	53	30	40	360	haze	6
14:53	43	53	32	41	10		9
15:53	41	53	35	43	360	haze	2
16:08	41	53	36	46	10	haze	1
16:15	40	55	36	44	360	haze	2
16:29	40	55	37	44	360	haze	4
16:53	39	52	30	40	10		8
17:53	38	57	30	40	10		10
18:53	37	56	22	32	10		10

Table 3: Weather observations for Pueblo, Colorado, on March 11, 2014 (Source: http://mesowest.utah.edu/)

Time MST March 11, 2014	Temperature Degrees F	Relative Humidity in %	Wind Speed in mph	Wind Gust in mph	Wind Direction in Degrees	Weather	Visibility in miles
0:53	45	40	9		190		10
1:53	45	35	5		200		10
2:53	51	22	5		230		10
3:53	45	34	10		290		10
4:53	43	38	10		260		10
5:53	39	46	6		290		10
6:53	40	46	8		300		10
7:53	40	44	10		290		10
8:53	51	36	5		310		10
9:53	58	22	25	32	290		10
10:53	60	18	27	36	290		10
11:53	55	31	28	36	30		10
12:53	50	43	32	44	20		10
13:07	48	44	33	46	30	haze	6
13:53	47	44	41	48	20	haze	6
14:53	45	45	38	47	20	haze	6
15:53	43	47	43	52	20		10
16:53	41	45	36	47	20		10
17:53	39	48	32	45	20		10
18:53	38	52	33	43	20		10
19:53	36	56	23	33	30		10
20:53	36	54	29	33	30		10
21:53	35	54	25		30		10
22:53	35	49	18		20		10

Table 4: Weather observations for Garden City, Kansas, on March 11, 2014 (Source: http://mesowest.utah.edu/)

Time MST March 11, 2014	Temperature Degrees F	Relative Humidity in %	Wind Speed in mph	Wind Gust in mph	Wind Direction in Degrees	Weather	Visibility in miles
6:54	53	41	27		340		10
7:54	57	39	33	43	360		10
8:54	58	40	36	44	360		10
9:54	54	53	38	46	350		10
10:25	55	51	38	50	350	blowing dust	7
10:54	54	50	32	50	340	haze; blowing dust	5
11:25	52	52	38	51	360	blowing dust	7
11:54	49	54	40	52	350	blowing dust	7
12:01	49	54	38	52	360	blowing dust	7
12:08	49	54	43	51	350	blowing dust	7
12:54	47	56	43	52	360	haze; blowing dust	6
13:01	48	54	41	52	350	haze; blowing dust	5
13:54	43	62	41	53	360	blowing dust	8
14:54	44	57	35	52	10	blowing dust	10
15:11	45	56	40	52	10	blowing dust	10
15:47	43	62	38	53	360	blowing dust	7
15:54	43	62	33	47	360	blowing dust	8
16:54	39	70	41	56	360	blowing dust	10
17:16	37	82	38	52	360	lt snow; blowing dust	6
17:40	37	82	44	52	360	blowing dust	10
17:54	37	78	35	45	360	blowing dust	10
18:54	37	78	33	40	360	blowing dust	10
19:25	37	75	29	43	360	blowing dust	10
19:54	36	75	28	40	360	blowing dust	10

Satellite imagery from March 11, 2014 provides further evidence that dust caused the PM_{10} exceedance in Lamar. Specifically, the Moderate Resolution Imaging Spectroradiometer (MODIS) Terra and Aqua images clearly show dust plumes blowing across southeast Colorado at the same time haze and reduced visibility were being reported in Lamar. Additional information on MODIS can be found at the National Aeronautics and Space Administration (NASA) website (https://earthdata.nasa.gov/data/near-real-time-data/data/instrument/modis)

Figure 7 shows the MODIS Terra satellite image zoomed on southeast Colorado at approximately 11:05 AM MST (1805Z). Numerous dust plumes can be easily identified throughout the region. According to the surface observation for Lamar at 10:53 PM MST (12

minutes before the MODIS Terra image) in Table 1, sustained winds of 39 mph were recorded along with wind gusts of 47 mph, haze and visibility reduced to 3 statute miles. This is an observation that is consistent with blowing dust conditions in southeast Colorado (30 mph sustained winds, 40 mph gusts; see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2). Figure 8 is the MODIS Aqua satellite image of southeast Colorado at around 12:45 PM MST (1945Z). Dust plumes remain prominent in southeast Colorado, indicating that there was an extended period of blowing dust in the Lamar area.

The National Oceanic and Atmospheric Administration (NOAA) Satellite Services Division was in agreement with the conclusion that blowing dust was occurring in southeast Colorado. The Smoke Text Product from NOAA at 11:00 AM MST on March 11, 2014 stated:

> "Several large plumes of blowing dust/sand were observed over southeast Colorado and far western Kansas moving to the south towards the Oklahoma Panhandle." (Source: http://www.ssd.noaa.gov/PS/FIRE/DATA/SMOKE/2014/2014C111803.html)

Additionally, the Pueblo office of the National Weather Service and the Colorado Department of Public Health and Environment issued Blowing Dust Advisories for southeast Colorado in anticipation of the blowing dust event of March 11, 2014. Text from these advisories includes:

> "Visibilities…will drop to less than 1 mile at times due to blowing dust…particularly down wind of plowed fields or in areas where vegetation growth has been limited by long term drought and soils remain loose." (Source: http://mesonet.agron.iastate.edu/wx/afos/)

> "People with heart or lung disease, older adults, and children in the affected area should reduce prolonged or heavy indoor and outdoor exertion." (Source: http://www.colorado.gov/airquality/forecast_archive.aspx?seeddate=03%2f11%2f2014)

And to further confirm the presence of a dust storm in southeast Colorado, a webcam image at Gobblers Knob (20 miles south of Lamar) is presented in Figure 9. This image was captured at 11:15 AM MST (10 minutes after the MODIS Terra image of Figure 7) and verifies that there was a considerable amount of airborne dust over southeast Colorado with the horizon almost completely obscured.

Satellite products combined with reports, advisories and webcam imagery from southeast Colorado on March 11 clearly reveal that a regional dust storm was anticipated and did take place which was not controllable or preventable.

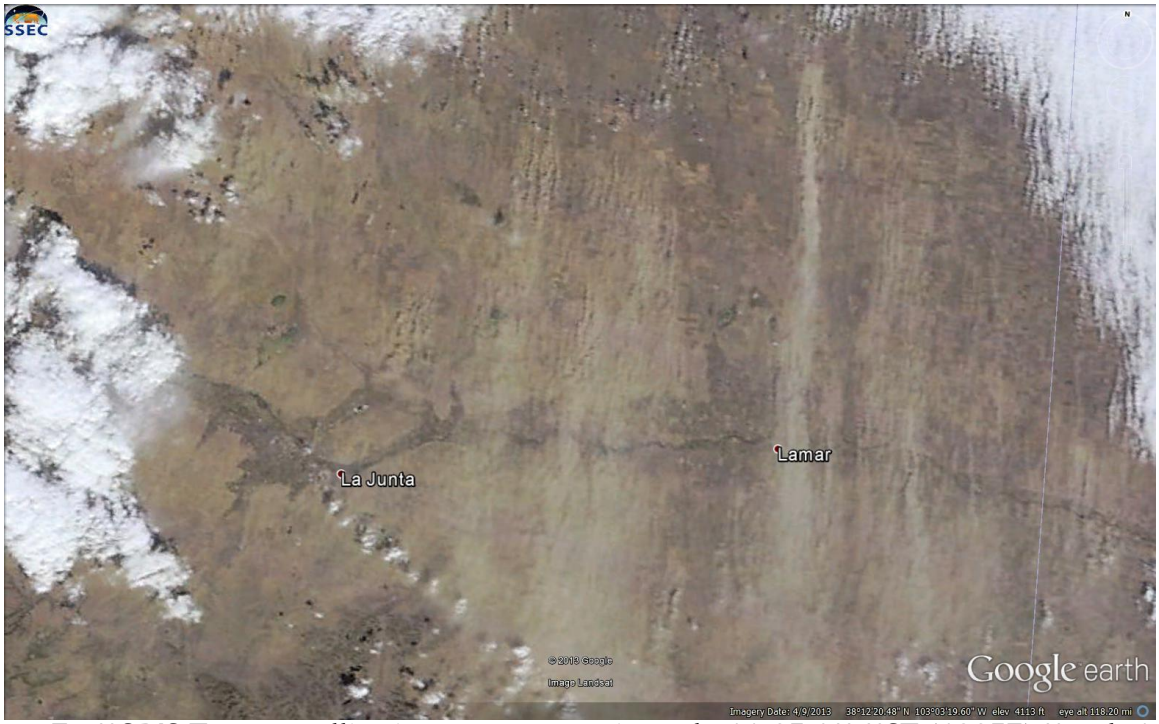


Figure 7: MODIS Terra satellite image at approximately 11:05 AM MST (1805Z) March 11, 2014.
(Source: http://ge.ssec.wisc.edu/modis-today/index.php)

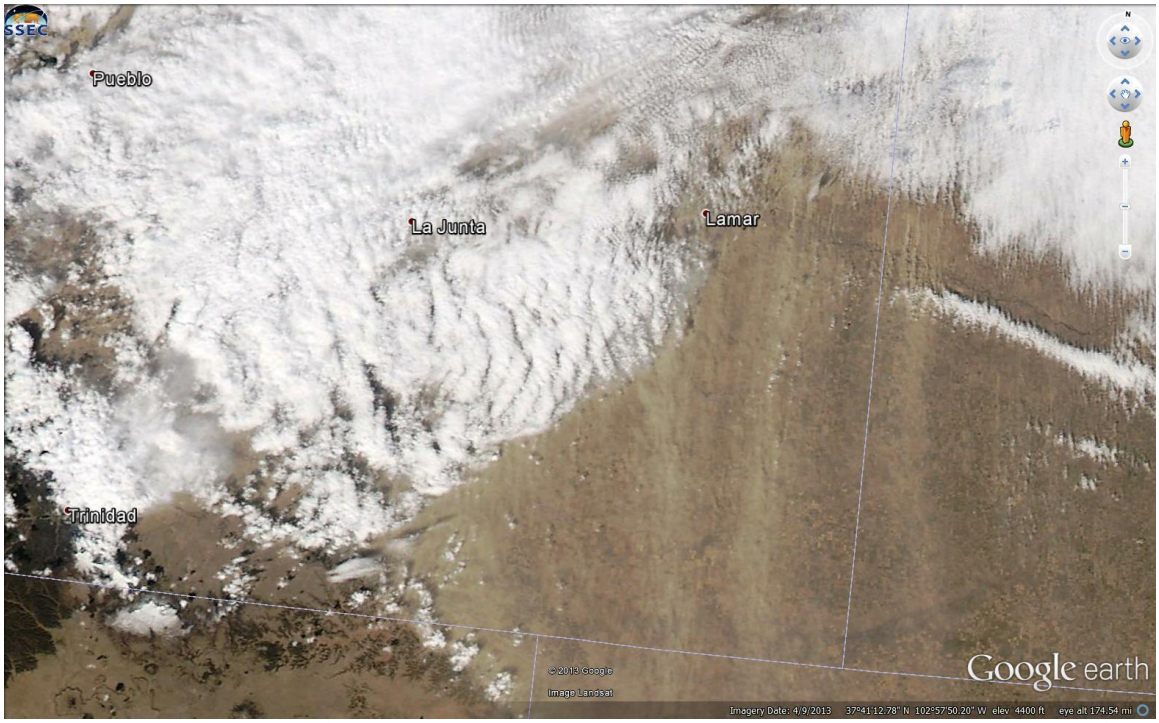


Figure 8: MODIS Aqua satellite image at approximately 12:45 AM MST (1945Z) March 11, 2014.
(Source: http://ge.ssec.wisc.edu/modis-today/index.php)

Figure 9: Gobblers Knob webcam image at 11:15 AM MST March 11, 2014. (Source: http://amos.cse.wustl.edu/)

The synoptic weather conditions described above impacted a region that was in the midst of a severe to exceptional drought (Figure 10). Sustained drought conditions are known to make topsoil susceptible to high winds and produce blowing dust (see the following link from the National Climatic Data Center for more information: https://www.ncdc.noaa.gov/paleo/drought/drght_history.html). Figure 11 shows the total precipitation in inches from February 10, 2014 to March 11, 2014 for Colorado. Note that a large portion of southeast Colorado received less than 0.3 inches of precipitation, particularly upwind from Lamar (northerly), during the 30-day period leading up to the March 11, 2014 dust event in Lamar. Based on previous research 0.5 to 0.6 inches of precipitation over a 30-day period has been found to be the approximate threshold, below which, blowing dust exceedances at Lamar are more likely to occur when combined with high winds (see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2).

The U.S. Drought Monitor and 30-day precipitation totals indicate that soils in southeast Colorado near Lamar were dry enough to produce blowing dust when winds were above the thresholds for blowing dust. This information, combined with other evidence provided in this report, proves that this dust storm was a natural, regional event that was not reasonably controllable or preventable.

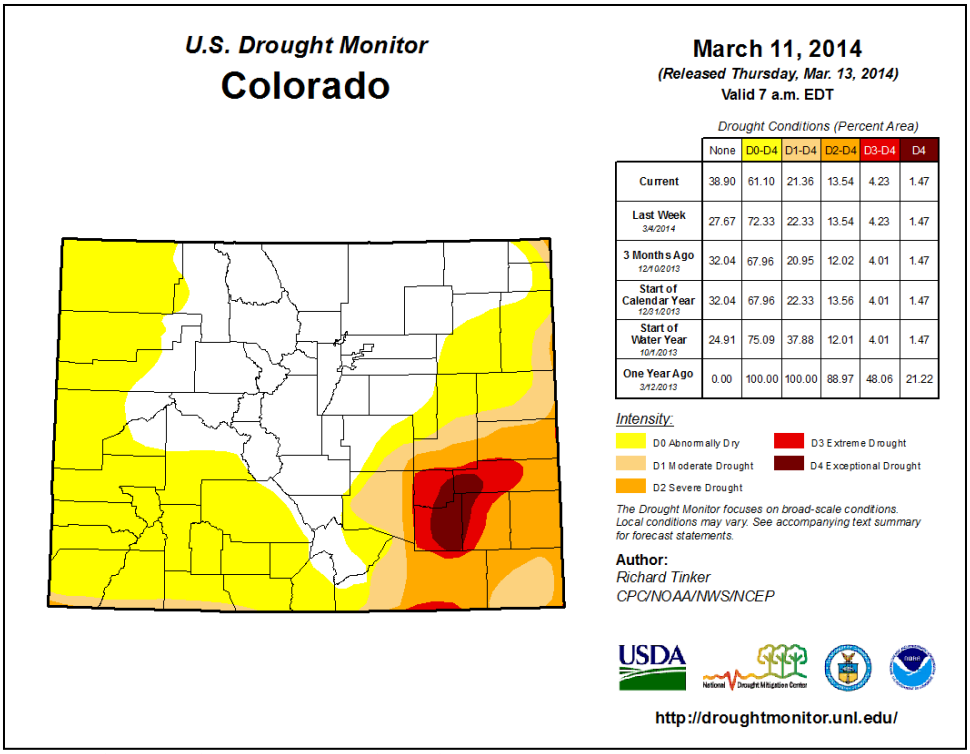


Figure 10: Drought conditions for Colorado at 5:00 AM MST March 11, 2014. (Source: http://droughtmonitor.unl.edu/MapsAndData/MapArchive.aspx)

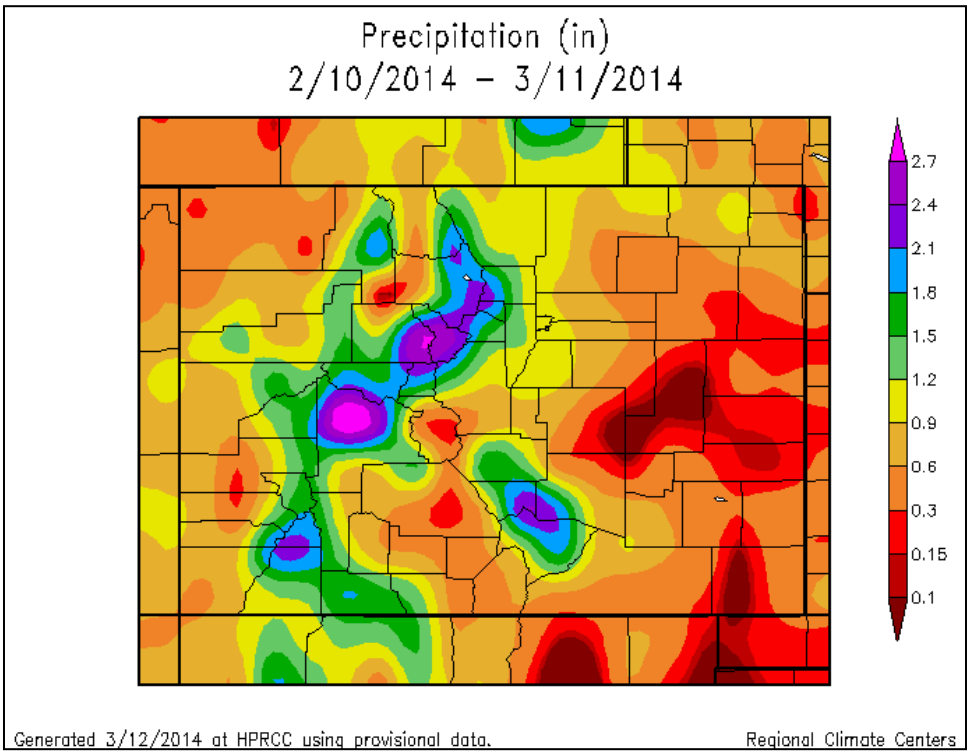


Figure 11: Total precipitation in inches for Colorado, February 10, 2014 – March 11, 2014.
(Source: http://www.hprcc.unl.edu/maps/current/)

2.2 March 15, 2014 Meteorological Analysis

On March 15 of 2014, a powerful late winter storm system caused an exceedance of the 24-hour PM_{10} standard in Lamar, Colorado, at the Municipal Building monitor with a concentration of 173 $\mu g/m^3$. This elevated reading and the location of the monitor is plotted on a map of the Greater Lamar area in Figure 12. The exceedance in Lamar was the result of intense surface winds which were produced by a very strong upper-level trough that was moving across the western United States. The surface winds were predominantly out of a northerly direction which moved over dry soils in eastern Colorado, producing significant blowing dust.

Figure 12: 24-hour PM_{10} concentration for the Lamar Municipal Building monitor, March 15, 2014.
(Source: http://webapps.datafed.net/datafed.aspx?dataset=AQS_D&parameter=pm10)

The upper-level trough associated with this storm system is shown on the 700 mb and 500 mb height analysis maps at 5:00 AM MST, March 15, 2014 in Figure 13 and Figure 14, respectively. The 700 mb level is located roughly 3 kilometers above mean sea level (MSL) while the 500 mb level is approximately 6 kilometers above MSL. These two charts show that a deep trough of low pressure was present at both the 700 and 500 mb level just a few hours before the onset of the blowing dust event of March 15 and that it was moving over the southwestern United States. This is a typical upper-air pattern for blowing dust events in Colorado (see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2).

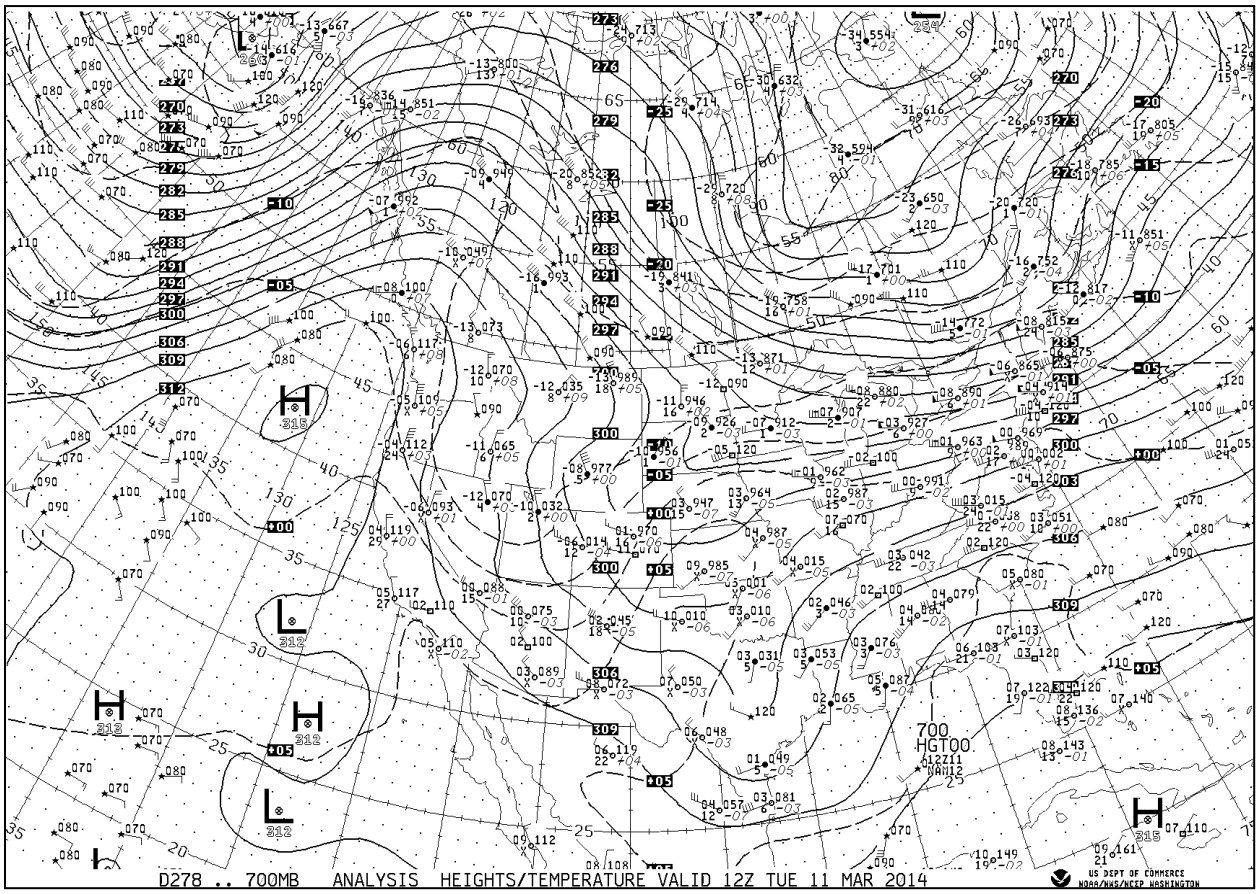


Figure 13: 700 mb (about 3 kilometers above mean sea level) analysis for 12Z March 15, 2014, or 5:00 AM MST March 15, 2014.
(Source: http://nomads.ncdc.noaa.gov/ncep/NCEP)

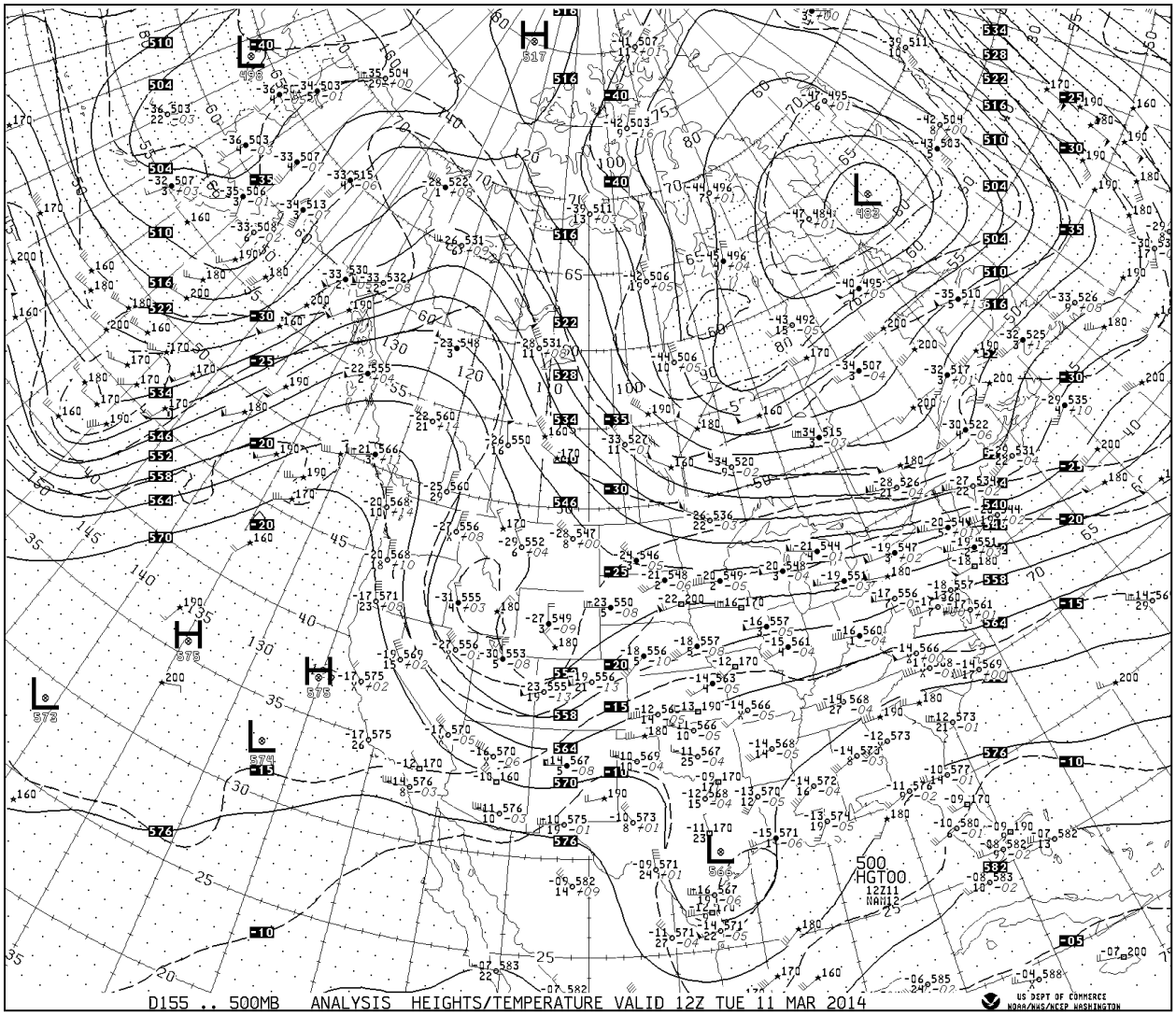


Figure 14: 500 mb (about 6 kilometers above mean sea level) analysis for 12Z March 15, 2014, or 5:00 AM MST March 15, 2014.
(Source: http://nomads.ncdc.noaa.gov/ncep/NCEP)

In order to fully evaluate the synoptic meteorological scenario of March 15, 2014, a regional surface weather map is provided showing individual station observations during the height of the event in question. Figure 15 presents weather observations for eastern Colorado and adjacent states at 5:43 PM MST, March 15. The station observation for Lamar (LAA) shows winds sustained at 35 knots (40 mph), gusts to 46 knots (53 mph), and a reduced visibility of 2 statute miles with the weather symbol of infinity (∞). The infinity sign is the weather symbol for haze. Haze is often reported during dust storms, and in dry and windy conditions haze typically refers to blowing dust (see the following link for the description of haze published by the National Oceanic and Atmospheric Administration (NOAA): http://www.crh.noaa.gov/lmk/?n=general_glossary). Also note that to the west of Lamar in nearby La Junta (LHX), similar weather conditions were reported with high winds, haze and poor visibility. This indicates that a regional blowing dust event was occurring in southeast Colorado on March 15, 2014, and was not confined to the Lamar area.

Hourly surface observations, in table form, from Lamar and La Junta provide supporting evidence that there was an extended period of high winds and haze (blowing dust) across southeast Colorado. Table 5 lists observations for the PM_{10} exceedance location of Lamar while La Junta observations can be found in Table 6. Observations that are climatologically consistent with blowing dust conditions (see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2) are highlighted in yellow. Collectively, these two sites experienced many hours of reduced visibility along with sustained wind speeds and gusts at or above the thresholds for blowing dust.

Surface weather maps and hourly observations show that a regional dust storm occurred under northerly flow. This data provides clear evidence of blowing dust and winds above the threshold speeds for blowing dust on March 15, 2014.

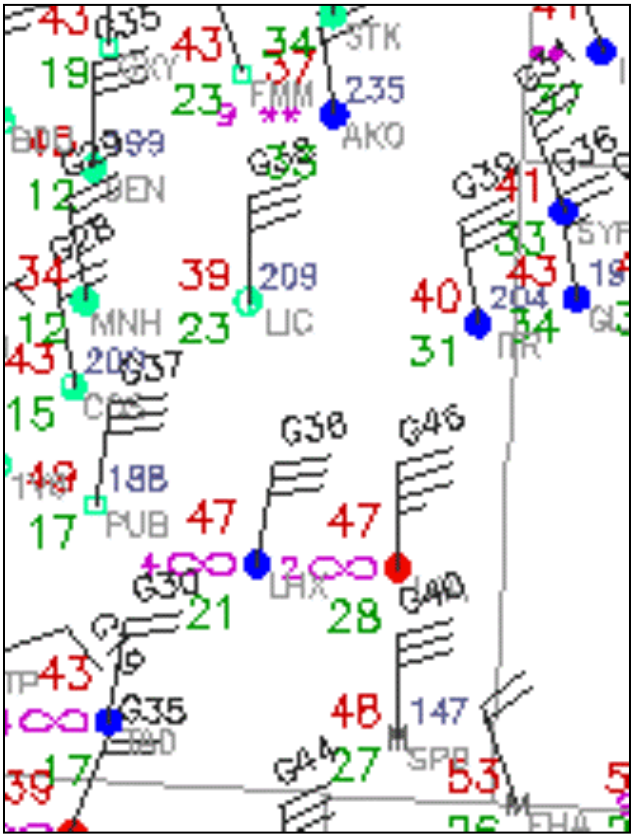


Figure 15: High Plains regional surface analysis for 5:43 PM MST, March 15, 2014. (Source: http://www.mmm.ucar.edu/imagearchive/)

Table 5: Weather observations for Lamar, Colorado, on March 15, 2014 (Source: http://mesowest.utah.edu/)

Time MST March 15, 2014	Temperature Degrees F	Relative Humidity in %	Wind Speed in mph	Wind Gust in mph	Wind Direction in Degrees	Weather	Visibility in miles
0:53	41	44	12		200		10
1:53	41	42	6		320		10
2:53	39	46	5		270		10
3:53	34	61	6		240		10
4:53	34	69	6		290		10
5:53	32	78	6		270		10
6:53	35	72	8		280		10
7:53	45	47	5		20		10
8:53	58	23	22	29	30		10
9:53	60	22	20	28	30		10
10:53	62	20	31	37	360		10
11:53	63	21	32	43	350	haze	6
12:03	62	22	32	44	360	haze	6
12:53	61	24	40	48	360	haze	6
13:53	55	38	40	53	360	haze	3
14:26	54	38	33	47	350	haze	5
14:53	53	38	33	44	360		7
15:53	53	39	32	40	350		7
16:53	48	46	36	48	360	haze	5
17:09	48	44	37	51	360	haze	3
17:24	47	48	40	53	360	haze	3
17:47	45	53	35	50	360	haze	3
17:53	45	53	37	50	360	haze	4
18:53	42	62	28	37	360		10
19:53	41	67	18	29	360		10
20:53	40	67	17	29	10		10
21:53	40	67	15		10		10
22:53	38	73	13		350		10
23:53	38	73	8		330		10

Table 6: Weather observations for La Junta, Colorado, on March 15, 2014 (Source: http://mesowest.utah.edu/)

Time MST March 15, 2014	Temperature Degrees F	Relative Humidity in %	Wind Speed in mph	Wind Gust in mph	Wind Direction in Degrees	Weather	Visibility in miles
0:53	44	55	15		230		10
1:53	44	57	16		250		10
2:53	38	70	14		270		10
3:53	34	79	14		270		10
4:53	34	75	15		270		10
5:53	33	72	10		270		10
6:53	36	64	14		290		10
7:53	44	49	10		300		10
8:53	54	28	6		50		10
9:53	58	19					10
10:53	61	16	22	32	360		7
11:43	58	22	38	45	360	haze	0.75
11:53	56	24	32	40	350	haze	0.25
12:00	57	23	30	39	350	haze	1.25
12:08	57	22	28	41	350	haze	0.75
12:13	57	21	31	39	340	haze	1.25
12:20	57	21	32	41	360	haze	0.75
12:33	56	21	35	44	350	haze	0.5
12:53	56	25	37	46	340	lt rain	0.25
13:15	53	26	38	50	350	lt rain	0.25
13:53	51	35	39	47	10	lt rain	0.25
14:09	51	35	37	51	360	lt rain	0.25
14:53	51	32	36	48	10	lt rain	0.25
15:53	51	32	37	51	20	haze	0.75
16:24	49	34	38	45	10	haze	1.25
16:30	49	34	39	48	20	haze	0.75
16:41	48	34	36	47	20	haze	1.25
16:49	48	34	37	46	10	haze	3
16:50	48	35	35	46	20	haze	3
16:56	48	34	41	48	10	haze	1.75
17:11	48	34	32	44	10	haze	3
17:27	47	35	32	41	10	haze	4
17:53	45	42	36	39	10	haze	5
18:53	42	55	24	38	10		10
19:53	40	62	20		20		10

Satellite imagery from March 15, 2014 provides further evidence that dust caused the PM_{10} exceedance in Lamar. Specifically, the Moderate Resolution Imaging Spectroradiometer (MODIS) Aqua image clearly shows dust plumes blowing across southeast Colorado at the same time haze and reduced visibility were being reported in Lamar. Additional information on MODIS can be found at the National Aeronautics and Space Administration (NASA) website (https://earthdata.nasa.gov/data/near-real-time-data/data/instrument/modis).

Figure 16 shows the MODIS Aqua satellite image zoomed on southeast Colorado at approximately 12:25 PM MST (1925Z). Numerous dust plumes can be seen to the northwest of Lamar (circled in red). Lamar is somewhat obscured by cloud cover, but surface observations confirm that blowing dust was occurring there as well. According to the surface observations for Lamar at 12:03 PM and 12:53 PM MST (Table 5, the time period encompassing the image of Figure 16), sustained winds of 32-40 mph were recorded along with wind gusts of 44-48 mph, haze and visibility reduced to 6 statute miles. This is an observation that is consistent with blowing dust conditions in southeast Colorado (30 mph sustained winds, 40 mph gusts; see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2).

The National Oceanic and Atmospheric Administration (NOAA) Satellite Services Division was in agreement with the conclusion that blowing dust was occurring in southeast Colorado. The Smoke Text Product from NOAA at 5:45 PM MST on March 15, 2014 stated:

> "Strong northerly winds are kicking up dust/sand and loose soils across much of SE Colorado south of US40 in Lincoln and Cheyenne counties where individual narrow N-S bands/plumes consolidated and became moderately to dense sand strom (sic) across E Animas and Baca counties before moving into NM, Texas county OK and far NW portions of the TX panhandle as far south as I-40 in Quay county." (Source: http://www.ssd.noaa.gov/PS/FIRE/DATA/SMOKE/2014/2014C160051.html)

Additionally, both the Pueblo office of the National Weather Service and the Colorado Department of Public Health and Environment issued Blowing Dust Advisories for southeast Colorado in anticipation of the blowing dust event of March 15, 2014. Text from these advisories includes:

> "A few areas may see visibility near zero in and around exposed fields." (Source: http://mesonet.agron.iastate.edu/wx/afos/)

> "People with heart or lung disease, older adults, and children in the affected area should reduce prolonged or heavy indoor and outdoor exertion." (Source: http://www.colorado.gov/airquality/forecast_archive.aspx?seeddate=03%2f15%2f2014)

And to further confirm the presence of a dust storm in southeast Colorado, a webcam image at Gobblers Knob (20 miles south of Lamar) is presented in Figure 17. This image was captured at 12:45 PM MST (20 minutes after the MODIS Terra image of Figure 16) and verifies that there was a considerable amount of airborne dust over southeast Colorado with the horizon highly obscured.

Satellite products combined with reports, advisories and webcam imagery from southeast Colorado on March 15 clearly reveal that a regional dust storm was anticipated and did take place which was not controllable or preventable.

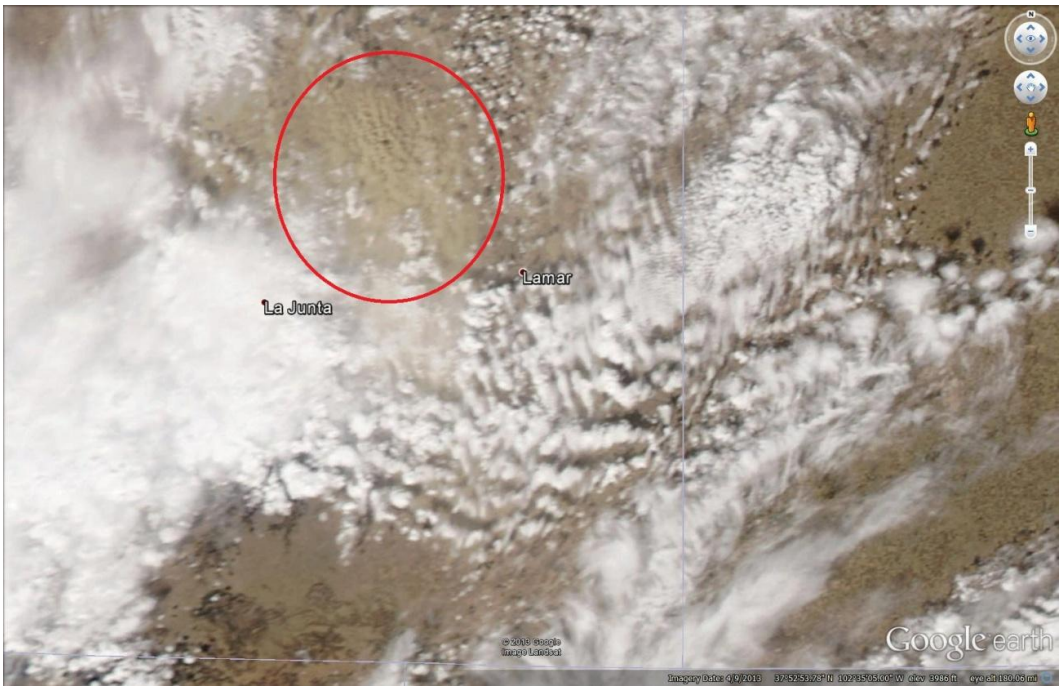


Figure 16: MODIS Aqua satellite image at approximately 12:25 PM MST (1925Z) March 15, 2014.
(Source: http://ge.ssec.wisc.edu/modis-today/index.php)

Figure 17: Gobblers Knob webcam image at 12:45 PM MST March 15, 2014.
(Source: http://amos.cse.wustl.edu/)

The synoptic weather conditions described above impacted a region that was in the midst of a severe to exceptional drought (Figure 18). Sustained drought conditions are known to make topsoil susceptible to high winds and produce blowing dust (see the following link from the National Climatic Data Center for more information: https://www.ncdc.noaa.gov/paleo/drought/drght_history.html). Figure 19 shows the total precipitation in inches from February 13, 2014 to March 14, 2014 for Colorado. Note that a large portion of southeast Colorado received less than 0.3 inches of precipitation, particularly upwind from Lamar (northerly), during the 30-day period leading up to the March 15 dust event in Lamar. Based on previous research 0.5 to 0.6 inches of precipitation over a 30-day period has been found to be the approximate threshold, below which, blowing dust exceedances at Lamar are more likely to occur when combined with high winds (see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2).

The U.S. Drought Monitor and 30-day precipitation totals indicate that soils in southeast Colorado near Lamar were dry enough to produce blowing dust when winds were above the thresholds for blowing dust. This information, combined with other evidence provided in this report, proves that this dust storm was a natural, regional event that was not reasonably controllable or preventable.

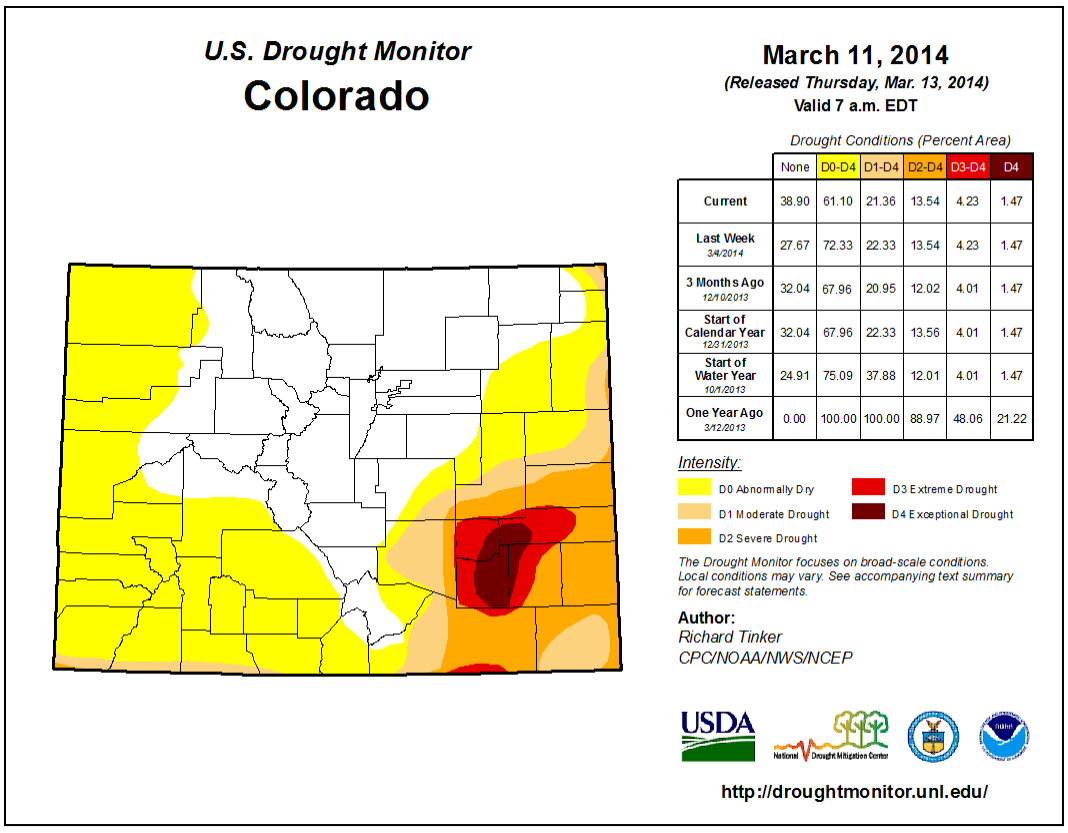


Figure 18: Drought conditions for Colorado at 5:00 AM MST March 11, 2014. (Source: http://droughtmonitor.unl.edu/MapsAndData/MapArchive.aspx)

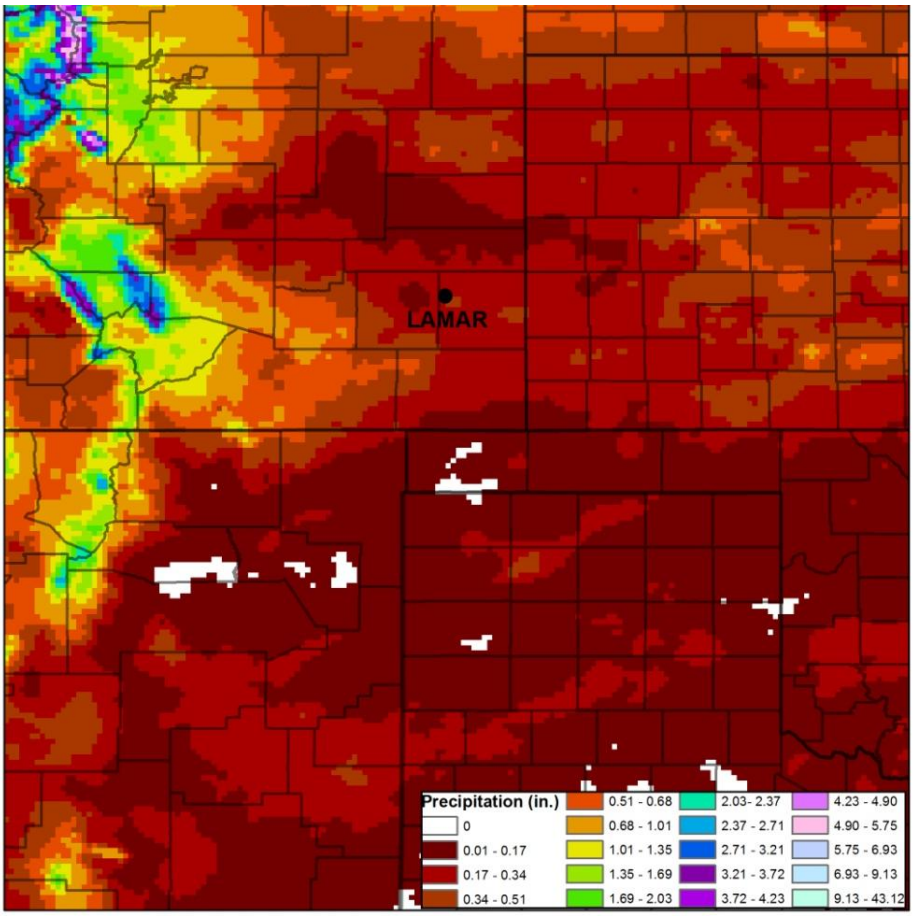


Figure 19: Total precipitation in inches for eastern Colorado and adjacent states, February 13, 2014 – March 14, 2014.
(Source: http://prism.nacse.org/recent/)

2.3 March 18, 2014 Meteorological Analysis

On March 18 of 2014, a powerful late winter storm system caused an exceedance of the 24-hour PM_{10} standard in Lamar, Colorado, at the Municipal Building monitor with a concentration of 299 $\mu g/m^3$. This highly elevated reading and the location of the monitor is plotted on a map of the Greater Lamar area in Figure 20. The exceedance in Lamar was the result of intense surface winds which were produced by a very strong upper-level trough that was moving across the western United States. The surface winds were predominantly out of a north to northwesterly direction which moved over dry soils in eastern Colorado, producing significant blowing dust.

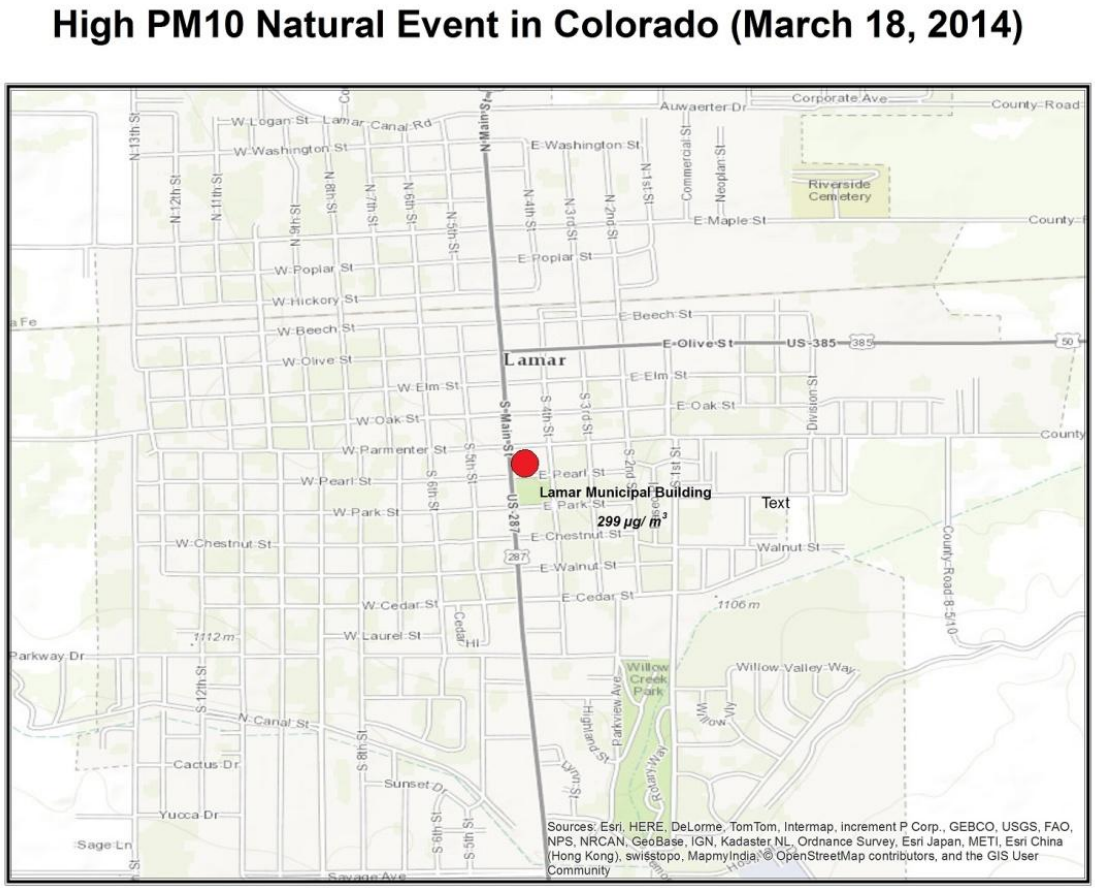


Figure 20: 24-hour PM_{10} concentration for the Lamar Municipal Building monitor, March 18, 2014.
(Source: http://webapps.datafed.net/datafed.aspx?dataset=AQS_D&parameter=pm10)

The upper-level trough associated with this storm system is shown on the 700 mb and 500 mb height analysis maps at 5:00 AM MST, March 18, 2014 in Figure 21 and Figure 22, respectively. The 700 mb level is located roughly 3 kilometers above mean sea level (MSL) while the 500 mb level is approximately 6 kilometers above MSL. These two charts show that a deep trough of low pressure was present at both the 700 and 500 mb level at the onset of the blowing dust event of March 18, 2014, and that it was moving over the southwestern United States. This is a typical upper-air pattern for blowing dust events in Colorado (see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2).

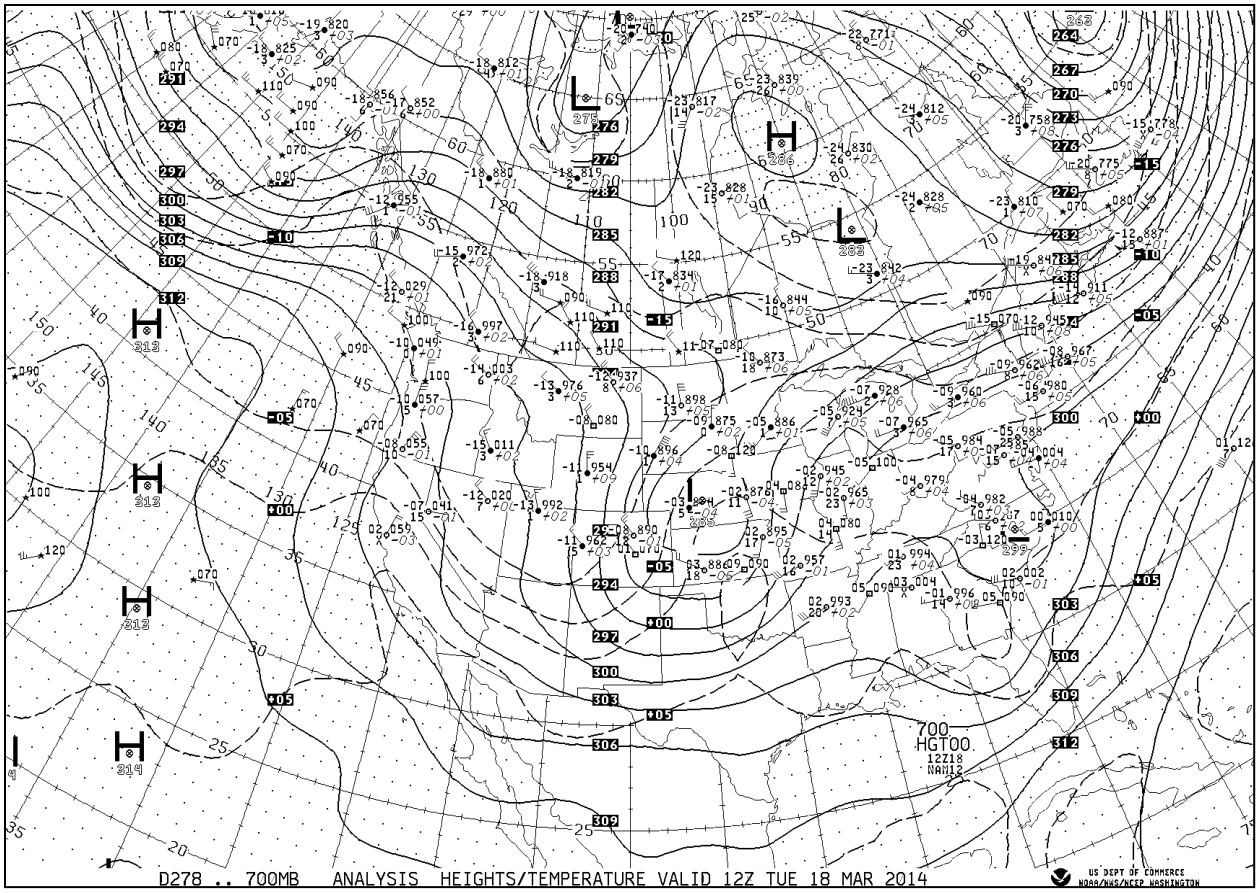


Figure 21: 700 mb (about 3 kilometers above mean sea level) analysis for 12Z March 18, 2014, or 5:00 AM MST March 18, 2014.
(Source: http://nomads.ncdc.noaa.gov/ncep/NCEP)

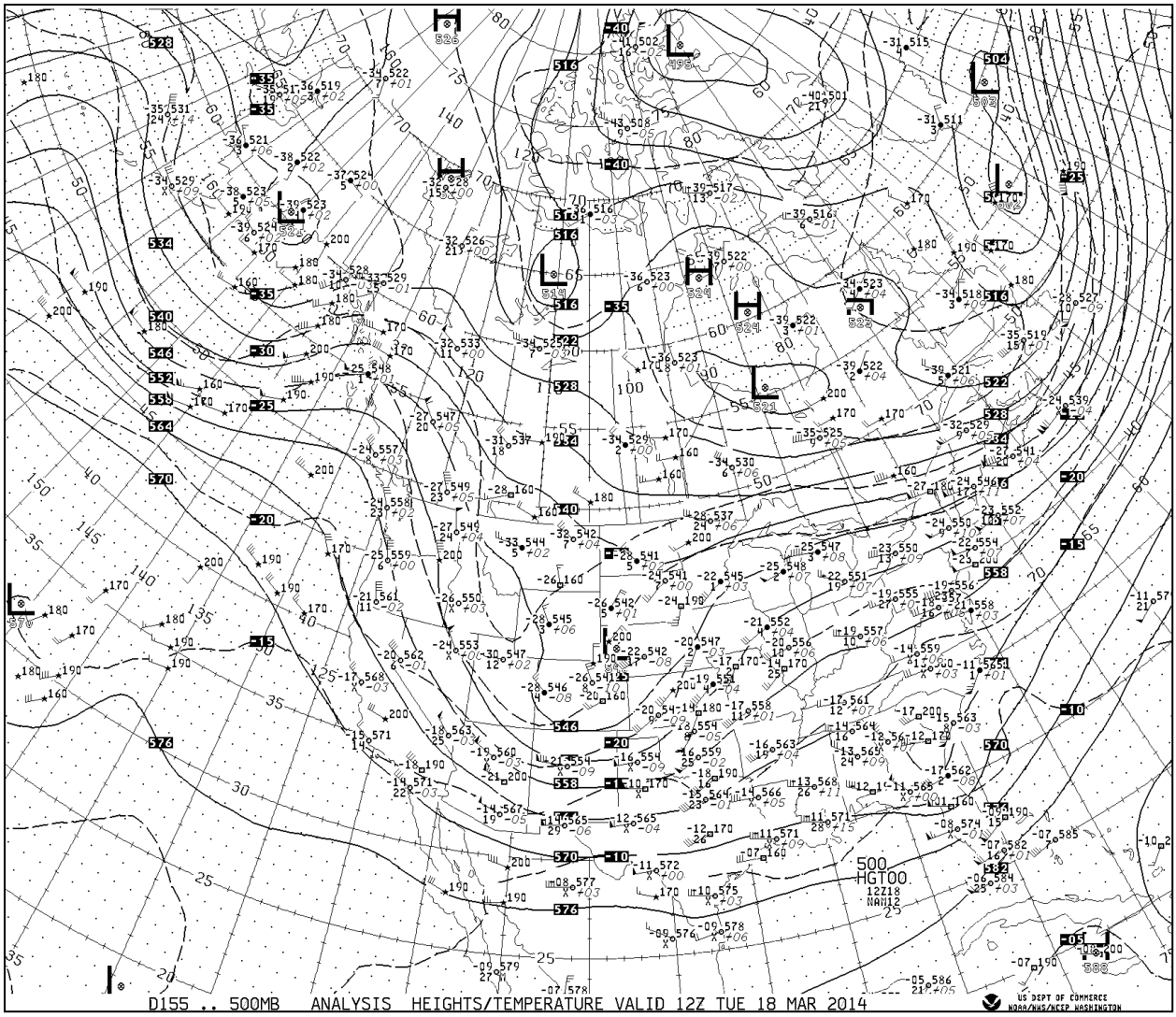


Figure 22: 500 mb (about 6 kilometers above mean sea level) analysis for 12Z March 18, 2014, or 5:00 AM MST March 18, 2014.
(Source: http://nomads.ncdc.noaa.gov/ncep/NCEP)

In order to fully evaluate the synoptic meteorological scenario of March 18, 2014, a regional surface weather map is provided showing individual station observations during the height of the event in question. Figure 23 presents weather observations for eastern Colorado and adjacent states at 10:43 AM MST, March 18. The station observation for Lamar (LAA) shows winds sustained at 30 knots (35 mph), gusts to 41 knots (47 mph), and a reduced visibility of 2 statute miles with the weather symbol of infinity (∞). The infinity sign is the weather symbol for haze. Haze is often reported during dust storms, and in dry and windy conditions haze typically refers to blowing dust (see the following link for the description of haze published by the National Oceanic and Atmospheric Administration (NOAA): http://www.crh.noaa.gov/lmk/?n=general_glossary). Also note that to the west of Lamar in nearby La Junta (LHX), the wind was even stronger with haze and very poor visibility (1/4 statute mile). This indicates that a regional blowing dust event was occurring in southeast Colorado on March 18, 2014 and was not confined to the Lamar area.

Hourly surface observations, in table form, from Lamar and La Junta provide supporting evidence that there was an extended period of high winds and haze (blowing dust) across southeast Colorado. Table 7 lists observations for the PM_{10} exceedance location of Lamar while La Junta observations can be found in Table 8. Observations that are climatologically consistent with blowing dust conditions (see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2) are highlighted in yellow. Collectively, these two sites experienced many hours of reduced visibility along with sustained wind speeds and gusts at or above the thresholds for blowing dust.

Surface weather maps and hourly observations show that a regional dust storm occurred under northerly flow. This data provides clear evidence of blowing dust and winds above the threshold speeds for blowing dust on March 18.

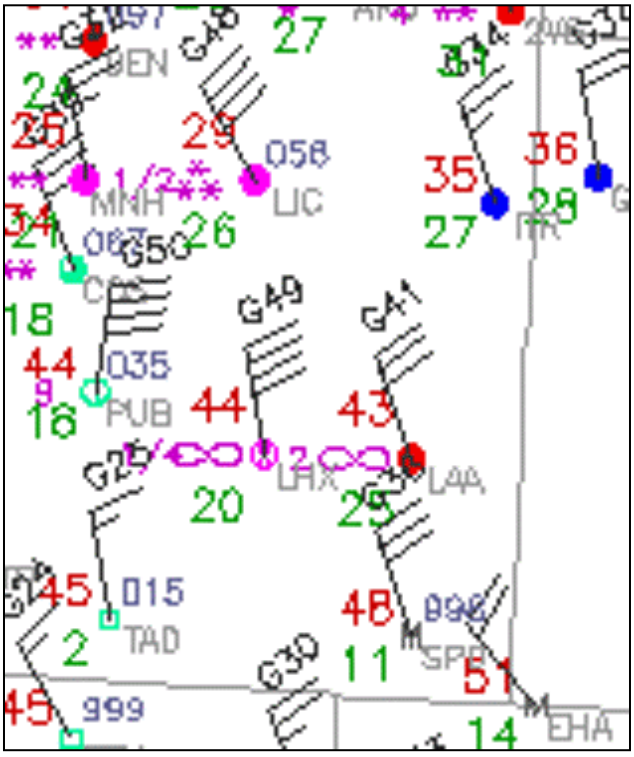


Figure 23: High Plains regional surface analysis for 10:43 AM MST, March 18, 2014. (Source: http://www.mmm.ucar.edu/imagearchive/)

Table 7: Weather observations for Lamar, Colorado, on March 18, 2014 (Source: http://mesowest.utah.edu/)

Time MST March 18, 2014	Temperature Degrees F	Relative Humidity in %	Wind Speed in mph	Wind Gust in mph	Wind Direction in Degrees	Weather	Visibility in miles
0:53	45	36	20	25	10		10
1:53	45	31	20		360		10
2:53	43	29	5				10
3:53	42	30	5		300		10
4:53	40	31	13	20	330		10
5:53	41	28	15	24	300		10
6:53	39	35	13		250		10
7:53	45	25	23	31	330		10
8:38	47	26	30	40	320	haze	6
8:53	48	27	39	47	320	haze	3
8:59	47	31	38	47	330	haze	1
9:18	46	37	32	48	330	haze	1
9:34	47	39	36	44	320	haze	1
9:51	45	45	43	51	320	haze	1
9:53	45	43	39	51	320	haze	1
10:06	44	49	35	50	330	haze	1
10:19	46	45	36	45	330	haze	1
10:35	43	51	38	51	340	haze	1
10:39	43	49	36	47	340	haze	2
10:45	43	49	32	47	350	haze	3
10:53	44	45	32	45	350	haze	3
11:36	45	40	35	46	340	haze	3
11:53	43	43	32	45	340	haze	3
12:03	43	43	33	44	330	haze	2
12:18	42	44	35	51	330	haze	1
12:26	42	46	31	44	340	haze	2
12:49	41	48	35	46	330	haze	2
12:53	41	48	32	45	340	haze	2
13:03	42	44	33	44	340	haze	3
13:07	42	44	41	50	340	haze	3
13:53	41	48	41	50	340	haze	3
14:04	40	48	37	52	350	haze	2
14:18	41	48	33	48	340	haze	4
14:53	42	46	36	50	360	haze	5
15:53	39	55	37	45	360		9
16:53	40	50	29	45	360		10
17:53	37	61	18	31	360		10
18:53	35	64	12		360		10

Table 8: Weather observations for La Junta, Colorado, on March 18, 2014 (Source: http://mesowest.utah.edu/)

Time MST March 18, 2014	Temperature Degrees F	Relative Humidity in %	Wind Speed in mph	Wind Gust in mph	Wind Direction in Degrees	Weather	Visibility in miles
7:53	41	42	10		270		10
8:32	46	24	30	36	340	haze	1.25
8:34	46	24	29	36	340	haze	0.75
8:37	47	24	33	44	340	haze	0.5
8:44	46	28	39	44	350	lt rain	0.25
8:53	46	30	36	44	340	lt rain	0.25
9:12	45	35	40	54	340	lt rain	0.25
9:53	44	38	46	56	340	haze	0.25
10:03	44	38	45	55	350	haze	0.25
10:34	44	38	48	56	350	haze	0.25
10:42	44	38	41	56	340	haze	0.25
10:53	43	39	44	58	340	haze	0.25
11:26	43	39	38	58	340	haze	0.25
11:53	42	46	47	59	350	haze	0.25
12:10	44	41	41	54	350	haze	0.25
12:25	44	40	46	55	340	haze	0.25
12:44	44	35	45	54	350	haze	0.25
12:53	44	36	44	55	350	haze	0.25
13:03	45	36	40	52	350	haze	0.25
13:39	44	38	45	52	350	haze	0.25
13:53	44	36	41	51	360	haze	0.25
14:40	45	35	38	54	360	haze	0.25
14:53	44	36	43	51	350	haze	0.25
15:04	44	36	39	50	360	haze	0.25
15:31	44	35	38	46	340	haze	1
15:33	44	35	37	46	360	haze	0.75
15:43	44	38	37	45	350	haze	1
15:47	43	39	36	46	350	haze	0.75
15:53	44	36	38	47	360	haze	0.75
16:01	43	38	40	51	360	haze	0.5
16:53	41	39	37	47	360	haze	0.75
17:14	39	44	38	44	10	haze	1.25
17:41	38	44	33	41	20	haze	3
17:53	38	44	30	39	10		8
18:53	37	48	0				10

Satellite imagery from March 18, 2014 provides further evidence that dust caused the PM_{10} exceedance in Lamar. Specifically, the Moderate Resolution Imaging Spectroradiometer (MODIS) Terra and Aqua images clearly shows dust plumes blowing across southeast Colorado at the same time haze and reduced visibility were being reported in Lamar. Additional information on MODIS can be found at the National Aeronautics and Space Administration

(NASA) website (https://earthdata.nasa.gov/data/near-real-time-data/data/instrument/modis).

Figure 24 shows the MODIS Terra satellite image zoomed on southeast Colorado at approximately 11:15 AM MST (1815Z). Numerous dust plumes can be seen to the south of Lamar. Lamar is somewhat obscured by cloud cover, but surface observations confirm that blowing dust was occurring there as well. According to the surface observations for Lamar at 10:53 PM and 11:36 AM MST (Table 7, the time period encompassing the image of Figure 24), sustained winds of 32-35 mph were recorded along with wind gusts of 45-46 mph, haze and visibility reduced to three statute miles. This is an observation that is consistent with blowing dust conditions in southeast Colorado (30 mph sustained winds, 40 mph gusts; see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2). Figure 25 is the MODIS Aqua satellite image of southeast Colorado at around 12:55 PM MST (1955Z). Dust plumes remain prominent in southeast Colorado, indicating that there was an extended period of blowing dust in the Lamar area.

The National Oceanic and Atmospheric Administration (NOAA) Satellite Services Division was in agreement with the conclusion that blowing dust was occurring in southeast Colorado. The Smoke Text Product from NOAA at 9:45 AM MST on March 18, 2014 stated:

> "A fairly large area of dust, partially obscured by clouds, was seen moving south-southeast across southeastern Colorado and extreme southwestern Kansas." (Source: http://www.ssd.noaa.gov/PS/FIRE/DATA/SMOKE/2014/2014C181714.html)

Additionally, the Pueblo office of the National Weather Service issued a Dust Storm Warning for southeast Colorado while the Colorado Department of Public Health and Environment issued a Blowing Dust Advisory in anticipation of the blowing dust event of March 18, 2014. Text from these advisories includes:

> "Significant amounts of blowing dust will likely occur which will reduce visibility to around ¼ mile throughout the day." (Source: http://mesonet.agron.iastate.edu/wx/afos/)

> "People with heart or lung disease, older adults, and children in the affected area should reduce prolonged or heavy indoor and outdoor exertion." (Source: http://www.colorado.gov/airquality/forecast_archive.aspx?seeddate=03%2f18%2f2014)

And to further confirm the presence of a dust storm in southeast Colorado, a webcam image at Gobblers Knob (20 miles south of Lamar) is presented in Figure 26. This image was captured at 11:15 PM MST (around the same time as the MODIS Terra image of Figure 24) and verifies that there was a considerable amount of airborne dust over southeast Colorado with the horizon almost completely obscured.

Satellite products combined with reports, advisories and webcam imagery from southeast Colorado on March 18 clearly reveal that a regional dust storm was anticipated and did take place which was not controllable or preventable.

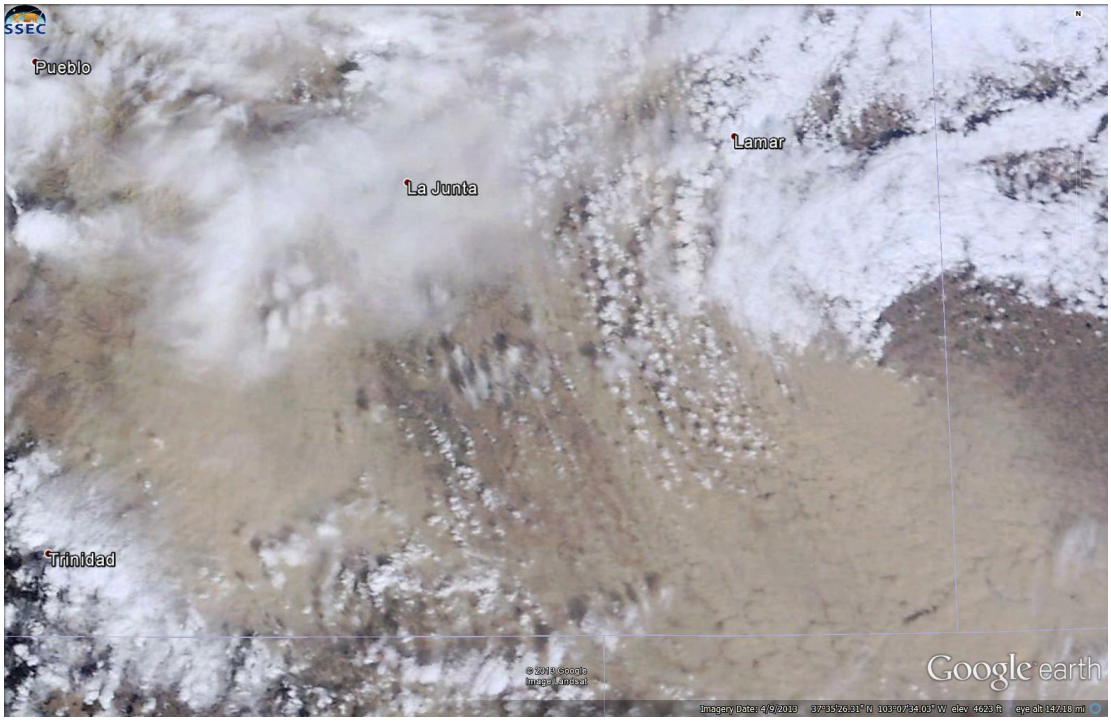


Figure 24: MODIS Terra satellite image at approximately 11:15 PM MST (1815Z) March 18, 2014.
(Source: http://ge.ssec.wisc.edu/modis-today/index.php)

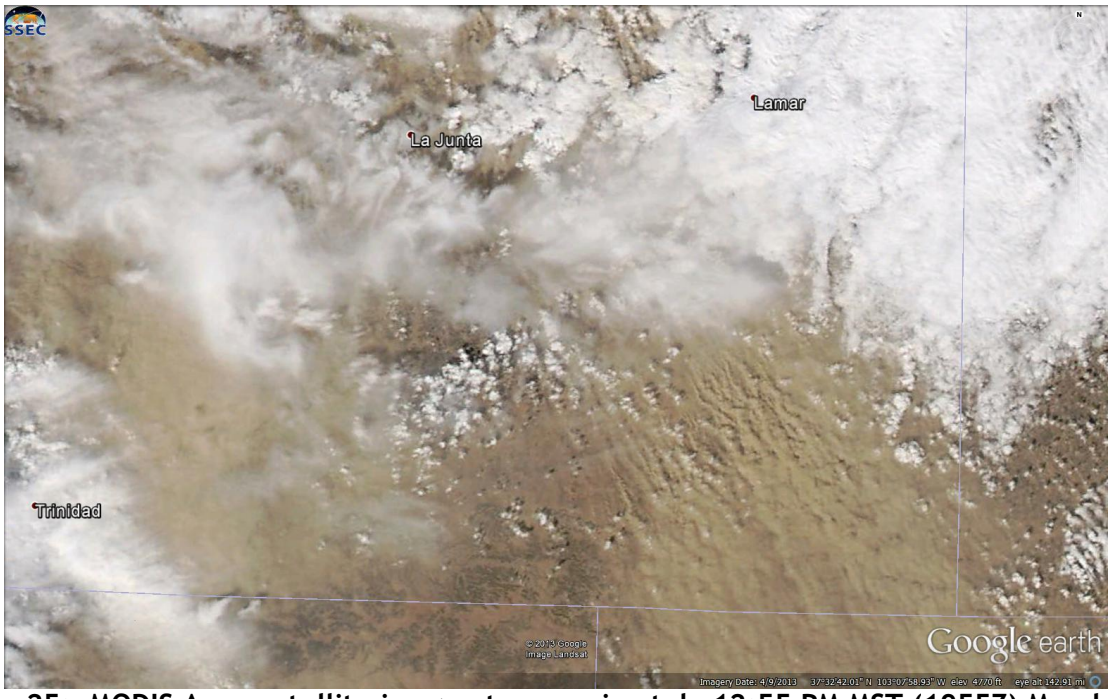


Figure 25: MODIS Aqua satellite image at approximately 12:55 PM MST (1955Z) March 18, 2014.
(Source: http://ge.ssec.wisc.edu/modis-today/index.php)

Figure 26: Gobblers Knob webcam image at 11:15 PM MST March 18, 2014. (Source: http://amos.cse.wustl.edu/)

The synoptic weather conditions described above impacted a region that was in the midst of a severe to exceptional drought (Figure 27). Sustained drought conditions are known to make topsoil susceptible to high winds and produce blowing dust (see the following link from the National Climatic Data Center for more information: https://www.ncdc.noaa.gov/paleo/drought/drght_history.html). Figure 28 shows the total precipitation in inches from February 16, 2014 to March 17, 2014 for Colorado. Note that a large portion of southeast Colorado received less than 0.34 inches of precipitation, particularly upwind from Lamar (northerly), during the 30-day period leading up to the March 18 dust event in Lamar. Based on previous research 0.5 to 0.6 inches of precipitation over a 30-day period has been found to be the approximate threshold, below which, blowing dust exceedances at Lamar are more likely to occur when combined with high winds (see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2).

The U.S. Drought Monitor and 30-day precipitation totals indicate that soils in southeast Colorado near Lamar were dry enough to produce blowing dust when winds were above the thresholds for blowing dust. This information, combined with other evidence provided in this report, proves that this dust storm was a natural, regional event that was not reasonably controllable or preventable.

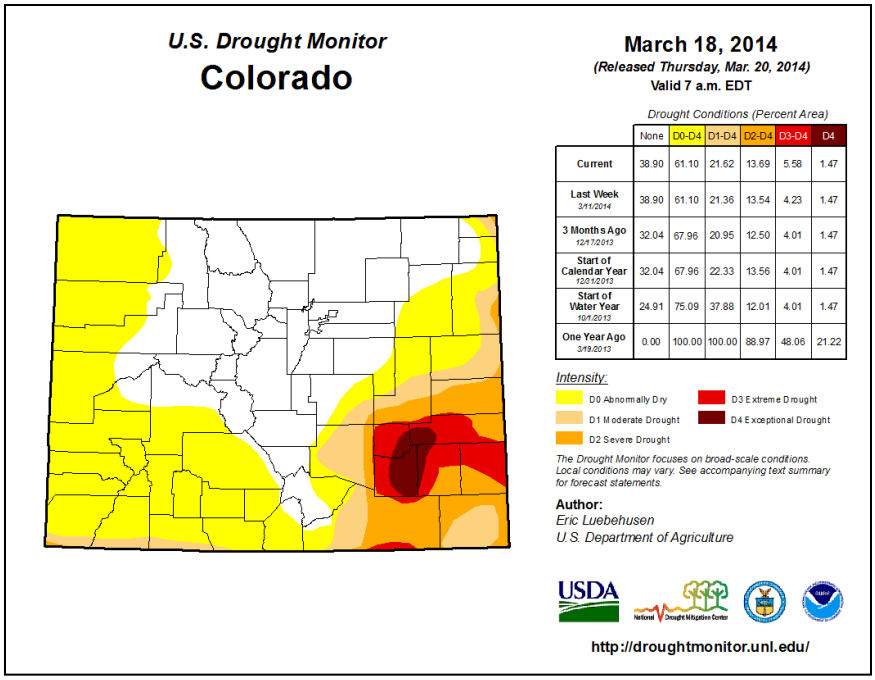


Figure 27: Drought conditions for Colorado at 5:00 AM MST March 18, 2014. (Source: http://droughtmonitor.unl.edu/MapsAndData/MapArchive.aspx)

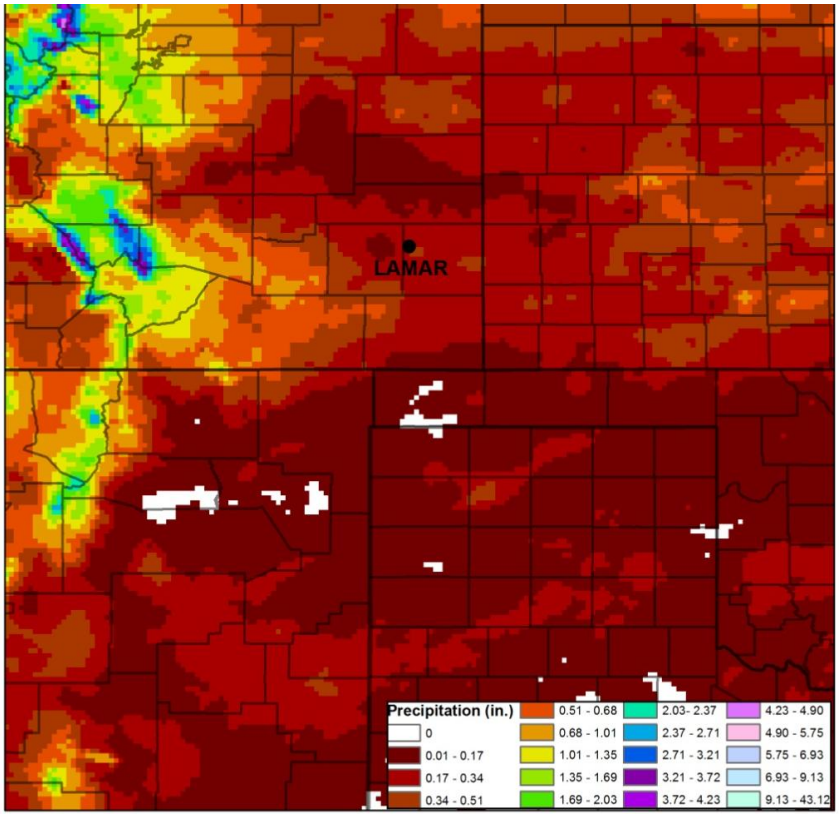


Figure 28: Total precipitation in inches for eastern Colorado and adjacent states, February 16, 2014 – March 17, 2014. (Source: http://prism.nacse.org/recent/)

2.4 March 29, 2014 Meteorological Analysis

On March 29 of 2014, a powerful winter storm system caused an exceedance of the 24-hour PM_{10} standard in Lamar, Colorado, at the Municipal Building monitor with a concentration of 263 $\mu g/m^3$. This elevated reading and the location of the monitor is plotted on a map of the Greater Lamar area in Figure 29. The exceedance in Lamar was the result of intense surface winds which were produced by a strong upper-level trough that was moving across the western United States. The surface winds were predominantly out of a south to southwest direction which moved over dry soils in southeast Colorado, producing significant blowing dust.

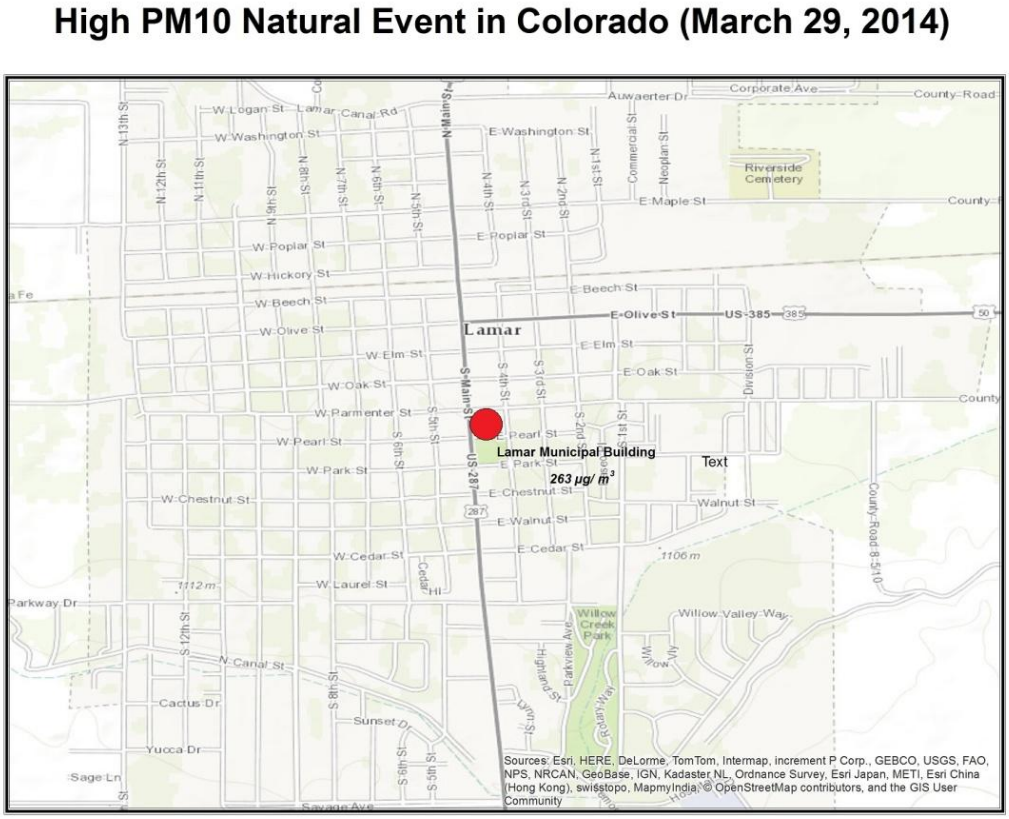


Figure 29: 24-hour PM_{10} concentrations for March 29, 2014.
(Source: http://webapps.datafed.net/datafed.aspx?dataset=AQS_D&parameter=pm10)

The upper-level trough associated with this storm system is shown on the North American Regional Reanalysis (NARR) 700 mb height analysis map at 11:00 AM MST, March 29, 2014 in Figure 30. This chart shows that a deep trough of low pressure was entering southeast Colorado at the onset of the blowing dust event of March 29. In advance of this upper-level trough was a band of high winds ranging from 25-35 kts (29-40 mph), including over Lamar and areas downwind (south to southwest). By viewing Figure 31 it can be seen that relatively deep atmospheric mixing was occurring over southeast Colorado at the same time the 700 mb jet streak was overhead. Mixing of 2.5-3.5 km above mean sea level (MSL) over Lamar and areas upwind would have been sufficient to transfer momentum to the surface from the zone of strong winds that were present at 700 mb (about 3 km above MSL).

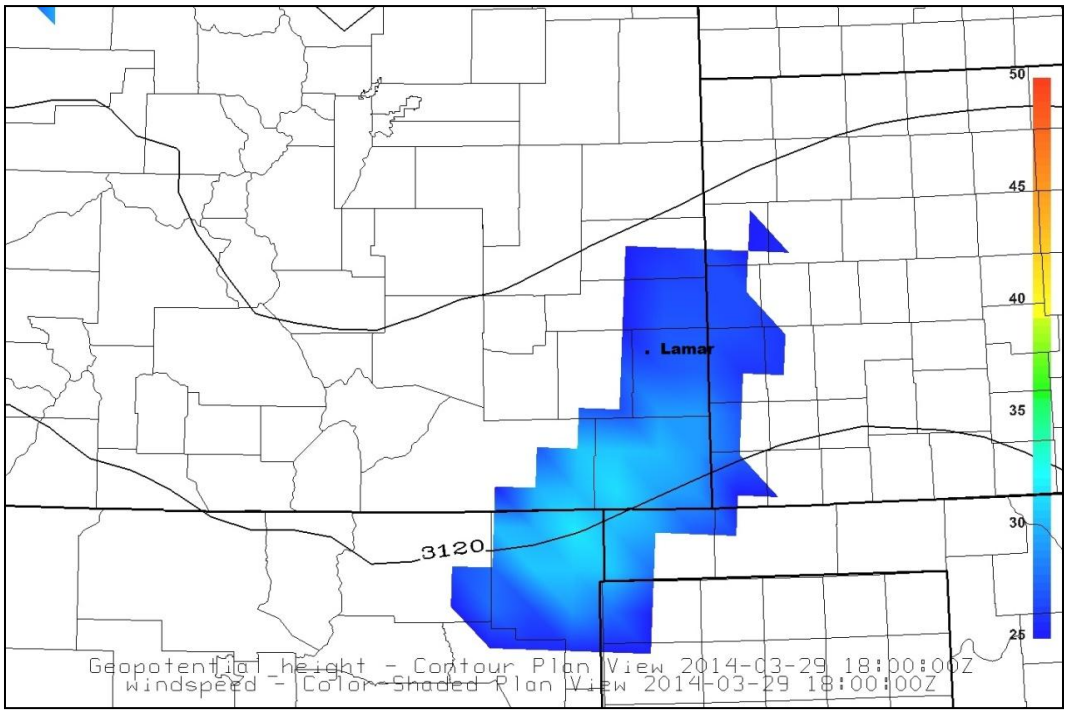


Figure 30: NARR 700 mb analysis for 18Z March 29, 2014, or 11:00 AM MST March 29, 2014 showing wind speeds in knots. Only speeds above 25 knots are shown.
(Source: http://nomads.ncdc.noaa.gov/data.php?name=access#hires_weather_datasets)

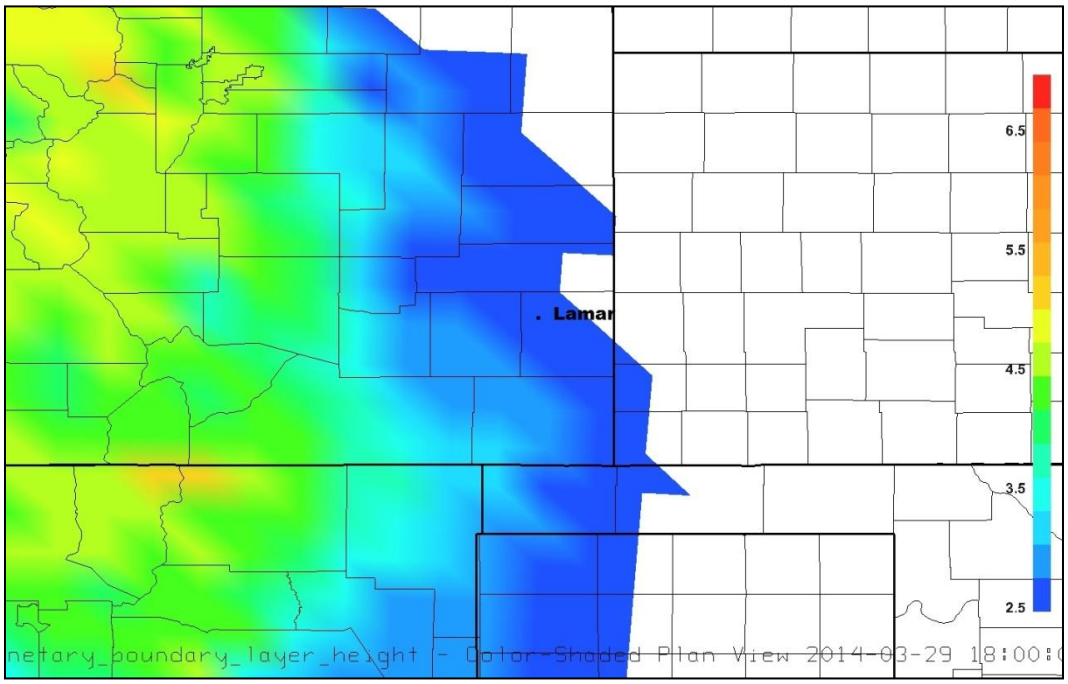


Figure 31: Height of the mixed layer in kilometers above mean sea level from the NARR at 18Z March 29, 2014, or 11:00 AM MST March 29, 2014. Only mixing heights above 2.5 kilometers are shown.
(Source: http://nomads.ncdc.noaa.gov/data.php?name=access#hires_weather_datasets)

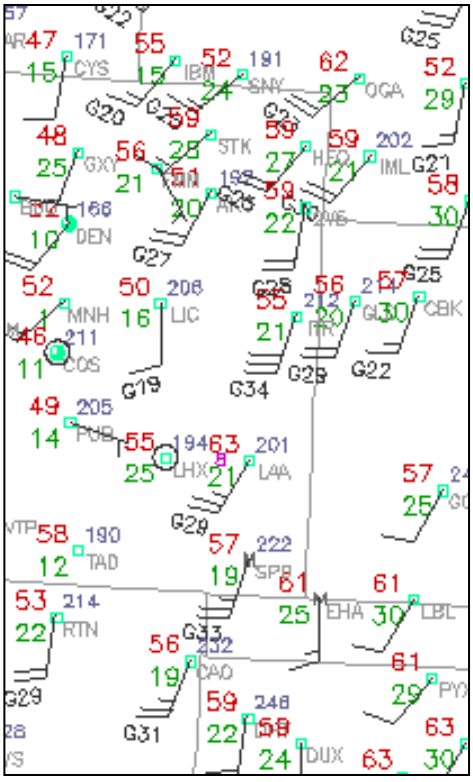
In order to fully evaluate the synoptic meteorological scenario of March 29, 2014, regional surface weather maps are provided showing individual station observations during the height of the event in question. Figure 32 presents weather observations for eastern Colorado and adjacent states at (a) 10:43 AM and (b) 1:43 PM MST on March 29, 2014. On the map in Figure 32(a) the station observation for Lamar (LAA) shows winds sustained at 25 knots (29 mph), gusts to 29 knots (33 mph), and a reduced visibility of 8 statute miles.

Three hours later at 1:43 PM MST (Figure 32 (b)), visibility in Lamar continued to be obscured at 8 statute miles with sustained winds of 25 knots (29 mph) and gusts to 33 knots (38 mph). This reveals that there was a prolonged period of time when weather observations in Lamar were at or very near climatological levels for blowing dust conditions in southeast Colorado (30 mph sustained winds, 40 mph gusts; see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2). Also note that areas upwind of Lamar such as Clayton (CAO) and Raton (RTN), New Mexico reported similar wind speeds in both images of Figure 32, suggesting that this dust event was likely regional in scale.

Hourly surface observations, in table form, from Lamar provide additional evidence that there was an extended period of high winds and restricted visibility. Table 9 lists observations for the PM_{10} exceedance location of Lamar. Observations that are climatologically consistent with blowing dust conditions (see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2) are highlighted in yellow. The data shows that there was a 7-hour period of time (9:53 AM to 4:53 PM MST) where sustained winds and gusts were at or very near the level where blowing dust is known to occur in southeast Colorado.

Surface weather maps and hourly observations show that a dust storm occurred under south to southwesterly flow in response to a strong upper-level trough overhead. This data provides clear evidence of blowing dust and winds at or very near the threshold speeds for blowing dust on March 29, 2014.

a)



b)

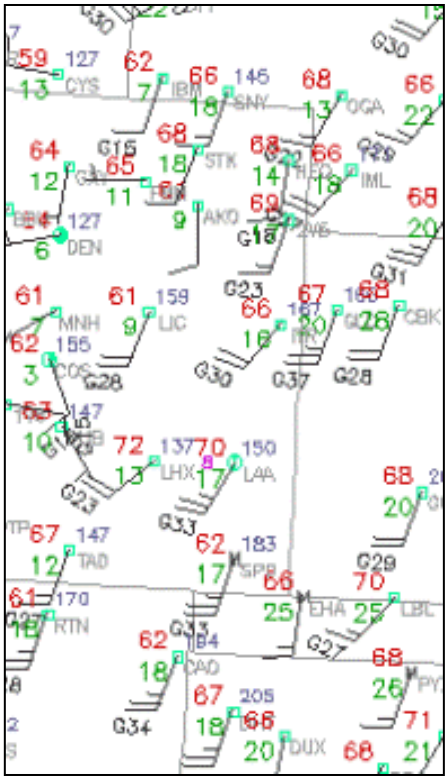


Figure 32: High Plains regional surface analysis for (a) 10:43 AM MST and (b) 1:43 AM MST, March 29, 2014.
(Source: http://www.mmm.ucar.edu/imagearchive/)

Table 9: Weather observations for Lamar, Colorado, on March 29, 2014 (Source: http://mesowest.utah.edu/)

Time MST March 29, 2014	Temperature Degrees F	Relative Humidity in %	Wind Speed in mph	Wind Gust in mph	Wind Direction in Degrees	Weather	Visibility in miles
0:53	29	61	6		210		10
1:53	24	71	5		220		10
2:53	24	71	4		220		10
3:53	25	71	0				10
4:53	26	68	0				10
5:53	24	74	0				10
6:53	29	66	0				10
7:53	41	46	4		40		10
8:53	59	24	22		200		9
9:53	63	20	27	33	210		8
10:53	66	17	30	36	200		8
11:53	70	14	25	35	210		8
12:53	70	13	27	38	210		8
13:53	72	12	29	39	200		7
14:53	73	10	24	37	190		9
15:53	73	10	25	36	200		9
16:53	71	13	27	33	200		8
17:53	66	16	17		180		9
18:53	62	21	18		180		10
19:53	59	26	18		180		10
20:53	59	26	21		190		10
21:53	59	27	20		210		10
22:53	59	27	23		220		10
23:53	55	31	15		210		10

Satellite-generated data products also indicate that dust caused the PM_{10} exceedance in Lamar. Figure 33 displays the Atmospheric Infrared Sounder (AIRS) Dust Score zoomed on southeast Colorado based on the MODIS Aqua satellite image from 12:35 PM MST on March 29, 2014 (see the following link for more information on Dust Score and other AIRS variables: http://disc.sci.gsfc.nasa.gov/nrt/data-holdings/airs-nrt-products). The tan pixels represent dust scores greater than 360, which is indicative of dust particles. It should be noted that at the time of this image Lamar was in the midst of an extended period of high winds and reduced visibility, suggesting that a dust storm was indeed occurring in southeast Colorado at 12:35 PM MST. By referring back to Table 9, from 11:53 AM to 12:53 PM MST (the time period encompassing Figure 33) Lamar reported sustained winds of 25-27 mph, gusts of 35-38 mph and visibility reduced to 8 statute miles.

Ten minutes after the MODIS image of Figure 33, webcam imagery was able to capture blowing dust at Gobbler's Knob (20 miles south of Lamar). Unfortunately the web camera lens was contaminated by mud (Figure 34) from a dust storm earlier in the month, but in the background some airborne dust is visible with the horizon partially obscured. As stated in the previous paragraph, Lamar was reporting weather observations consistent with blowing dust conditions in the time period surrounding this webcam image.

The blowing dust of March 29, 2014 was not only observed, but also anticipated. The Navy Aerosol Analysis and Prediction System (NAAPS) accurately forecast that blowing dust would be an issue in southeast Colorado during the late morning and afternoon hours. Figure 35 shows the output from this model covering the time period from 18Z (11:00 AM MST), March 29 to 0Z (5:00 PM MST, March 29), March 30. The NAAPS system models blowing dust emissions and transport based on soil moisture content, soil erodibility factors and a variety of meteorological factors known to be conducive to blowing dust (for a description of NAAPS see: http://www.nrlmry.navy.mil/aerosol_web/Docs/globaer_model.html). The forecast panel in the upper left of Figure 35 clearly shows above normal Total Optical Depth values attributed to dust over southeast Colorado.

Additionally, the Colorado Department of Public Health and Environment (CDPHE) was alerted to blowing dust on March 29, 2014 and consequently issued a Blowing Dust Advisory for most of southeast Colorado. Text from that advisory includes:

> "Strong gusty winds will bring a threat for blowing dust to portions of southeastern Colorado." and, "People with heart or lung disease, older adults, and children in the affected area should reduce prolonged or heavy indoor and outdoor exertion." (Source: http://www.colorado.gov/airquality/forecast_archive.aspx?seeddate=03%2f29%2f2014)

Satellite-generated products combined with webcam imagery, forecast models and advisories indicate that a dust storm took place on March 29, 2014 in southeast Colorado.

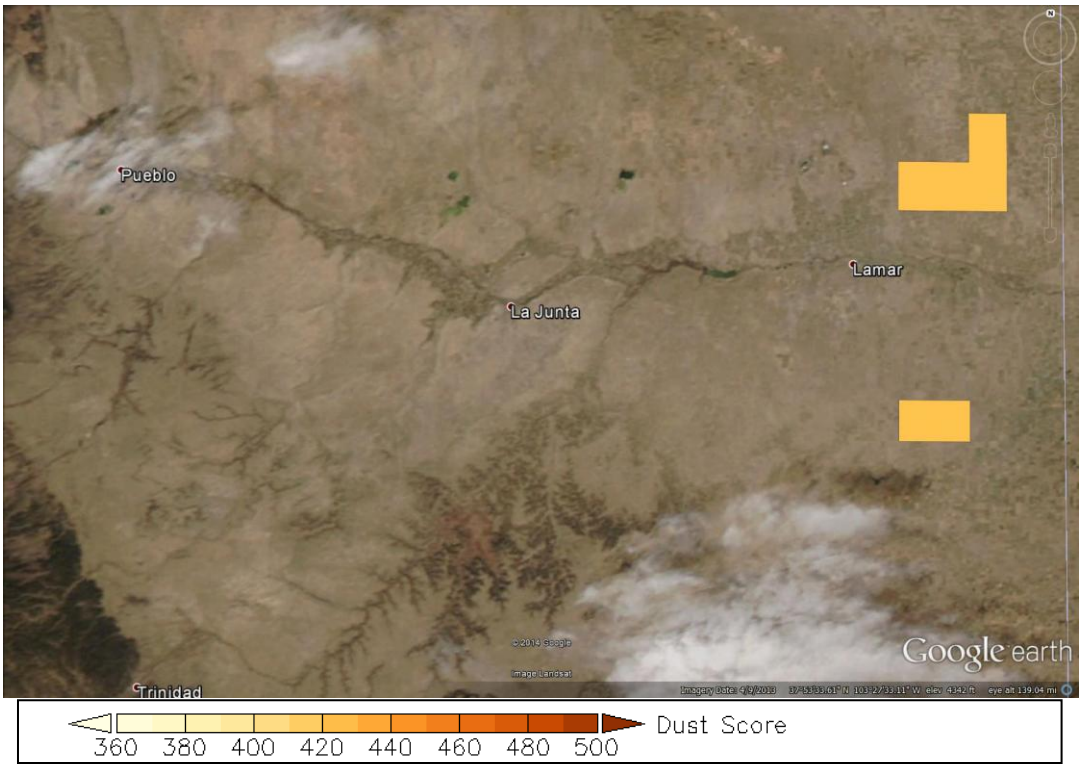


Figure 33: AIRS Dust Score from the MODIS Aqua satellite image at 12:35 PM MST (1935Z) March 29, 2014.
(Source: http://www.earthdata.nasa.gov/labs/worldview)

Figure 34: Gobblers Knob webcam image at 12:45 PM MST March 29, 2014.
(Source: http://amos.cse.wustl.edu/)

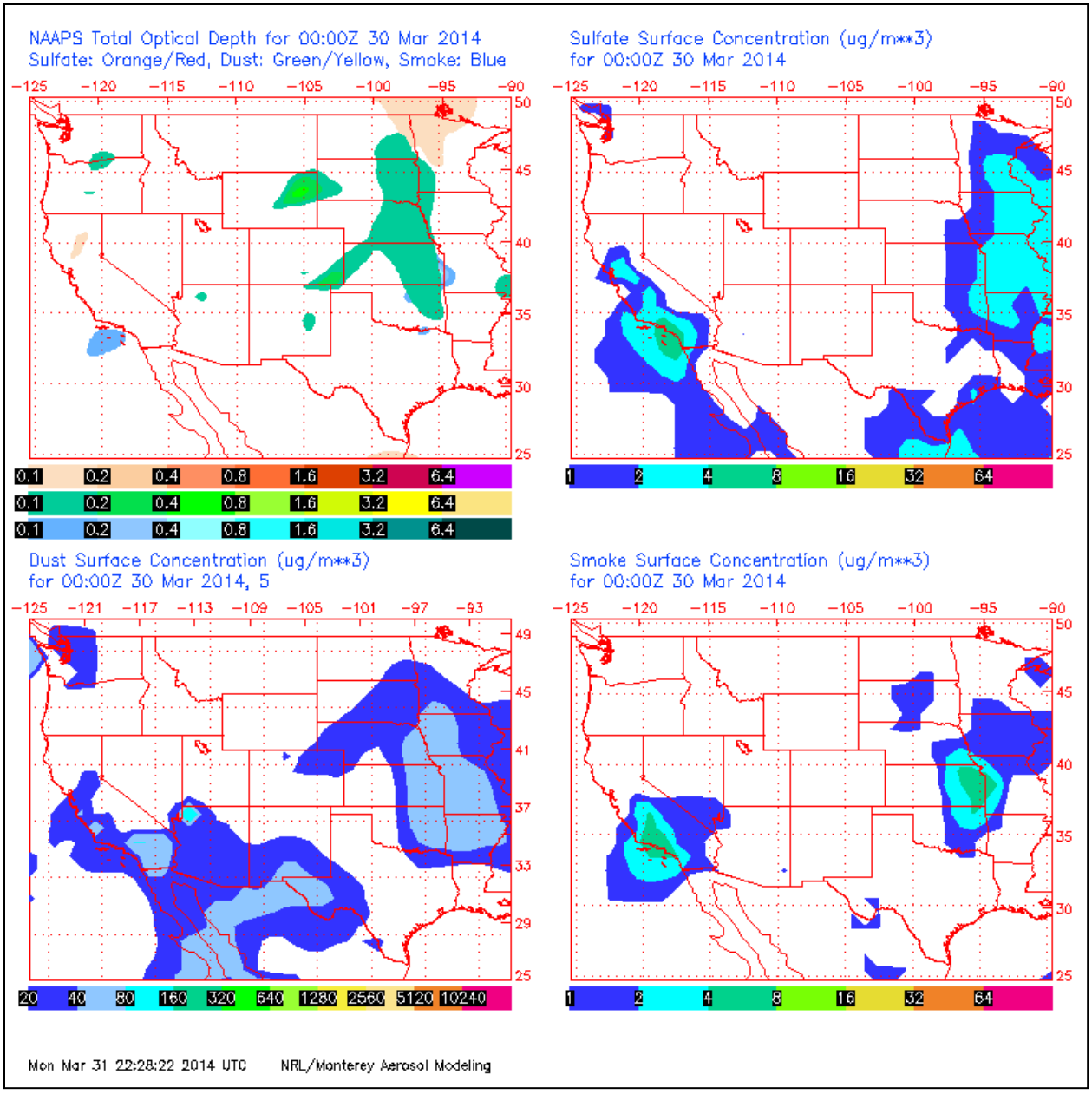


Figure 35: NAAPS forecast for 5:00 PM MST (0Z, March 30), March 29, 2014. (Source: http://www.nrlmry.navy.mil/aerosol-bin/aerosol/display_directory_all?DIR=/web/aerosol/public_html/globaer/ops_01/wus/)

The synoptic weather conditions described above impacted a region that was in the midst of a severe to exceptional drought (Figure 36). Sustained drought conditions are known to make topsoil susceptible to high winds and produce blowing dust (see the following link from the National Climatic Data Center for more information: https://www.ncdc.noaa.gov/paleo/drought/drght_history.html). Figure 37 shows the total precipitation in inches from February 27, 2014 to March 28, 2014 for eastern Colorado and adjacent states. From Lamar upwind (south to southwest) into northeast New Mexico, most areas received less than 0.34 inches of precipitation during the 30-day period leading up to

the March 29, 2014 dust event in Lamar. Based on previous research 0.5 to 0.6 inches of precipitation over a 30-day period has been found to be the approximate threshold, below which, blowing dust exceedances at Lamar are more likely to occur when combined with high winds (see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2).

The U.S. Drought Monitor and 30-day precipitation totals indicate that soils in southeast Colorado were dry enough to produce blowing dust when winds were above the thresholds for blowing dust. This information, combined with other evidence provided in this report, proves that this dust storm was a natural, regional event that was not reasonably controllable or preventable.

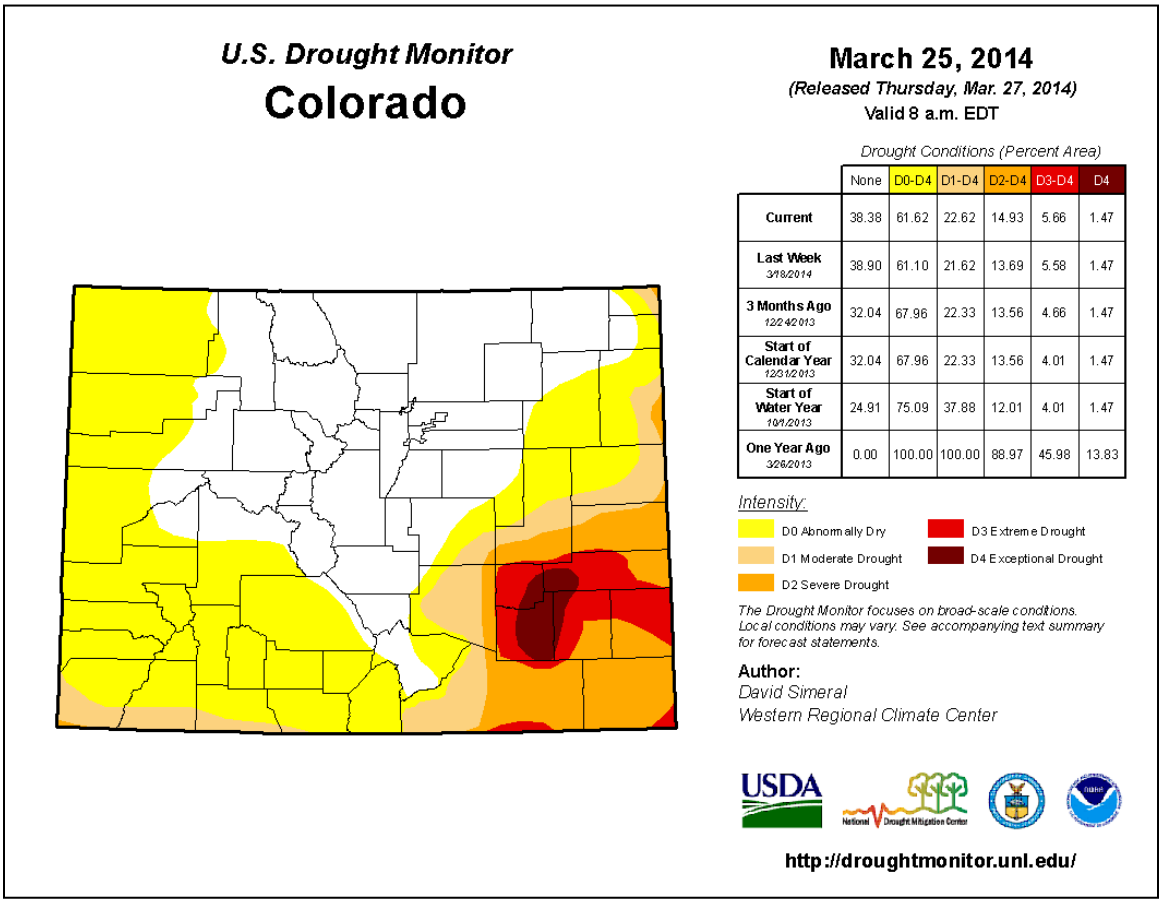


Figure 36: Drought conditions for the Western U.S. at 5:00 AM MST March 25, 2014. (Source: http://droughtmonitor.unl.edu/MapsAndData/MapArchive.aspx)

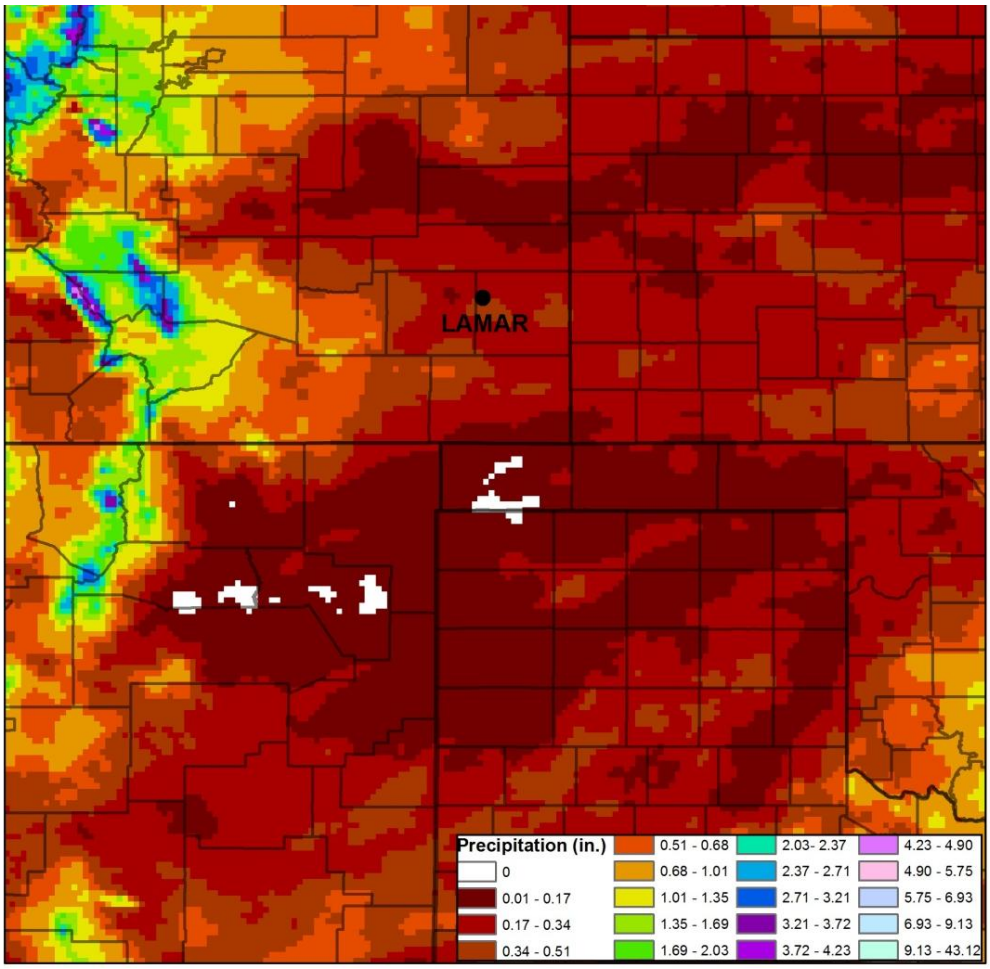


Figure 37: Total precipitation in inches for the eastern Colorado and adjacent states, February 27, 2014 – March 28, 2014.
(Source: http://prism.nacse.org/recent/)

2.5 March 30, 2014 Meteorological Analysis

On March 30 of 2014, a powerful spring storm system caused an exceedance of the 24-hour PM_{10} standard in Lamar, Colorado, at the Municipal Building monitor with a concentration of 264 $\mu g/m^3$. This elevated reading and the location of the monitor is plotted on a map of the Greater Lamar area in Figure 38. The exceedance was the result of an intense upper-level trough producing strong winds in southeast Colorado which transported blowing dust into the Lamar area. The surface winds were predominantly out of a west to southwest direction which moved over dry soils in southeast Colorado, producing significant blowing dust.

Figure 38: 24-hour PM_{10} concentrations for March 30, 2014.
(Source: http://webapps.datafed.net/datafed.aspx?dataset=AQS_D&parameter=pm10)

The upper-level trough associated with this storm system is shown on the North American Regional Reanalysis (NARR) 700 mb height analysis map at 5:00 PM MST, March 30, 2014 in Figure 39. This chart shows that a deep trough of low pressure was entering southeast Colorado at the onset of the blowing dust event of March 30. In advance of this upper-level trough was a band of high winds ranging from 35-45 kts (40-52 mph), including over Lamar and areas upwind (west to southwest). Also ahead of the upper-level trough was a very unstable atmosphere that was in place over southeast Colorado. By viewing Figure 40 it can be seen that very deep atmospheric mixing was occurring over southeast Colorado at precisely the same time that the 700 mb jet streak was overhead. Mixing of 6-8 km above mean sea level (MSL) over Lamar and areas upwind would have been more than sufficient to transfer momentum to the surface from the zone of strong winds that were present at 700 mb (about 3 km above MSL). If those winds (40-52 mph) were indeed mixed to the surface, they would have been well in excess of wind speeds that are known to cause blowing dust in southeast Colorado (30 mph sustained winds, 40 mph gusts; see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2).

As the trough moved over southeast Colorado (Figure 41) during the late evening hours of March 30, the winds aloft at 700 mb intensified. Directly over Lamar the 700 mb wind speeds ranged from 50-60 knots (57-69 mph) at 11:00 PM MST. Mixing at this time had decreased significantly (Figure 42), but still ranged from 3-5 km above MSL over the Lamar area. As stated in the previous paragraph, the 700 mb level is about 3 km above MSL. This indicates that atmospheric mixing at 11:00 PM MST was still sufficient to mix down the very strong winds that were occurring at the 700 mb level at that time.

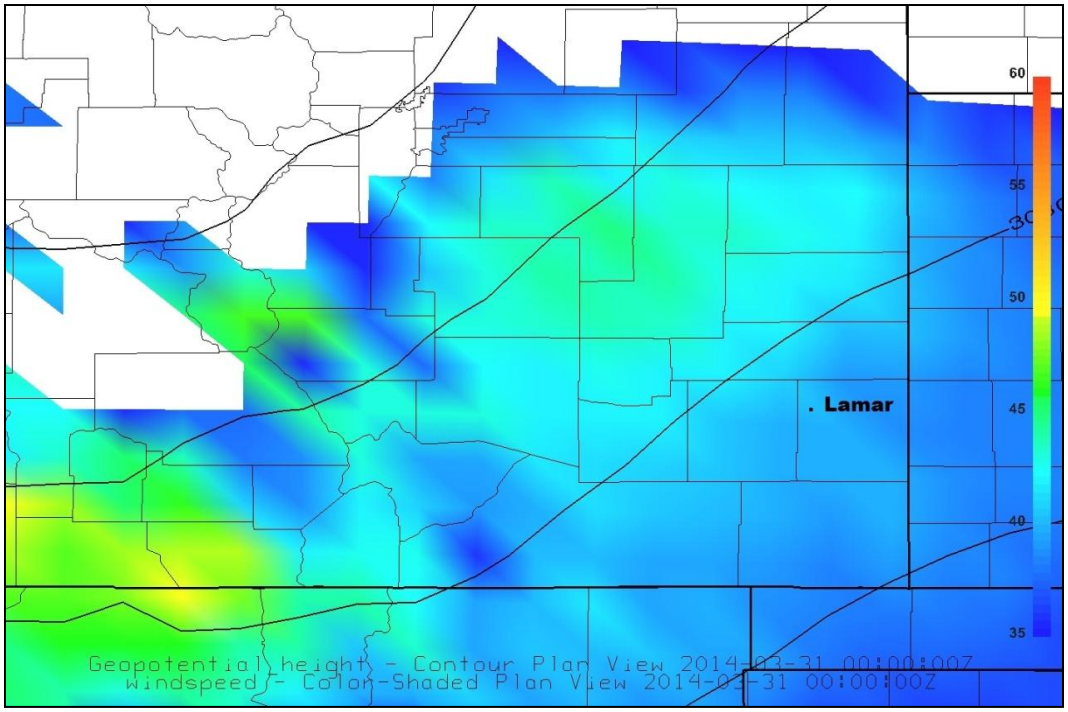


Figure 39: NARR 700 mb analysis for 0Z March 31, 2014, or 5:00 PM MST March 30, 2014 showing wind speeds in knots. Only speeds above 35 knots are shown.
(Source: http://nomads.ncdc.noaa.gov/data.php?name=access#hires_weather_datasets)

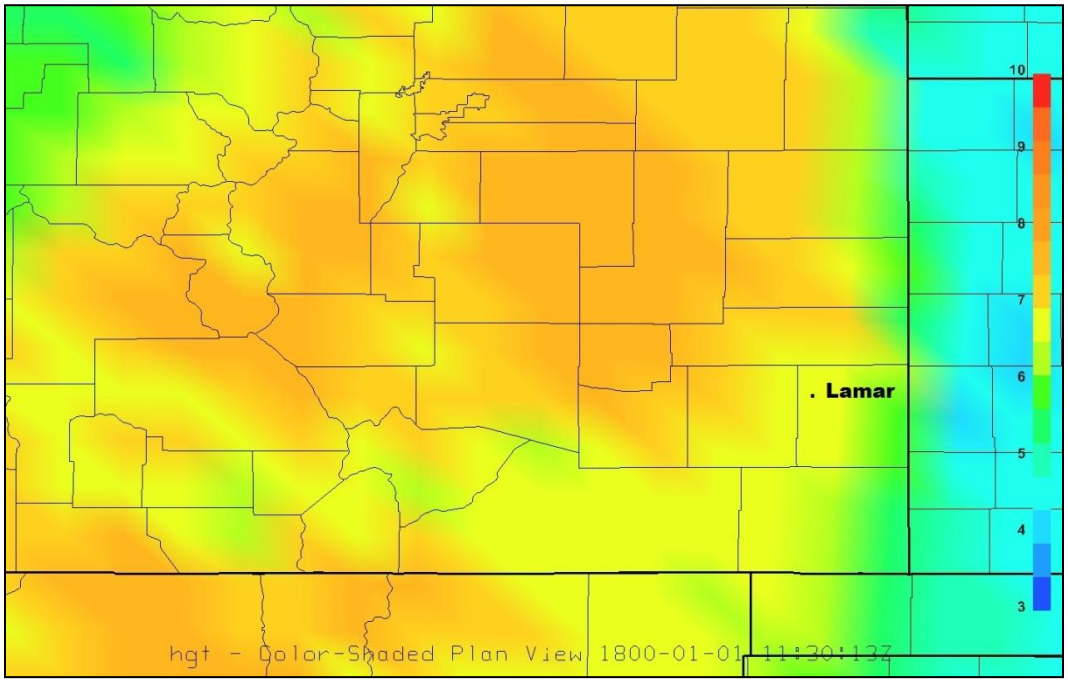


Figure 40: Height of the mixed layer in kilometers above mean sea level from the NARR at 0Z March 31, 2014, or 5:00 PM MST March 30, 2014. Only mixing heights above 3 kilometers are shown.
(Source: http://nomads.ncdc.noaa.gov/data.php?name=access#hires_weather_datasets)

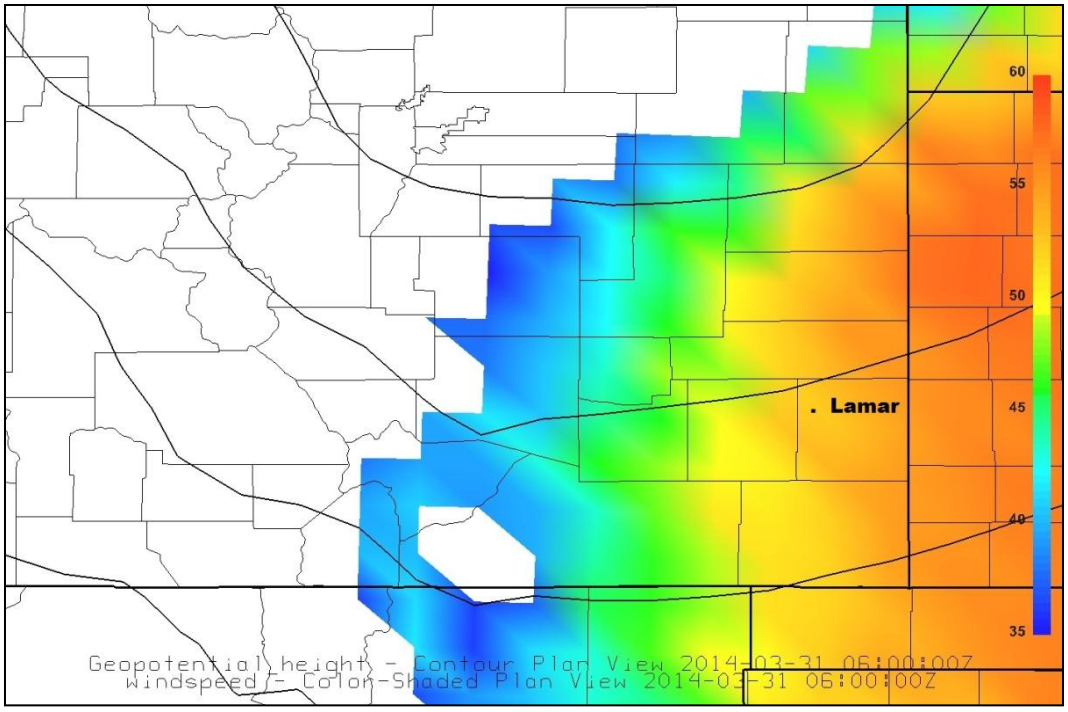


Figure 41: NARR 700 mb analysis for 6Z March 31, 2014, or 11:00 PM MST March 30, 2014 showing wind speeds in knots. Only speeds above 35 knots are shown.
(Source: http://nomads.ncdc.noaa.gov/data.php?name=access#hires_weather_datasets)

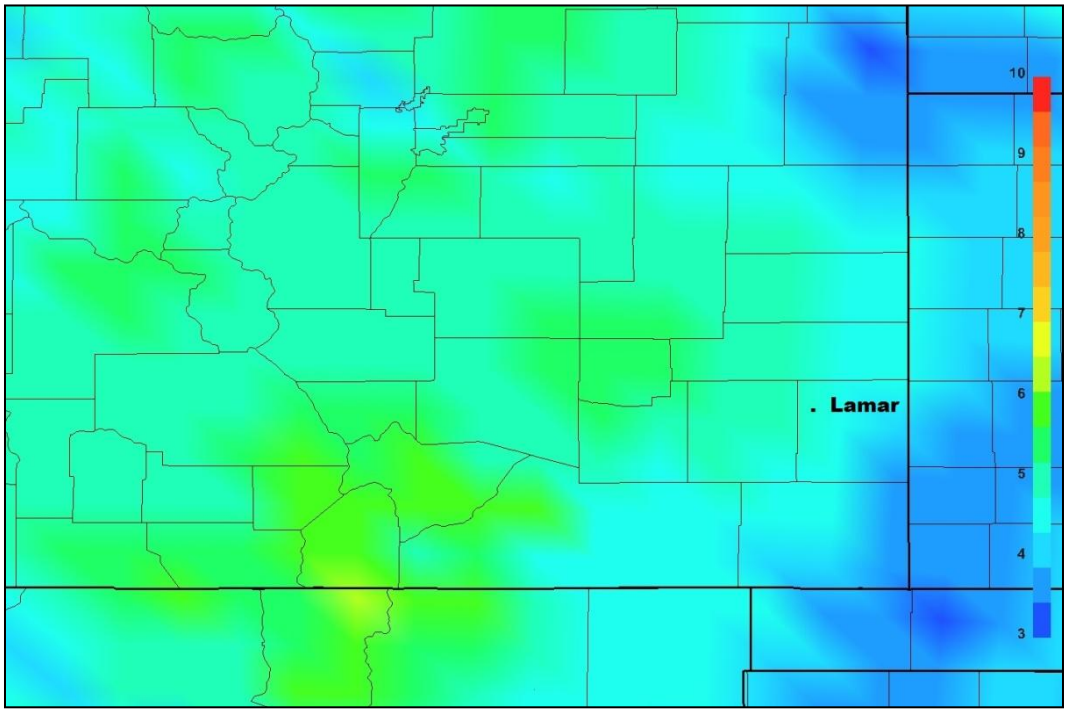


Figure 42: Height of the mixed layer in kilometers above mean sea level from the NARR at 6Z March 31, 2014, or 11:00 PM MST March 30, 2014. Only mixing heights above 3 kilometers are shown.
(Source: http://nomads.ncdc.noaa.gov/data.php?name=access#hires_weather_datasets)

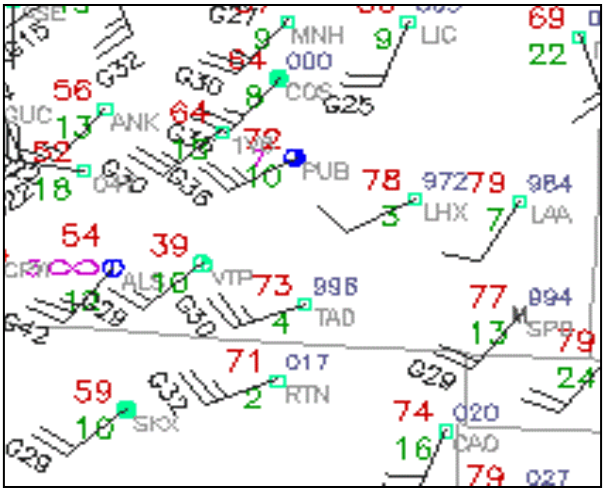
In order to fully evaluate the synoptic meteorological scenario of March 30, 2014, regional surface weather maps are provided showing individual station observations during the height of the event in question. Figure 43 presents weather observations for eastern Colorado and adjacent states at (a) 3:43 PM, (b) 5:43 PM and (c) 7:43 PM MST on March 30. On the map in Figure 43(a) the station observation for Lamar (LAA) shows generally light winds at 10 knots with unrestricted visibility. However to the west and southwest (upwind of Lamar) the wind was considerably stronger with some evidence of blowing dust. In Pueblo (PUB), Trinidad (TAD) and Raton (RTN), sustained winds were generally running at 25 knots (29 mph) with gusts of 30-36 knots (35-41 knots). These are wind speeds known to cause blowing dust in southeast Colorado (30 mph sustained winds, 40 mph gusts; see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2). Additionally, in Alamosa (ALS) high winds were also being reported with the weather symbol of infinity (∞). The infinity sign is the weather symbol for haze. Haze is often reported during dust storms, and in dry and windy conditions haze typically refers to blowing dust (see the following link for the description of haze published by the National Oceanic and Atmospheric Administration (NOAA): http://www.crh.noaa.gov/lmk/?n=general_glossary).

Two hours later at 5:43 PM MST (Figure 43 (b)), it appears that blowing dust had arrived in the Lamar area. The weather observation includes haze and visibility reduced to 3 miles. At 7:43 PM MST (Figure 43 (c)) the weather observation of haze and obscured visibility of 3 statute miles continued in Lamar. This reveals that there was a prolonged period of time when weather observations in Lamar indicated that blowing dust was present. Also note that 50 miles to the west of Lamar in La Junta (LHX), haze and highly reduced visibility were also reported at both 5:53 PM and 7:53 PM MST. Combined with the reports of high winds, haze and reduced visibility in the other areas upwind of Lamar referenced above, indications are that this dust event was likely regional in scale.

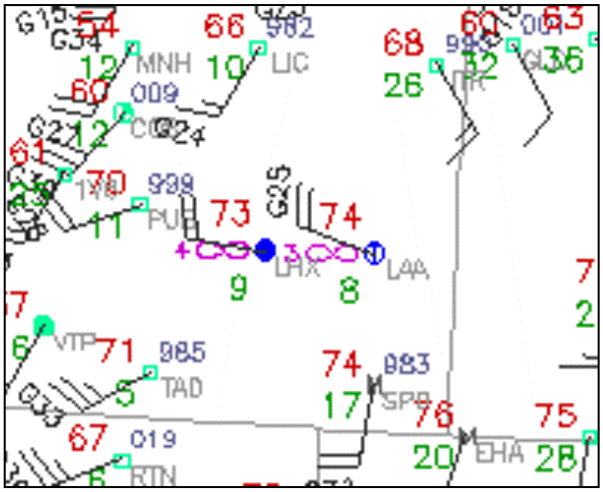
Hourly surface observations, in table form, from Lamar and other weather stations provide additional evidence that a regional blowing dust event occurred on March 30. Table 10 lists observations for the PM_{10} exceedance location of Lamar while other regional weather stations can be found in Table 11 through Table 15. Observations that are climatologically consistent with blowing dust conditions (see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2) are highlighted in yellow. Collectively, these six sites experienced many hours of reduced visibility along with sustained wind speeds and gusts at or above the thresholds for blowing dust. Specifically for Lamar, data from Table 10 shows that from 5:30 PM to 7:40 PM MST haze and restricted visibility were reported. This suggests that for over 2 hours airborne dust was impacting Lamar. Additionally there was a brief period of time shortly before midnight (starting at 11:31 PM and continuing through 11:53 PM MST) when the winds dramatically increased, haze was reported and visibility dropped considerably. This appears to be a second period of blowing dust that was associated with the main trough moving over southeast Colorado (Figure 41 and Figure 42) which likely had a substantial impact on the 24-hour PM_{10} concentration in Lamar on March 30, 2014.

Surface weather maps and hourly observations show that a dust storm occurred under south to southwesterly flow in response to a strong upper-level trough overhead. This data provides clear evidence of blowing dust and winds at or above the threshold speeds for blowing dust across southeast Colorado on March 30, 2014.

a)



b)



c)

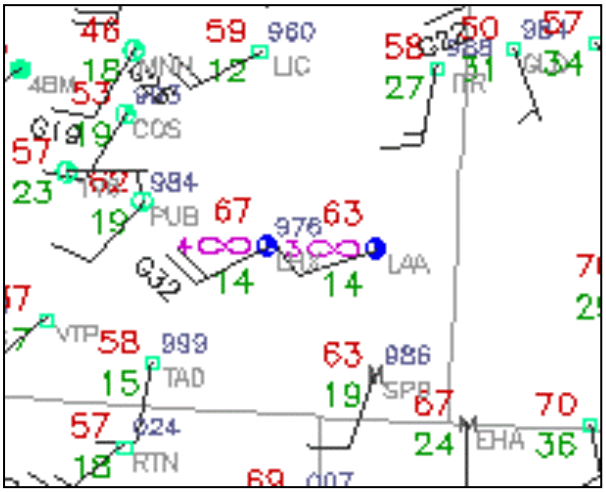


Figure 43: High Plains regional surface analysis for (a) 3:43 PM MST, (b) 5:43 PM MST, and (c) 7:43 PM MST, March 30, 2014.
(Source: http://www.mmm.ucar.edu/imagearchive/)

Table 10: Weather observations for Lamar, Colorado, on March 30, 2014 (Source: http://mesowest.utah.edu/)

Time MST March 30, 2014	Temperature Degrees F	Relative Humidity in %	Wind Speed in mph	Wind Gust in mph	Wind Direction in Degrees	Weather	Visibility in miles
0:53	53	33	5		250		10
1:53	49	39	7		230		10
2:53	50	37	9		240		10
3:53	50	36	9		230		10
4:53	50	36	8		200		10
5:53	42	49	10		230		10
6:53	47	42	8		200		10
7:53	51	39	4		50		10
8:53	57	28	6		300		10
9:53	63	21	0				10
10:53	70	17	0				10
11:53	78	10	16		230		10
12:53	76	9	14		220		10
13:53	76	8	6		240		10
14:53	79	6	9		210		10
15:53	80	6	16	24	230		10
16:53	77	8	20	29	200		10
17:30	74	8	22	29	290	haze	3
17:40	74	8	6		250	haze	3
17:53	73	8	10		310	haze	3
18:24	70	10	5		260	haze	3
18:53	67	12	8		240	haze	3
19:02	66	13	8		250	haze	3
19:14	62	15	8		230	haze	3
19:22	63	15	12		250	haze	3
19:40	64	13	13		260	haze	4
19:53	65	13	12		240		7
20:53	61	16	16		210		9
21:53	54	22	14		220		10
22:53	58	18	18		220		10
23:31	63	10	25		240	haze	4
23:53	65	8	33	48	260	haze	4

Table 11: Weather observations for Alamosa, Colorado, on March 30, 2014 (Source: http://mesowest.utah.edu/)

Time MST March 30, 2014	Temperature Degrees F	Relative Humidity in %	Wind Speed in mph	Wind Gust in mph	Wind Direction in Degrees	Weather	Visibility in miles
3:52	27	50	0				10
4:52	27	50	6		90		10
5:52	28	50	7		60		10
6:52	31	47	5		340		10
7:52	40	36	4		20		10
8:52	53	18	21		190		10
9:52	55	15	18		180		10
10:52	59	12	22	30	220		10
11:06	60	11	22	29	210		10
11:52	61	11	24	41	230		10
12:12	61	11	29	52	240	haze	4
12:35	59	13	36	51	230	haze	2
12:42	58	13	32	46	240	haze	3
12:52	58	13	32	45	230	haze	5
13:52	55	17	25	38	230		10
14:52	56	14	22	31	200		10
15:34	54	18	31	48	220	haze	3
15:44	53	20	40	56	230	haze	2
15:52	52	22				haze	1
16:02	51	24	36	47	220	haze	2
16:10	51	24	24	41	220	haze	5
16:52	53	21	24	36	200		10
17:26	55	16				haze	2
17:36	54	16	35	53	220	haze	1
17:46	54	16	37	52	220	haze	3
17:52	54	15	31	52	230	haze	3
18:03	53	14	41	50	240	haze	2
18:09	53	14	32	50	230	haze	2
18:13	53	15	33	45	230	haze	3
18:52	51	15	36	45	210		8
19:52	49	13	22	36	240		10
20:52	47	22	35	48	230	haze	3

Table 12: Weather observations for La Junta, Colorado, on March 30, 2014 (Source: http://mesowest.utah.edu/)

Time MST March 30, 2014	Temperature Degrees F	Relative Humidity in %	Wind Speed in mph	Wind Gust in mph	Wind Direction in Degrees	Weather	Visibility in miles
7:53	51	39	4		50		10
8:53	57	28	6		300		10
9:53	63	21	0				10
10:53	70	17	0				10
11:53	78	10	16		230		10
12:53	76	9	14		220		10
13:53	76	8	6		240		10
14:53	79	6	9		210		10
15:53	80	6	16	24	230		10
16:01	77	8	20	29	200		10
16:17	74	8	22	29	290	haze	3
16:33	74	8	6		250	haze	3
16:53	73	8	10		310	haze	3
17:02	70	10	5		260	haze	3
17:53	67	12	8		240	haze	3
18:03	66	13	8		250	haze	3
18:07	62	15	8		230	haze	3
18:14	63	15	12		250	haze	3
18:24	64	13	13		260	haze	4
18:32	65	13	12		240		7
18:49	61	16	16		210		9
18:53	54	22	14		220		10
19:53	58	18	18		220		10
20:53	63	10	25		240	haze	4
21:53	61	17	22		220		10
22:53	61	10	23		240		10
23:00	63	9	38	47	250	haze	1.25
23:02	63	10	43	54	250	haze	0.5
23:16	65	11				lt rain	0.25
23:25	64	12				lt rain	0.25
23:51	61	17	30	48	270	lt rain	0.5
23:53	60	16	31	39	260	lt rain	0.75

Table 13: Weather observations for Pueblo, Colorado, on March 30, 2014 (Source: http://mesowest.utah.edu/)

Time MST March 30, 2014	Temperature Degrees F	Relative Humidity in %	Wind Speed in mph	Wind Gust in mph	Wind Direction in Degrees	Weather	Visibility in miles
0:53	42	31	5		60		10
1:53	39	35	4		240		10
2:53	37	38	0				10
3:53	37	42	7		320		10
4:53	32	47	0				10
5:53	34	43	5		330		10
6:53	39	37	0				10
7:53	46	32	5		260		10
8:53	53	23	0				10
9:53	58	19	0				10
10:53	63	15	0				10
11:53	66	14	4				10
12:53	71	12	0				10
13:53	72	9	5				10
14:53	73	9	28	39	250		9
15:07	72	9	29	41	240		7
15:51	70	11	23	39	250		10
15:53	70	11	23	39	240		10
16:53	70	10	24	32	250		10
17:53	67	13	31	41	220	haze	5
18:53	62	19	12		220		10
19:53	62	17	14	27	200		10
20:53	66	8	28	40	220		8
21:17	65	7	30	47	240	haze	1.75
21:33	65	7	27	43	240	haze	2.5
21:38	65	7	29	43	250	haze	3
21:45	65	8	37	46	250	haze	4
21:53	64	8	39	54	250	haze	4
22:53	54	21	38	48	290		9
23:53	53	17	32	39	280		10

Table 14: Weather observations for Trinidad, Colorado, on March 30, 2014 (Source: http://mesowest.utah.edu/)

Time MST March 30, 2014	Temperature Degrees F	Relative Humidity in %	Wind Speed in mph	Wind Gust in mph	Wind Direction in Degrees	Weather	Visibility in miles
0:54	48	30	14		240		10
1:54	48	29	5		220		10
2:54	47	31	16		240		10
3:54	46	31	15		230		10
4:54	47	29	14		240		10
5:54	46	30	10		240		10
6:54	47	29	5		150		10
7:54	52	26	0				10
8:54	63	14	23	31	240		10
9:54	68	9	23	37	230		10
10:54	70	8	14	31	210		10
11:54	72	7	20	28	180		10
12:04	72	7	21	32	210		10
12:54	74	7	24	38	220		10
13:09	75	6	28	35	250		10
13:54	74	6	21	28	270		10
14:54	73	7	29	35	250		10
15:54	71	7	24	31	260		10
16:54	71	7	31	38	240		10
17:54	62	16	30	43	250		10
18:54	58	18	13		190		10
19:54	59	16	18		200		10
20:54	57	15	20	26	220		10
21:54	59	8	36	50	240		9
22:54	56	11	30	39	250		10
23:54	52	20	33	50	270		8

Table 15: Weather observations for Raton, New Mexico, on March 30, 2014 (Source: http://mesowest.utah.edu/)

Time MST March 30, 2014	Temperature Degrees F	Relative Humidity in %	Wind Speed in mph	Wind Gust in mph	Wind Direction in Degrees	Weather	Visibility in miles
0:53	41	48	4		230		10
1:53	37	52	5		340		10
2:53	34	56	7		340		10
3:53	38	50	6		340		10
4:53	31	61	7		60		10
5:53	34	56	6		320		10
6:53	38	50	5		290		10
7:53	42	44	0				10
8:53	48	34	4				10
9:53	55	23	7		180		10
10:53	61	19	6				10
11:53	68	9	18	25	220		10
12:53	70	8	13	31	220		10
13:53	73	6	23	31	240		10
14:53	71	6	27	37	250		10
15:53	70	7	31	46	210		10
16:53	67	9	31	41	250		10
17:53	62	13	27	38	250		10
18:53	57	21	20	28	230		10
19:53	53	24	13		250		10
20:53	56	12	21	36	230		10
21:53	57	9	33	44	250		10
22:53	54	13	30	46	240		10
23:53	50	20	18	29	260		10

Extensive cloud cover on March 30, 2014 hindered any type of satellite detection of dust in southeast Colorado; however radar imagery does provide some evidence of blowing dust. Specifically the Pueblo NEXRAD base reflectively images in Figure 44 and Figure 45 appear to capture distinct areas of blowing dust. At 4:23 PM MST (Figure 44) a well-defined line of mainly low-reflectivity echoes can be observed to the southeast of La Junta oriented in a southwest to northeast direction. By referring to observations in La Junta at around this time (Table 12, 4:17 PM and 4:33 PM MST), we find that haze was being reported with visibility reduced to 3 statute miles. During the same general time period in Lamar, visibility was considered good at 10 statute miles (Table 10, 3:53 PM and 4:53 PM MST).

By 5:39 PM MST, radar echoes had moved into the Lamar area (Figure 45). This corresponds precisely to the time period when visibility decreased significantly in Lamar. By again referring to Table 10, at 5:30 PM and 5:40 PM MST (the time period encompassing the radar

image of Figure 45) haze had been introduced to the Lamar observation with visibility rapidly dropping to 3 statute miles. Therefore, it seems reasonable to conclude that the low-reflectivity radar echoes displayed in Figure 44 and Figure 45 are indeed areas of blowing dust.

Webcam imagery from Gobbler's Knob (20 miles south of Lamar) also appears to capture blowing dust near the time of the radar image from Figure 45. Unfortunately the web camera lens was contaminated by mud from a dust storm earlier in the month, but in Figure 46 some airborne dust in the background at 5:45 PM MST (6 minutes after the radar image of Figure 45) can be observed. This blowing dust becomes even more apparent at 6:15 PM MST (Figure 47) with the horizon highly obscured. Table 10 reveals that Lamar was still reporting haze and a visibility of 3 miles in the time period encompassing Figure 47 (5:53 PM and 6:24 PM MST).

The blowing dust of March 30, 2014 was not only observed, but also anticipated. The Navy Aerosol Analysis and Prediction System (NAAPS) accurately forecast that blowing dust would be an issue in southeast Colorado during the afternoon and evening hours. Figure 48 shows the output from this model covering the time period from 18Z (11:00 AM MST), March 30 to 0Z (5:00 PM MST, March 30), March 31 while Figure 49 shows the same model for the time period of 0Z (5:00 PM MST, March 30), March 31 to 6Z (11:00 PM MST, March 30), March 31. The NAAPS system models blowing dust emissions and transport based on soil moisture content, soil erodibility factors and a variety of meteorological factors known to be conducive to blowing dust (for a description of NAAPS see: http://www.nrlmry.navy.mil/aerosol_web/Docs/globaer_model.html). The forecast panels in the upper left of both Figure 48 and Figure 49 clearly show Total Optical Depth values increasing in southeast Colorado to above normal levels. The green and yellow shading indicates that those enhanced values are attributed to dust.

Additionally, the Colorado Department of Public Health and Environment (CDPHE) was alerted to blowing dust on March 30, 2014 and consequently issued a Blowing Dust Advisory for most of southeast Colorado. Text from that advisory includes:

> "Strong gusty winds will bring a threat for blowing dust to portions of southwestern, southern and southeastern Colorado." and, "People with heart or lung disease, older adults, and children in the affected area should reduce prolonged or heavy indoor and outdoor exertion." (Source: http://www.colorado.gov/airquality/forecast_archive.aspx?seeddate=03%2f30%2f2014)

Radar and webcam imagery, forecast models and advisories indicate that a dust storm was anticipated and did occur on March 30, 2014 in southeast Colorado.

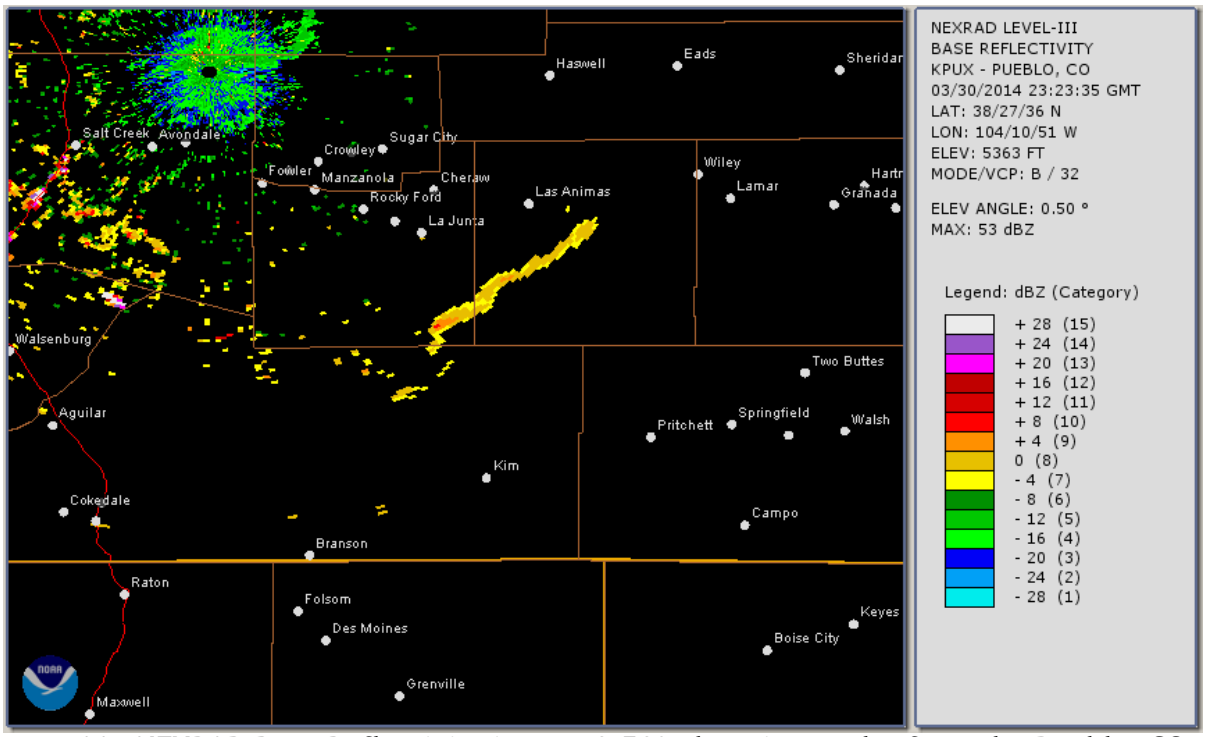


Figure 44: NEXRAD Base Reflectivity image, 0.50° elevation angle, from the Pueblo, CO radar at 4:23 PM MST (2323Z), March 30, 2014.
(Source: http://www.ncdc.noaa.gov/nexradinv/)

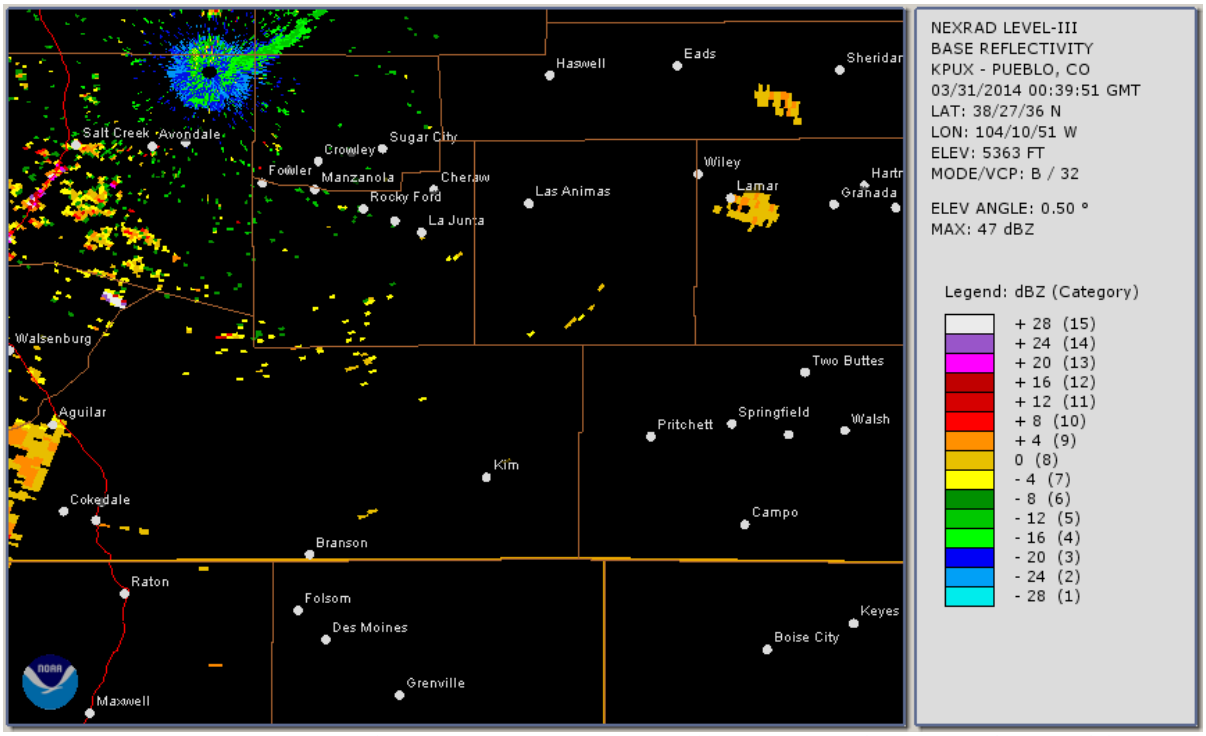


Figure 45: NEXRAD Base Reflectivity image, 0.50° elevation angle, from the Pueblo, CO radar at 5:39 PM MST (039Z, March 31), March 30, 2014.
(Source: http://www.ncdc.noaa.gov/nexradinv/)

Figure 46: Gobblers Knob webcam image at 5:45 PM MST March 30, 2014. (Source: http://amos.cse.wustl.edu/)

Figure 47: Gobblers Knob webcam image at 6:15 PM MST March 30, 2014. (Source: http://amos.cse.wustl.edu/)

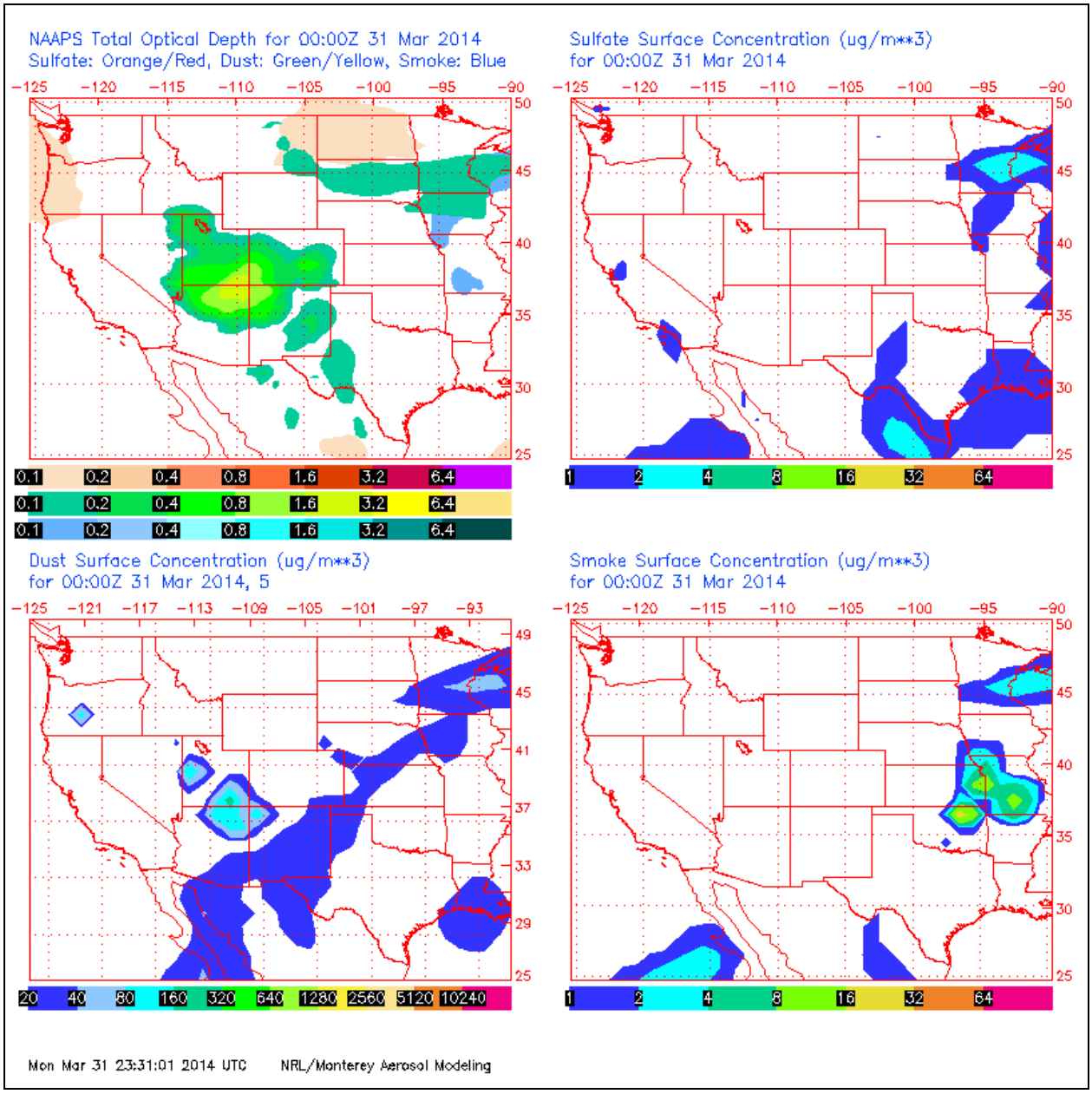


Figure 48: NAAPS forecast for 5:00 PM MST (0Z, March 31), March 30, 2014. (Source: http://www.nrlmry.navy.mil/aerosol-bin/aerosol/display_directory_all?DIR=/web/aerosol/public_html/globaer/ops_01/wus/)

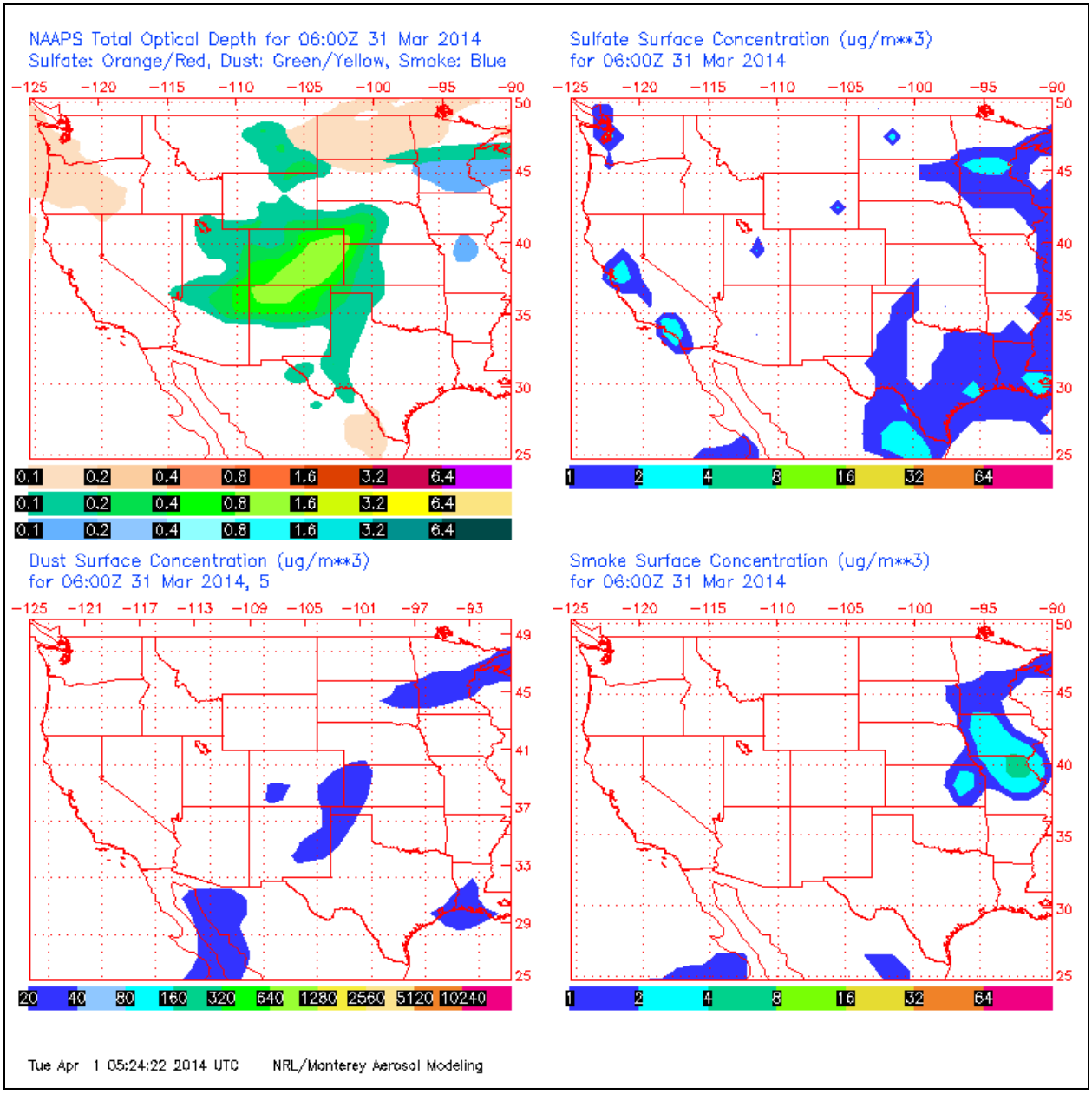


Figure 49: NAAPS forecast for 11:00 PM MST (6Z, March 31), March 30, 2014. (Source: http://www.nrlmry.navy.mil/aerosol-bin/aerosol/display_directory_all?DIR=/web/aerosol/public_html/globaer/ops_01/wus/)

The synoptic weather conditions described above impacted a region that was in the midst of a severe to exceptional drought (Figure 50). Note that the worst of the drought in southeast Colorado was impacting the area to the west and southwest of Lamar, which was the prevailing wind direction on March 30, 2014. Sustained drought conditions are known to make topsoil susceptible to high winds and produce blowing dust (see the following link from the National Climatic Data Center for more information: https://www.ncdc.noaa.gov/paleo/drought/drght_history.html). Figure 51 shows the total precipitation in inches from February 28, 2014 to March 29, 2014 for eastern Colorado and

adjacent states. The entire area surrounding Lamar, including locations upwind (west to southwest), received less than 0.51 inches of precipitation during the 30-day period leading up to the March 30 dust event in Lamar. Based on previous research 0.5 to 0.6 inches of precipitation over a 30-day period has been found to be the approximate threshold, below which, blowing dust exceedances at Lamar are more likely to occur when combined with high winds (see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2).

The U.S. Drought Monitor and 30-day precipitation totals indicate that soils in southeast Colorado were dry enough to produce blowing dust when winds were above the thresholds for blowing dust. This information, combined with other evidence provided in this report, proves that this dust storm was a natural, regional event that was not reasonably controllable or preventable.

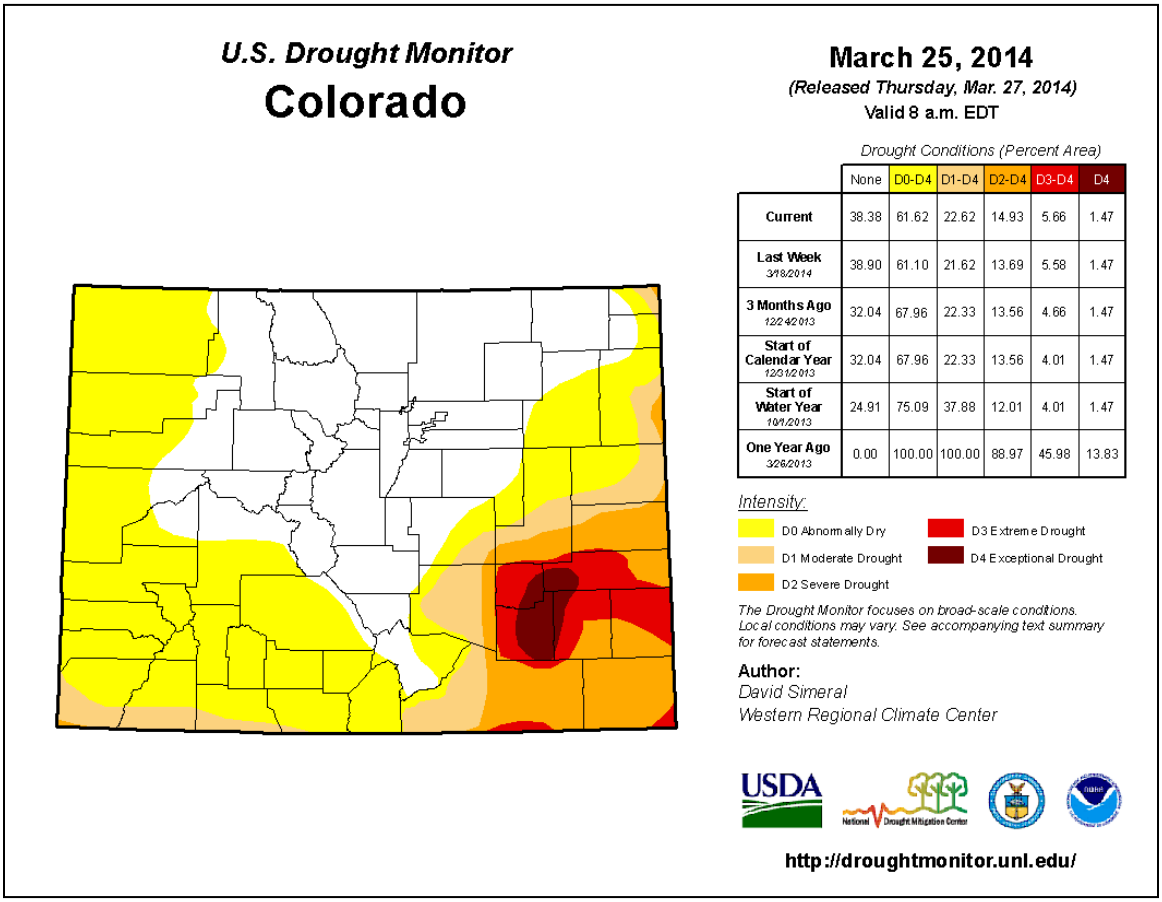


Figure 50: Drought conditions for the Western U.S. at 5:00 AM MST March 25, 2014. (Source: http://droughtmonitor.unl.edu/MapsAndData/MapArchive.aspx)

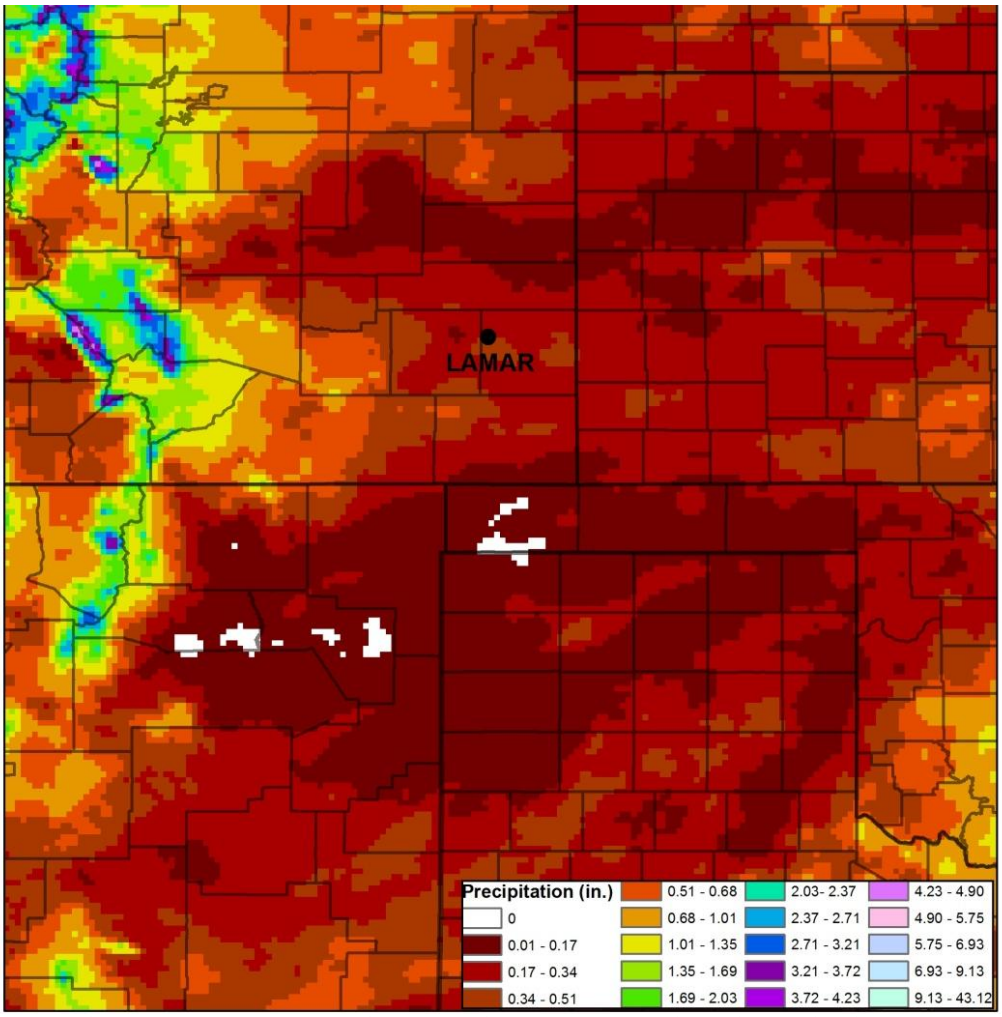


Figure 51: Total precipitation in inches for the eastern Colorado and adjacent states, February 28, 2014 – March 29, 2014.
(Source: http://prism.nacse.org/recent/)

2.6 March 31, 2014 Meteorological Analysis

On March 31 of 2014, a powerful spring storm system caused an exceedance of the 24-hour PM_{10} standard in Lamar, Colorado, at the Municipal Building monitor with a concentration of 223 $\mu g/m^3$. This elevated reading and the location of the monitor is plotted on a map of the Greater Lamar area in Figure 52. The exceedance in Lamar was the result of intense surface winds in the wake of a passing cold front. These surface features were associated with a strong upper-level trough that was moving across southeast Colorado. A secondary cold front passage later in the day also likely contributed to the PM_{10} exceedance. The surface winds in Lamar were predominantly out of a west to northwesterly direction which moved over dry soils in eastern Colorado, producing significant blowing dust.

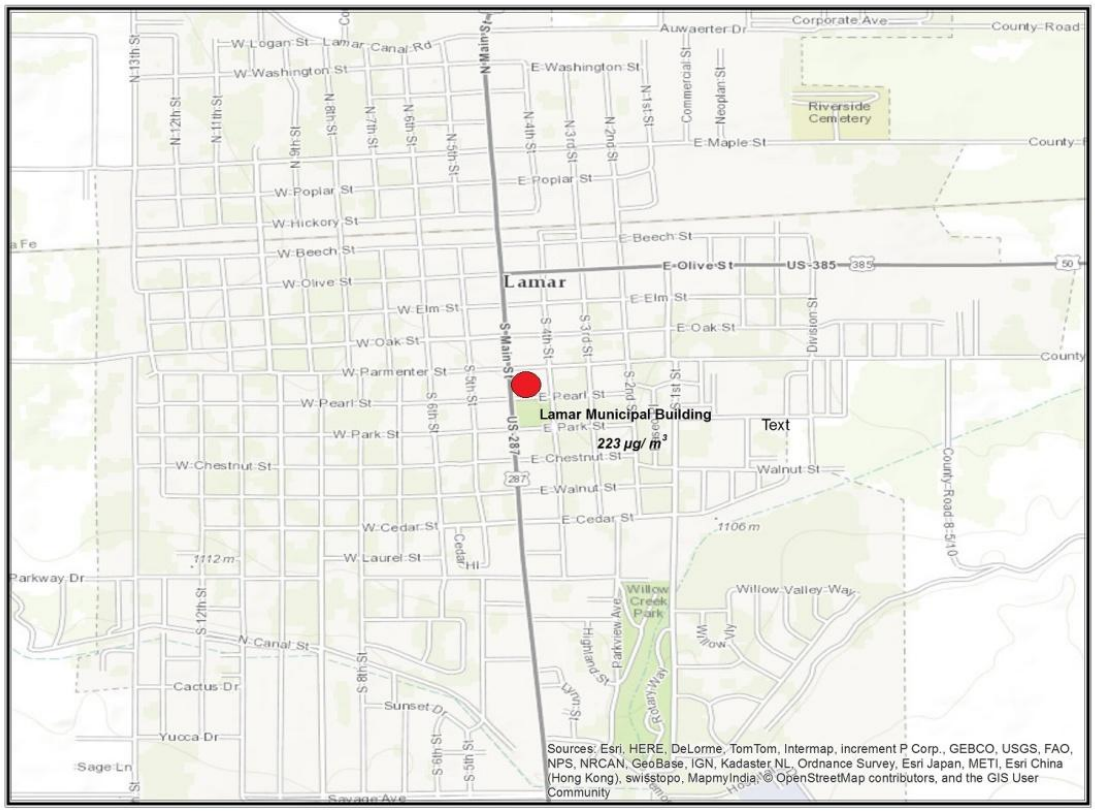


Figure 52: 24-hour PM_{10} concentration for the Lamar Municipal Building monitor, March 31, 2014.
(Source: http://webapps.datafed.net/datafed.aspx?dataset=AQS_D&parameter=pm10)

The surface weather associated with the storm system of March 31, 2014, is presented in Figure 53 and Figure 54. Significant surface features impacting southeast Colorado at 11:00 PM MST, March 30 (Figure 53) included a passing cold front moving eastward across southeast Colorado. This front was associated with a strong area of surface low pressure located in western Nebraska. The winds in southeast Colorado were predominantly out of a westerly direction in the wake of this cold front and were quite strong during the early morning hours of March 31. By 9:00 AM MST (Figure 54), another cold front moved into southeast Colorado from the north which shifted the wind from the west to a more northwesterly direction. Though not producing winds as strong as the cold front earlier in the day, this secondary cold front passage was also a likely contributor to the PM_{10} exceedance in Lamar.

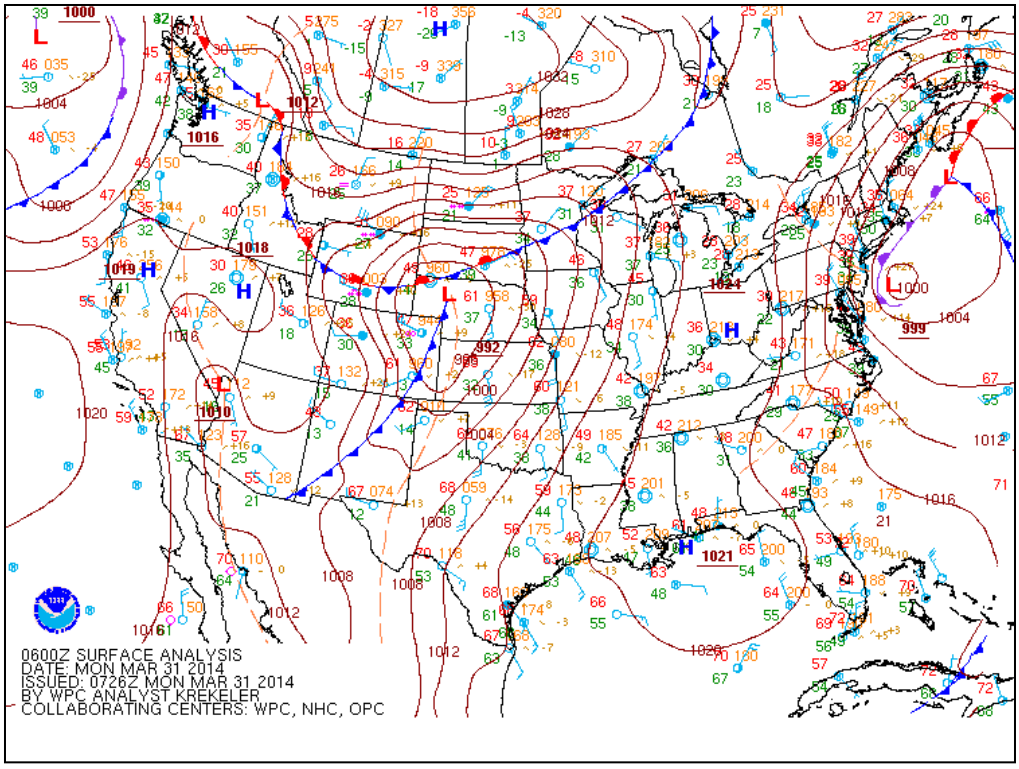


Figure 53: Surface analysis for 6Z March 31, 2014, or 11:00 PM MST March 31, 2014. (Source: http://nomads.ncdc.noaa.gov/ncep/NCEP)

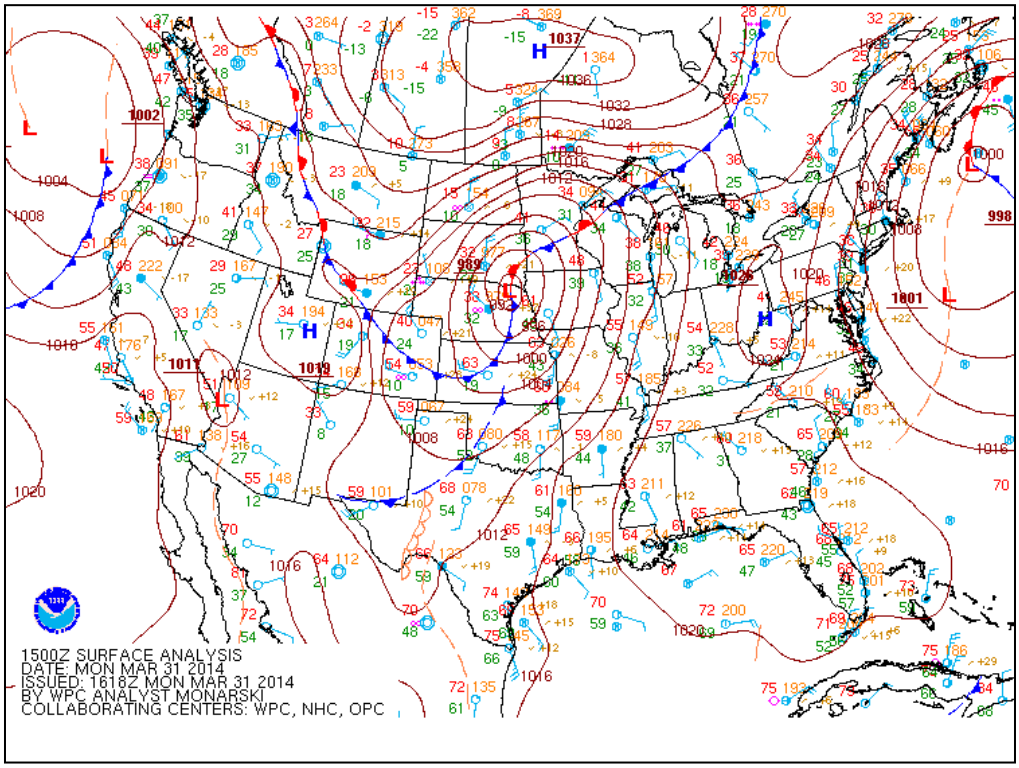


Figure 54: Surface analysis for 15Z March 31, 2014, or 9:00 AM MST March 31, 2014. (Source: http://nomads.ncdc.noaa.gov/ncep/NCEP)

The upper-level trough associated with this storm system is shown on the North American Regional Reanalysis (NARR) 700 mb height analysis map at 11:00 PM MST, March 30, 2014 in Figure 55. This chart shows that a deep trough of low pressure was moving over southeast Colorado at the onset of the blowing dust event of March 31. Directly over Lamar the 700 mb wind speeds ranged from 50-60 knots (57-69 mph). The atmosphere at this time was still fairly unstable as evidenced from the height of the mixed level shown in Figure 56. Over the Lamar area, mixing ranged from 3-5 km above mean sea level (MSL). The 700 mb level is located roughly 3 kilometers above MSL, so it is reasonable to believe that mixing was deep enough at 11:00 PM MST to transfer momentum to the surface from the zone of strong winds that were present at 700 mb. Winds of the magnitude found at 700 mb would have been well in excess of wind speeds that are known to cause blowing dust in southeast Colorado (30 mph sustained winds, 40 mph gusts; see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2).

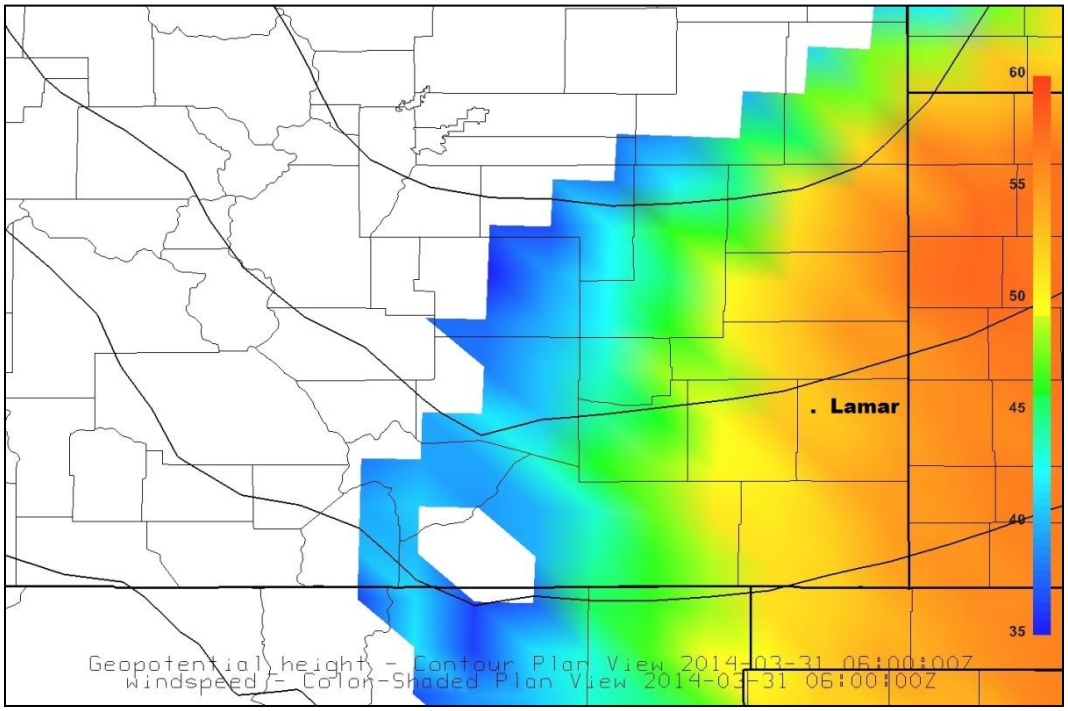


Figure 55: NARR 700 mb (about 3 kilometers above mean sea level) analysis for 6Z March 31, 2014, or 11:00 PM MST March 30, 2014.
(Source: http://nomads.ncdc.noaa.gov/data.php?name=access#hires_weather_datasets)

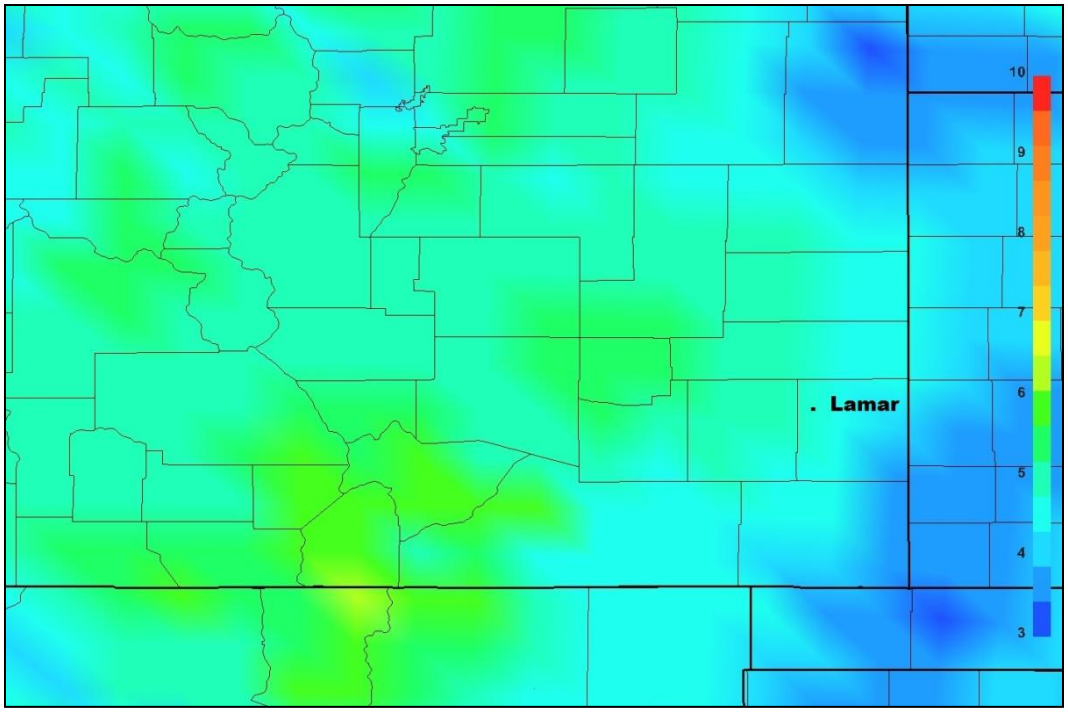


Figure 56: Height of the mixed layer in kilometers above mean sea level from the NARR at 6Z March 31, 2014, or 11:00 PM MST March 30, 2014. Only mixing heights above 3 kilometers are shown.
(Source: http://nomads.ncdc.noaa.gov/data.php?name=access#hires_weather_datasets)

In order to fully evaluate the synoptic meteorological scenario of March 31, 2014, regional surface weather maps are provided showing individual station observations during the height of the event in question. Figure 57 presents weather observations for eastern Colorado and adjacent states at (a) 12:43 AM MST, and (b) 8:43 AM MST on March 31. On the map in Figure 57(a), the station observation for Lamar (LAA) shows winds sustained at 35 knots (40 mph), gusts to 41 knots (47 mph). These are wind speeds known to cause blowing dust in southeast Colorado (30 mph sustained winds, 40 mph gusts; see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2). Additionally, the Lamar station observation includes a reduced visibility of 1 statute mile with the weather symbol of infinity (∞). The infinity sign is the weather symbol for haze. Haze is often reported during dust storms, and in dry and windy conditions haze typically refers to blowing dust (see the following link for the description of haze published by the National Oceanic and Atmospheric Administration (NOAA): http://www.crh.noaa.gov/lmk/?n=general_glossary). Fifty miles to the west and directly upwind of Lamar, La Junta (LHX) was reporting sustained winds at 20 knots (23 mph) with haze and visibility reduced to 5 statute miles. This observation indicates that this dust event was likely regional in scale and not solely confined to the Lamar area.

Eight hours later at 8:43 AM MST (Figure 57 (b)), a second period of high winds, haze and reduced visibility was observed in southeast Colorado. Visibility in Lamar was obscured at 7 statute miles and the wind remained strong (sustained at 25 knots (29 mph) with gusts to 31 knots (36 mph)). Also note that blowing dust conditions were continuing in La Junta with visibility significantly diminished at 1 statute mile. This second interval of blowing dust likely had a significant impact on the 24-hour PM_{10} concentration in Lamar on March 31, 2014.

Hourly surface observations, in table form, from Lamar and La Junta provide supporting evidence that there was an extended period of high winds and haze (blowing dust) in southeast Colorado. Table 16 lists observations for the PM_{10} exceedance location of Lamar while observations for La Junta can be found in Table 17. Observations that are climatologically consistent with blowing dust conditions (see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2) are highlighted in yellow. Both of these weather observation sites experienced many hours of reduced visibility along with sustained wind speeds and gusts at or above the thresholds for blowing dust.

Surface weather maps and hourly observations show that a regional dust storm occurred under west to northwesterly flow in conjunction with two cold front passages. This data provides clear evidence of blowing dust and winds at or above the threshold speeds for blowing dust on March 31, 2014.

a) b)

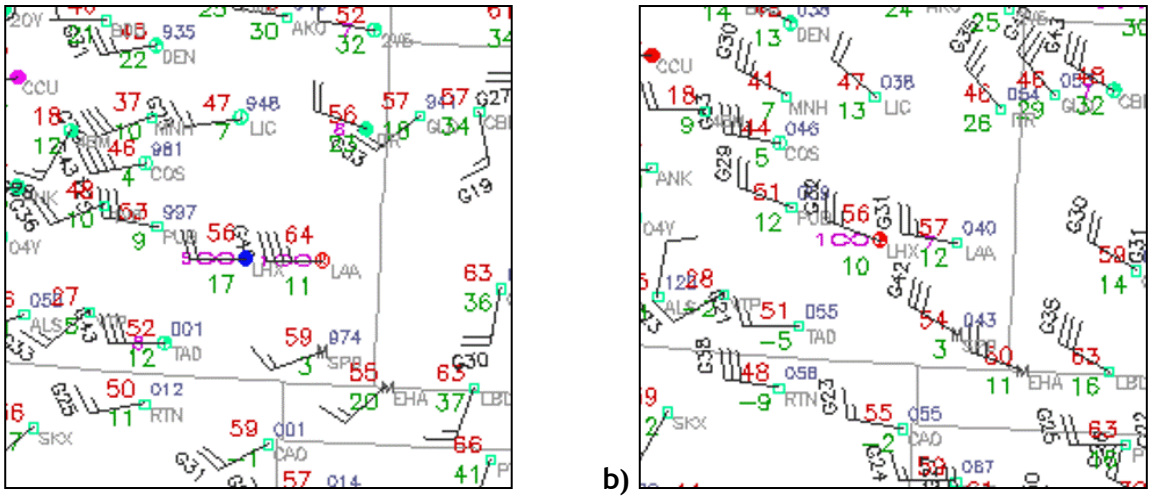


Figure 57: High Plains regional surface analysis for (a) 12:43 AM MST and (b) 8:43 AM MST, March 31, 2014.
(Source: http://www.mmm.ucar.edu/imagearchive/)

Table 16: Weather observations for Lamar, Colorado, on March 31, 2014 (Source: http://mesowest.utah.edu/)

Time MST March 31, 2014	Temperature Degrees F	Relative Humidity in %	Wind Speed in mph	Wind Gust in mph	Wind Direction in Degrees	Weather	Visibility in miles
0:11	64	12	36	47	260	haze	2
0:23	65	12	37	47	260	haze	1
0:28	64	12	39	46	270	haze	1
0:43	61	16	25	38	280	haze	2
0:48	61	17	27	38	280	haze	2
0:53	59	18	27	37	280	haze	3
1:01	58	18	23	36	280	haze	3
1:53	57	18	27	32	260	haze	5
2:40	54	15	27		260		7
2:53	53	15	24	31	260		7
3:53	50	16	18		270		10
4:53	47	17	15		260		9
5:53	48	18	20		270		8
6:53	52	18	27	35	280		9
7:53	57	17	29	36	280		7
8:53	61	13	31	38	290		7
9:53	63	11	24	36	300		9
10:53	65	10	23	32	320		9
11:53	67	8	24	38	320		9
12:53	67	8	14	32	350		8
13:53	68	7	20	31	310		9
14:53	67	6	12	18	320		9
15:53	65	12	21	29	40		7
17:53	56	19	16		50		8
18:53	51	27	20		50		9
19:53	47	31	17		60		10
20:53	43	41	18		80		9
21:53	40	48	9		90		10
22:53	36	54	8		100		10
23:53	36	56	8		90		10

Table 17: Weather observations for La Junta, Colorado, on March 31, 2014 (Source: http://mesowest.utah.edu/)

Time MST March 31, 2014	Temperature Degrees F	Relative Humidity in %	Wind Speed in mph	Wind Gust in mph	Wind Direction in Degrees	Weather	Visibility in miles
0:05	60	12	36	45	250	lt rain	0.75
0:13	58	17	21	45	270	lt rain	1.25
0:19	56	20	18		270	haze	3
0:29	56	21	21		270	haze	5
0:53	55	20	25	31	260		7
1:53	52	16	20		240		10
2:53	51	14	29		260	haze	6
3:53	47	16	20		240		10
4:53	46	18	14		280		10
5:17	46	19	16		260	haze	6
5:30	46	21	15		250	haze	2.5
5:53	46	20	16		260	haze	4
6:53	50	19	21		280		10
7:40	53	17	27	39	280	haze	2
7:53	54	17	25		280	haze	3
7:59	55	16	31	38	280	haze	1.75
8:03	55	16	35	39	280	haze	0.75
8:13	55	16	35	39	280	lt rain	0.5
8:23	56	16	30	37	270	haze	0.75
8:39	56	16	27	37	290	haze	1.25
8:53	57	14	27		290	haze	2
9:06	58	14	24		300	haze	5
9:53	60	12	22	30	300		8
10:53	62	10	13	32	300		10
11:53	62	9	13	21	300		10
12:53	66	7	15	24	340		10
13:53	65	7	5				10
14:53	66	6	8	22	330		10
15:53	67	5	8	23	270		10
16:46	65	9	27	32	40	haze	2.5
16:56	62	12	23		30	haze	3
17:53	58	15	23		50	haze	4
18:53	54	20	21		60		10
19:13	52	25	29	33	60	haze	2.5
19:21	51	27	24		60	haze	1.5
19:27	50	28	27	32	60	haze	3
19:40	50	28	23	33	60	haze	2.5
19:53	49	29	25		70		8
20:53	45	34	17		80		10

Satellite imagery provides strong supporting evidence that a regional dust storm was taking place on March 31, 2014. The GOES 1-km visible satellite image at 8:45 AM MST, March 31 (Figure 58) reveals several distinct dust plumes (circled in red) oriented in a northwest to southeast direction. Although none of this dust plumes is directly impacting Lamar at the time of this image, it is reasonable to believe that smaller, less discernible, areas of blowing dust were simultaneously occurring in other parts of southeast Colorado. By referring back to Table 16, one can see that at 8:53 AM MST (8 minutes after the satellite image of Figure 58) Lamar was reporting sustained winds of 31 mph, gusts to 38 mph with visibility reduced to 7 statute miles. This is an observation reasonably consistent with conditions known to create blowing dust in southeast Colorado (30 mph sustained winds, 40 mph gusts; -- see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2).

Webcam imagery from Gobbler's Knob (20 miles south of Lamar) at 8:45 AM MST also appears to capture blowing dust at approximately the same time as the satellite image from Figure 58. Unfortunately the web camera lens in Figure 59 was contaminated by mud from a dust storm earlier in the month, some airborne dust in the background with the horizon highly obscured can be observed.

The National Oceanic and Atmospheric Administration (NOAA) Satellite Services Division was in agreement with the conclusion that blowing dust was moving through southeast Colorado during the morning of March 31. The Smoke Text Product from NOAA at 11:00 AM MST on March 31, 2014 stated:

> "A group of dust events are visible in satellite imagery moving through the Southern Plains this morning....the third group of plumes is visible at 1500Z in SE Colorado moving SE towards Kansas and Oklahoma." (Source: http://www.ssd.noaa.gov/PS/FIRE/DATA/SMOKE/2014/2014C311711.html)

Satellite and webcam imagery combined with reports from NOAA offices clearly reveal that blowing dust was taking place throughout southeast Colorado on March 31, 2014. This collection of data indicates that this dust storm was a regional event and therefore not controllable or preventable.

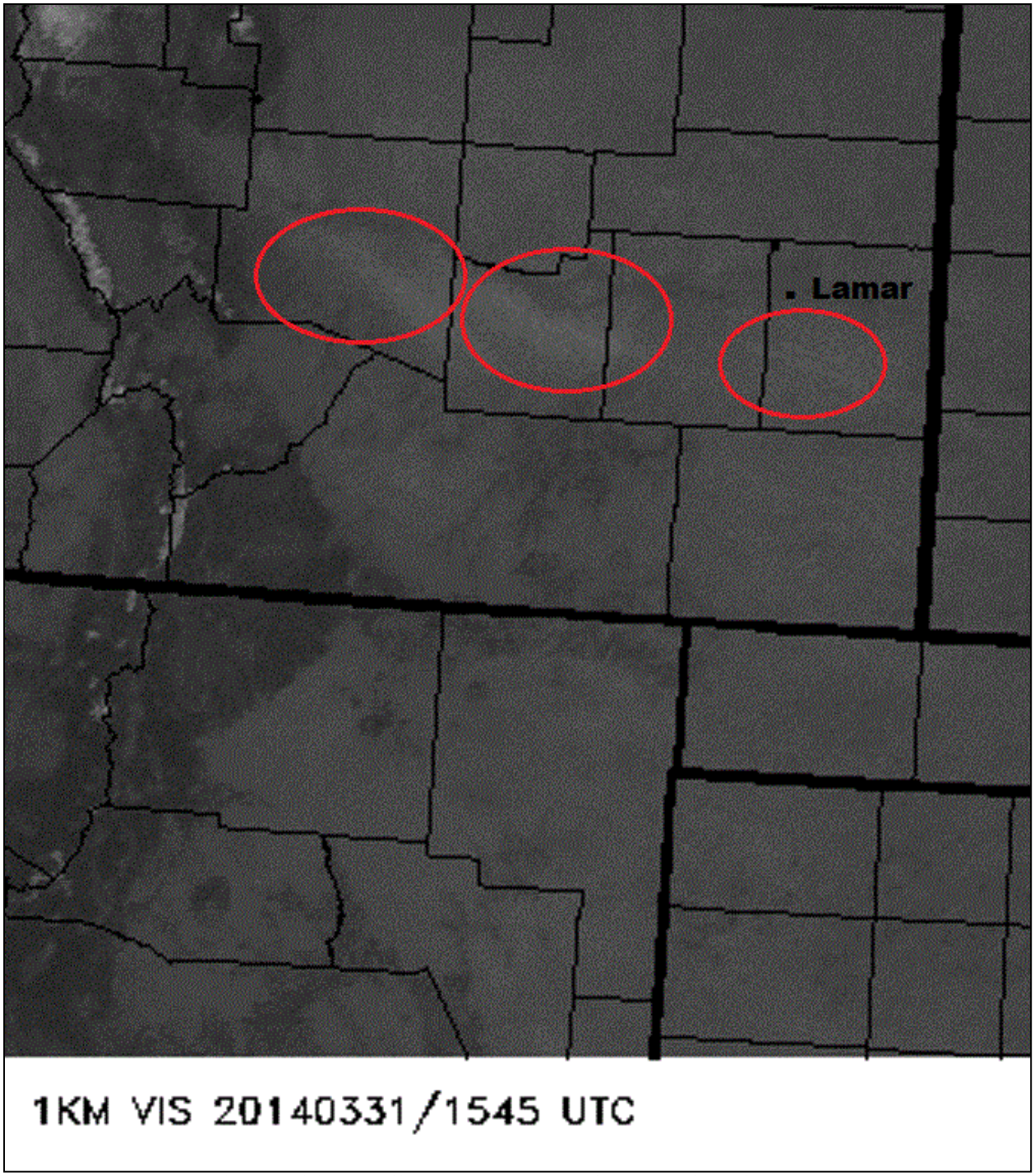


Figure 58: GOES 1-km visible satellite image of southeast Colorado at 8:45 AM MST (1545Z), March 31, 2014.
(Source: http://schumacher.atmos.colostate.edu/weather/rt.php)

Figure 59: Gobblers Knob webcam image at 8:45 AM MST March 31, 2014. (Source: http://amos.cse.wustl.edu/)

The blowing dust of March 31, 2014 was not only observed, but also anticipated. The Navy Aerosol Analysis and Prediction System (NAAPS) accurately forecast that blowing dust would be an issue in southeast Colorado during the morning hours of March 31. Figure 60 shows the output from this model covering the time period from 6Z (11:00 PM MST, March 30), March 31 to 12Z (5:00 AM MST), March 31 while Figure 61 shows the same model for the time period of 12Z (5:00 AM MST), March 31 to 18Z (11:00 AM MST), March 31. The NAAPS system models blowing dust emissions and transport based on soil moisture content, soil erodibility factors and a variety of meteorological factors known to be conducive to blowing dust (for a description of NAAPS see: http://www.nrlmry.navy.mil/aerosol_web/Docs/globaer_model.html). The forecast panels in the upper left of both Figure 60 and Figure 61 clearly show Total Optical Depth values in southeast Colorado above normal levels. The green and yellow shading indicates that those enhanced values are attributed to dust.

Additionally, the Colorado Department of Public Health and Environment (CDPHE) was alerted to the threat for blowing dust on March 31, 2014 and consequently issued a Blowing Dust Advisory for most of southeast Colorado, including the Lamar area. Text from that advisory included:

> "Strong gusty winds will bring a threat for blowing dust to large portions of eastern Colorado." and, "People with heart or lung disease, older adults, and children in the

affected area should reduce prolonged or heavy indoor and outdoor exertion." (Source: http://www.colorado.gov/airquality/forecast_archive.aspx?seeddate=03%2f31%2f2014)

Forecast products and advisories show that a blowing dust event was expected on March 31, 2014 in southeast Colorado.

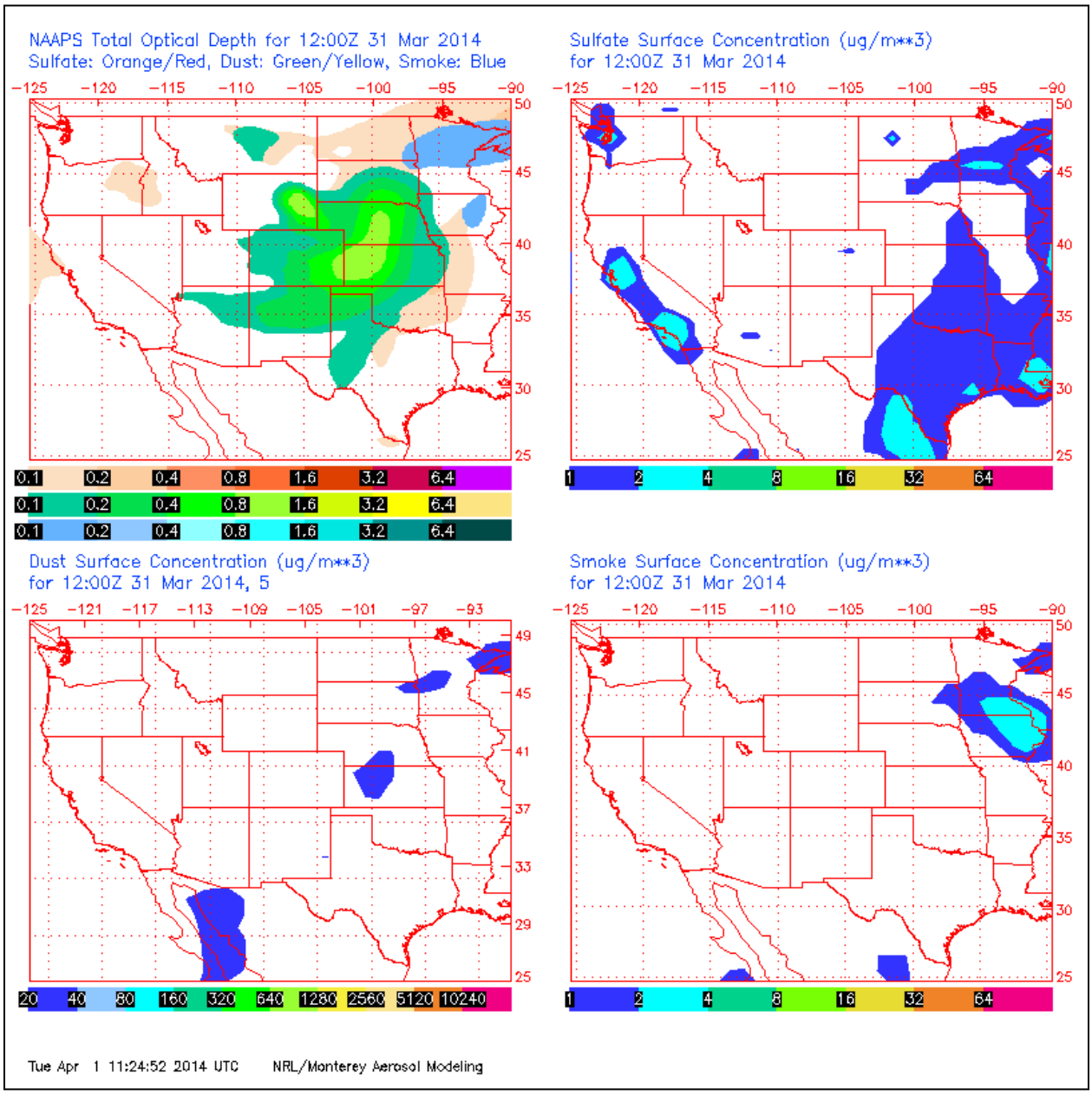


Figure 60: NAAPS forecast for 5:00 AM MST (12Z), March 31, 2014. (Source: http://www.nrlmry.navy.mil/aerosol-bin/aerosol/display_directory_all?DIR=/web/aerosol/public_html/globaer/ops_01/wus/)

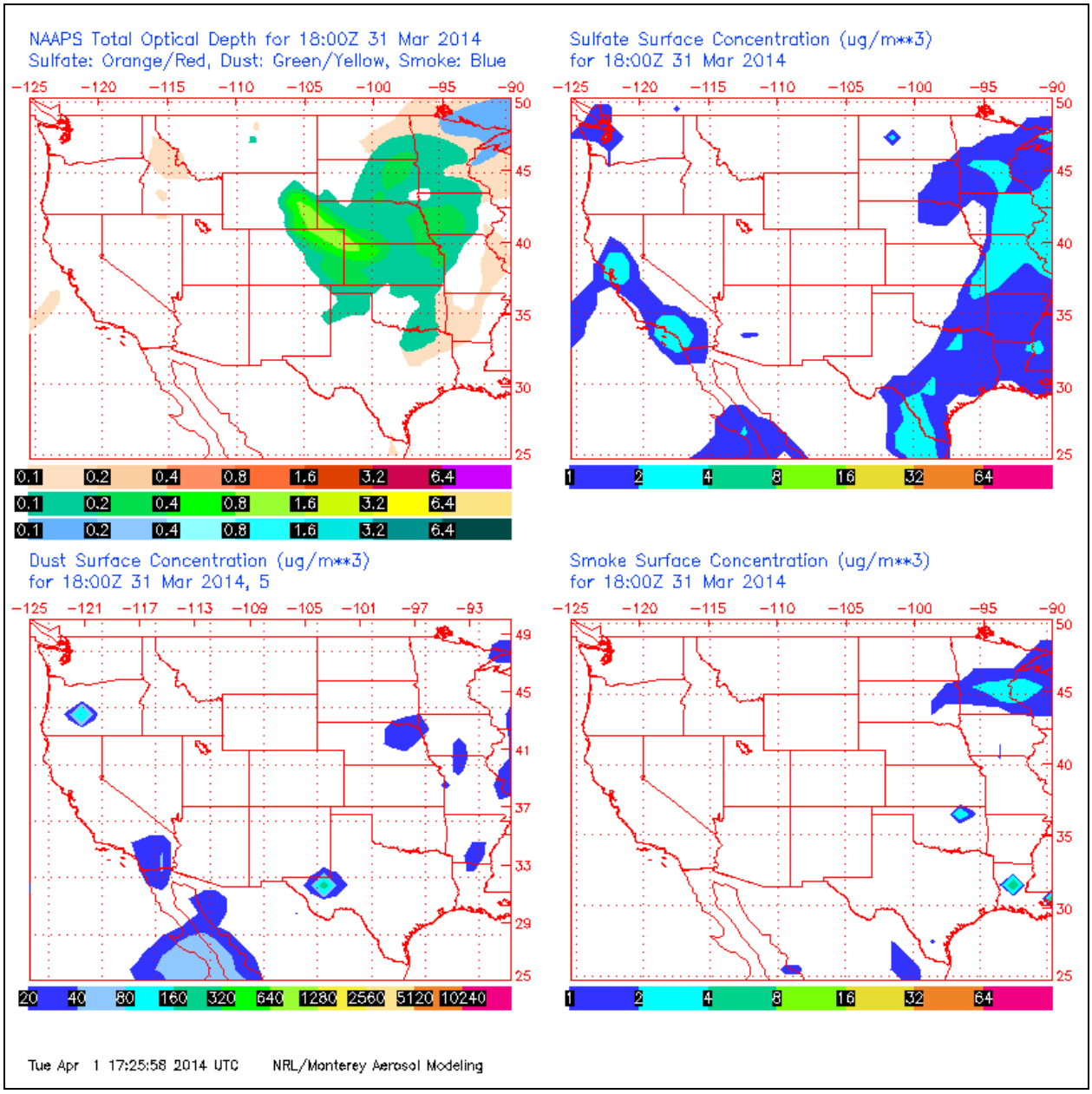


Figure 61: NAAPS forecast for 11:00 AM MST (18Z) March 31, 2014. (Source: http://www.nrlmry.navy.mil/aerosol-bin/aerosol/display_directory_all?DIR=/web/aerosol/public_html/globaer/ops_01/wus/)

The synoptic weather conditions described above impacted a region that was in the midst of a severe to exceptional drought (Figure 62). Note that the worst of the drought in southeast Colorado was impacting the area to the west and northwest of Lamar, which was the prevailing wind direction on March 31, 2014. Sustained drought conditions are known to make topsoil susceptible to high winds and produce blowing dust (see the following link from the National Climatic Data Center for more information: https://www.ncdc.noaa.gov/paleo/drought/drght_history.html). Figure 63 shows the total precipitation in inches from March 1, 2014 to March 30, 2014 for Colorado. The entire area

surrounding Lamar, including locations upwind (west to southwest), received less than 0.6 inches of precipitation during the 30-day period leading up to the March 31 dust event in Lamar. Based on previous research 0.5 to 0.6 inches of precipitation over a 30-day period has been found to be the approximate threshold, below which, blowing dust exceedances at Lamar are more likely to occur when combined with high winds (see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2).

The U.S. Drought Monitor and 30-day precipitation totals indicate that soils in southeast Colorado were dry enough to produce blowing dust when winds were above the thresholds for blowing dust. This information, combined with other evidence provided in this report, proves that this dust storm was a natural, regional event that was not reasonably controllable or preventable.

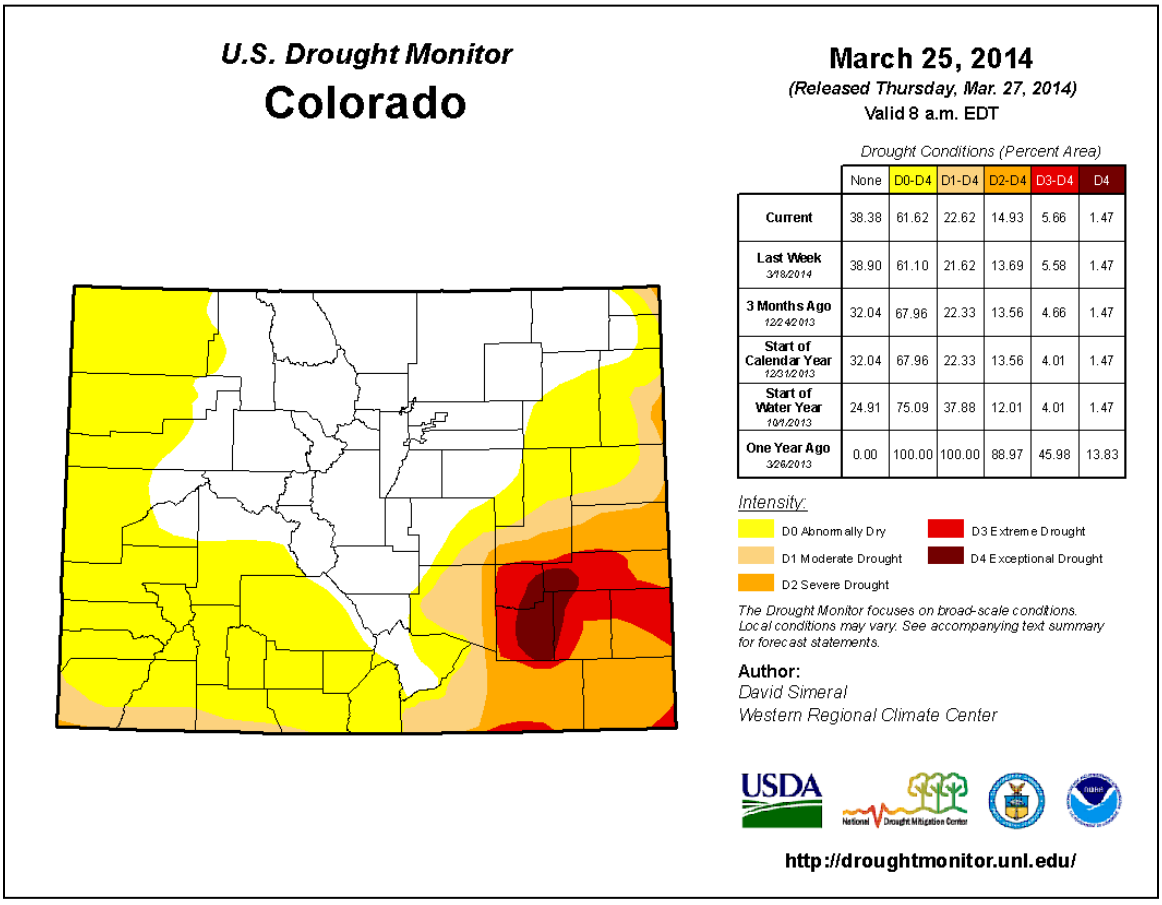


Figure 62: Drought conditions for Colorado at 5:00 AM MST March 25, 2014. (Source: http://droughtmonitor.unl.edu/MapsAndData/MapArchive.aspx)

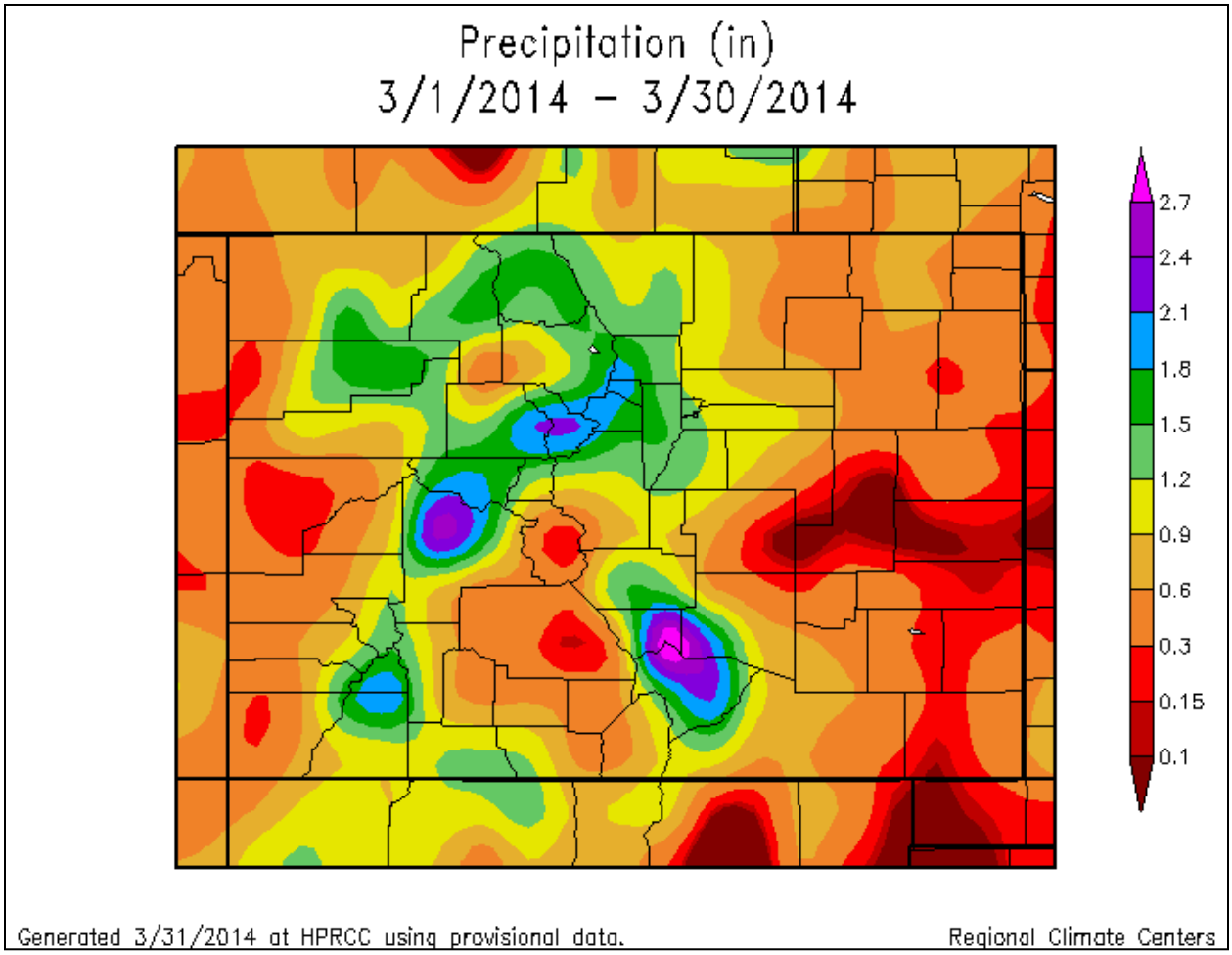


Figure 63: Total precipitation in inches for Colorado, March 1, 2014 – March 30, 2014. (Source: http://www.hprcc.unl.edu/maps/current/)

2.7 April 23, 2014 Meteorological Analysis

On April 23 of 2014, a powerful spring storm system caused an exceedance of the 24-hour PM_{10} standard in Lamar, Colorado, at the Municipal Building monitor with a concentration of 350 $\mu g/m^3$. This elevated reading and the location of the monitor is plotted on a map of the Greater Lamar area in Figure 64. The exceedance in Lamar was the result of intense surface winds in the wake of a passing cold front. These surface features were associated with a strong upper-level trough that was moving across the western United States. Post-frontal thunderstorms with strong outflow winds may also have had a significant contribution to PM_{10} concentrations. The surface winds in Lamar were predominantly out of a north to northeasterly direction which moved over dry soils in eastern Colorado, producing significant blowing dust.

High PM10 Natural Event in Colorado (April 23, 2014)

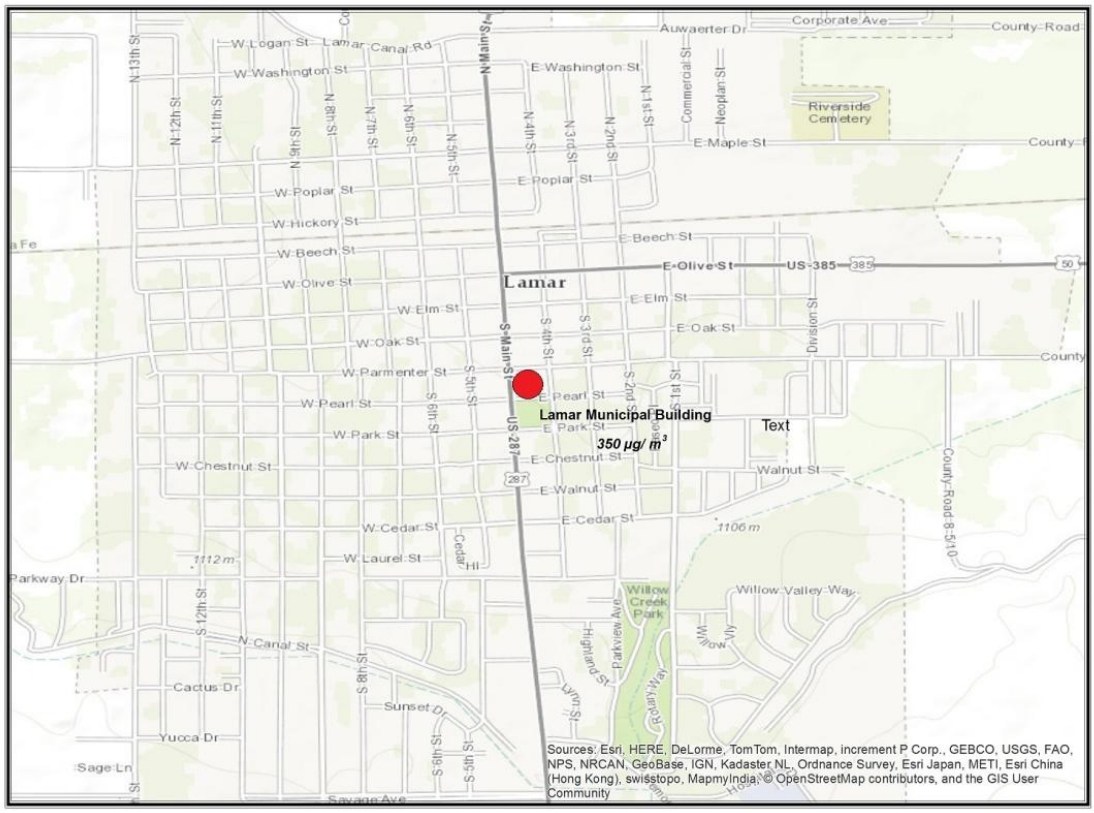


Figure 64: 24-hour PM_{10} concentration for the Lamar Municipal Building monitor, April 23, 2014.
(Source: http://webapps.datafed.net/datafed.aspx?dataset=AQS_D&parameter=pm10)

The upper-level trough associated with this storm system is shown on the 700 mb and 500 mb height analysis maps at 5:00 PM MST, April 23, 2014 in Figure 65 and Figure 66, respectively. The 700 mb level is located roughly 3 kilometers above mean sea level (MSL) while the 500 mb level is approximately 6 kilometers above MSL. These two charts show that a deep trough of low pressure was present at both the 700 and 500 mb level at the onset of the blowing dust event of April 23 and that it was moving over the southwestern United States. This is a typical upper-air pattern for blowing dust events in Colorado (see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2).

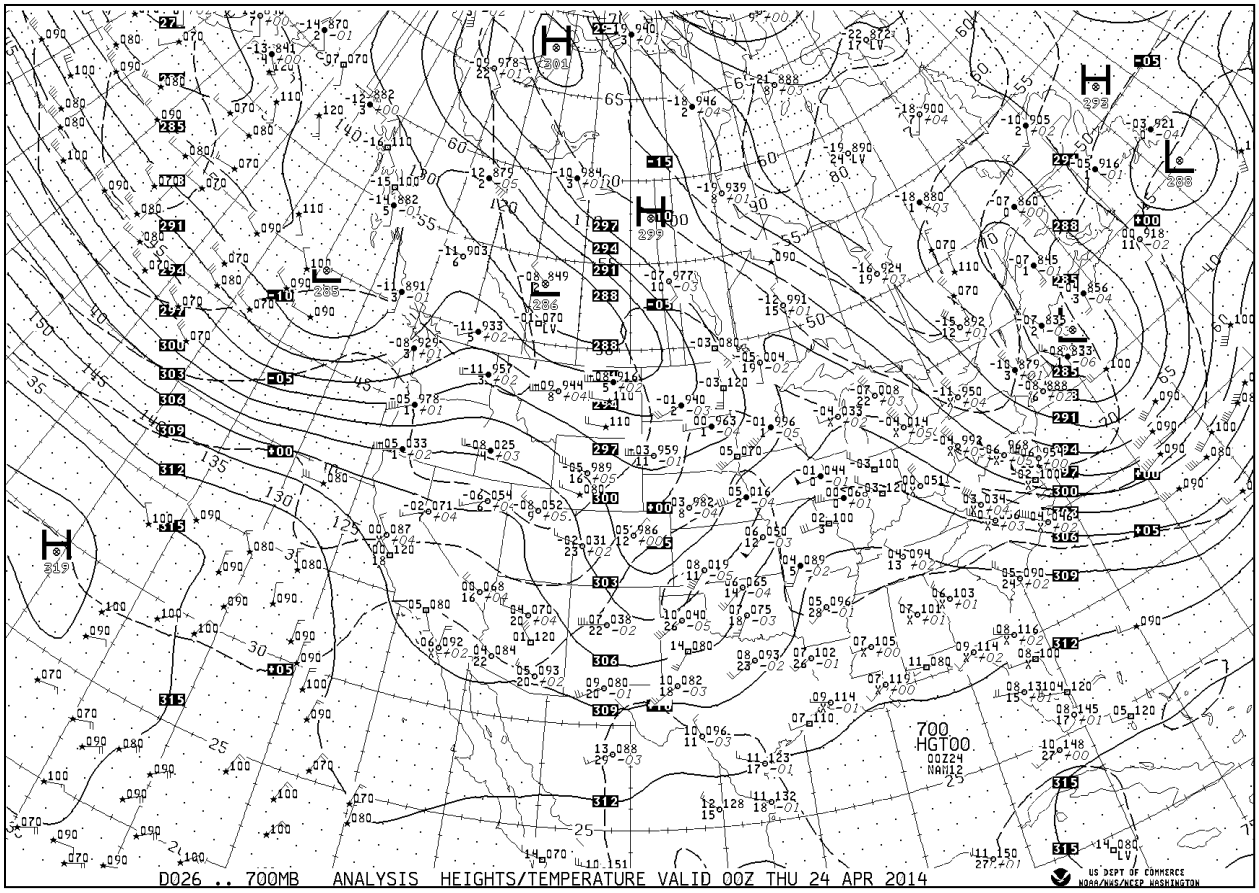


Figure 65: 700 mb (about 3 kilometers above mean sea level) analysis for 0Z April 24, 2014, or 5:00 PM MST April 23, 2014.
(Source: http://nomads.ncdc.noaa.gov/ncep/NCEP)

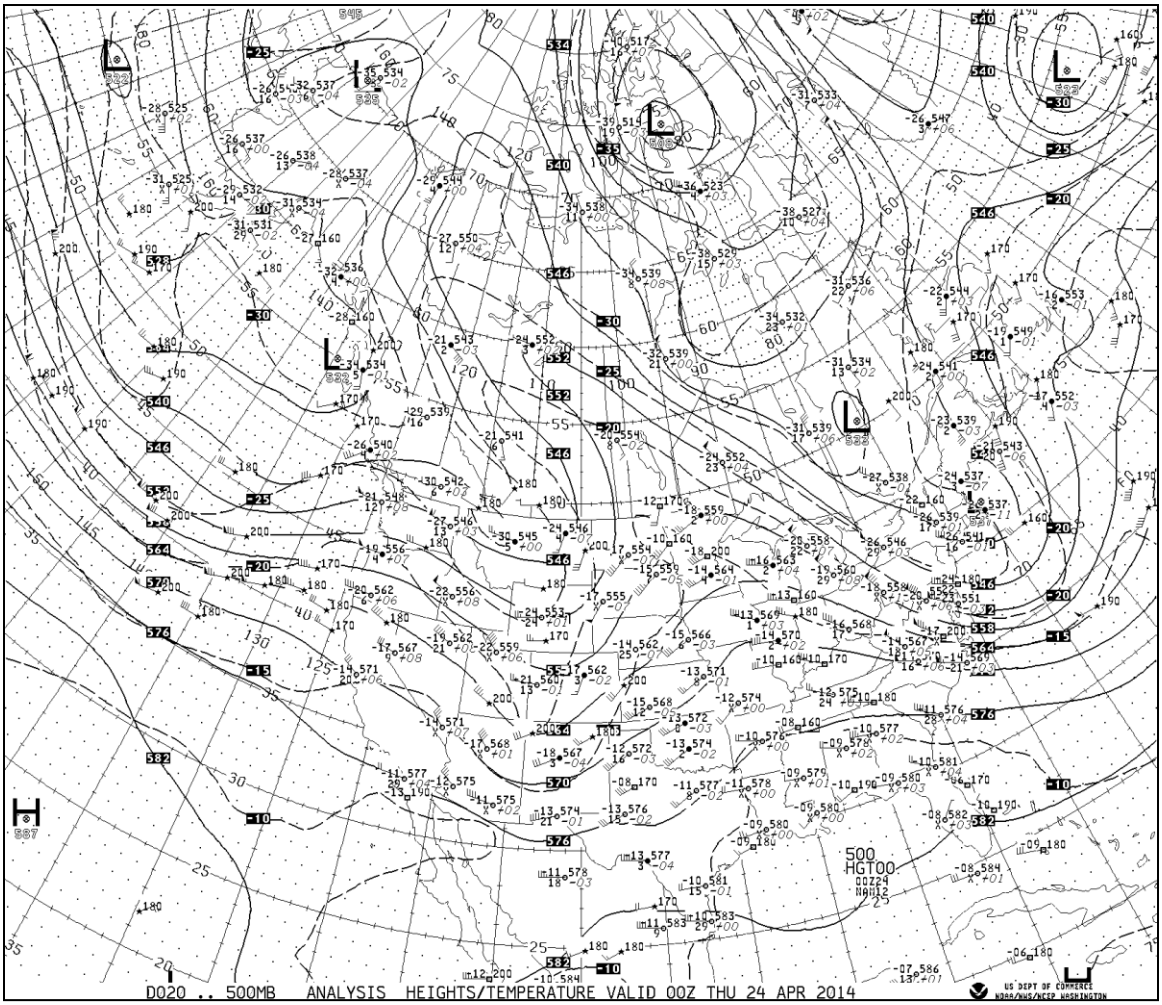


Figure 66: 500 mb (about 6 kilometers above mean sea level) analysis for 0Z April 24, 2014, or 5:00 PM MST April 23, 2014.
(Source: http://nomads.ncdc.noaa.gov/ncep/NCEP)

The surface weather associated with the storm system of April 23, 2014, is presented in Figure 67 and Figure 68. Significant surface features at 2:00 PM MST, April 23 (21Z, Figure 67) included a strong cold front which was moving through southeast Colorado. In advance of this front the wind in southeast Colorado was predominantly out of a southwesterly direction and was quite gusty at times, however the wind increased significantly once the cold front passed (Figure 68). By 8:00 PM MST, a significant amount of "bunching" of isobars was occurring in southeast Colorado behind the cold front. This indicates that a strong pressure gradient was in place. Wind speed is directly proportional to the pressure gradient, so a higher pressure gradient will produce stronger winds (see the following link for additional information on pressure gradient and its relationship to wind speed from the National Oceanic and Atmospheric Administration (NOAA): http://www.srh.noaa.gov/jetstream/synoptic/wind.htm). The increasing pressure gradient was in response to a building ridge of high pressure over northern Utah interacting with a strong low pressure area slowly moving into southwest Kansas. This chain of events consequently produced extremely gusty northerly winds across southeast Colorado by the evening of April 23.

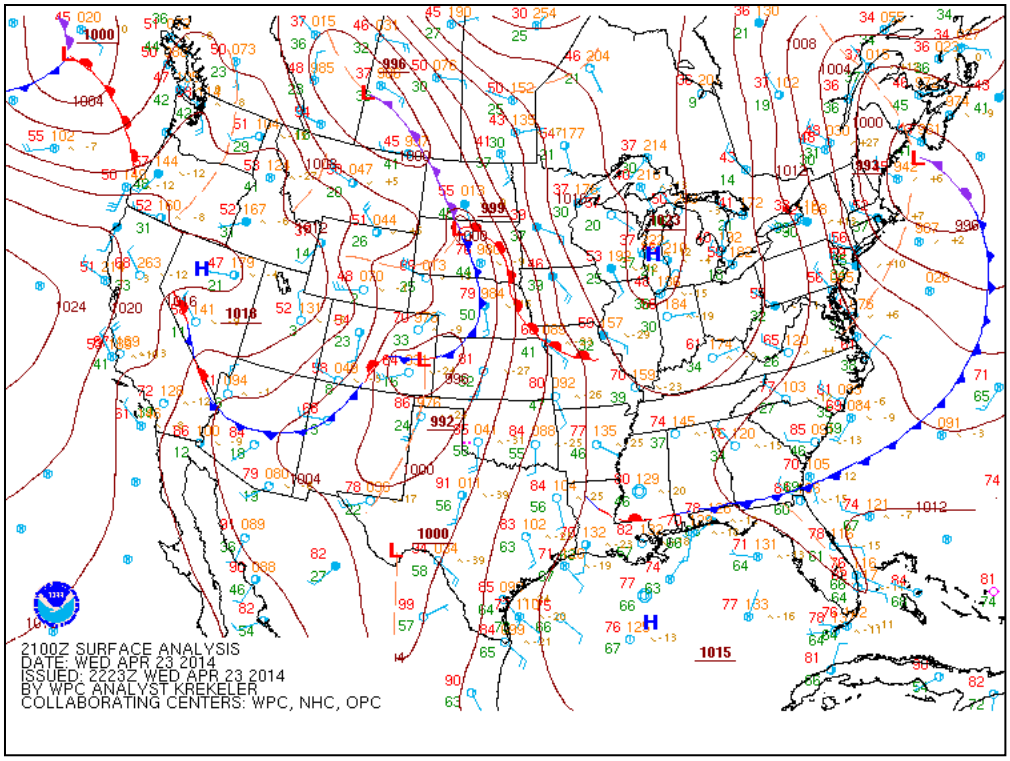


Figure 67: Surface Analysis for 21Z April 23, 2014, or 2:00 PM MST April 23, 2014. (Source: http://nomads.ncdc.noaa.gov/ncep/NCEP)

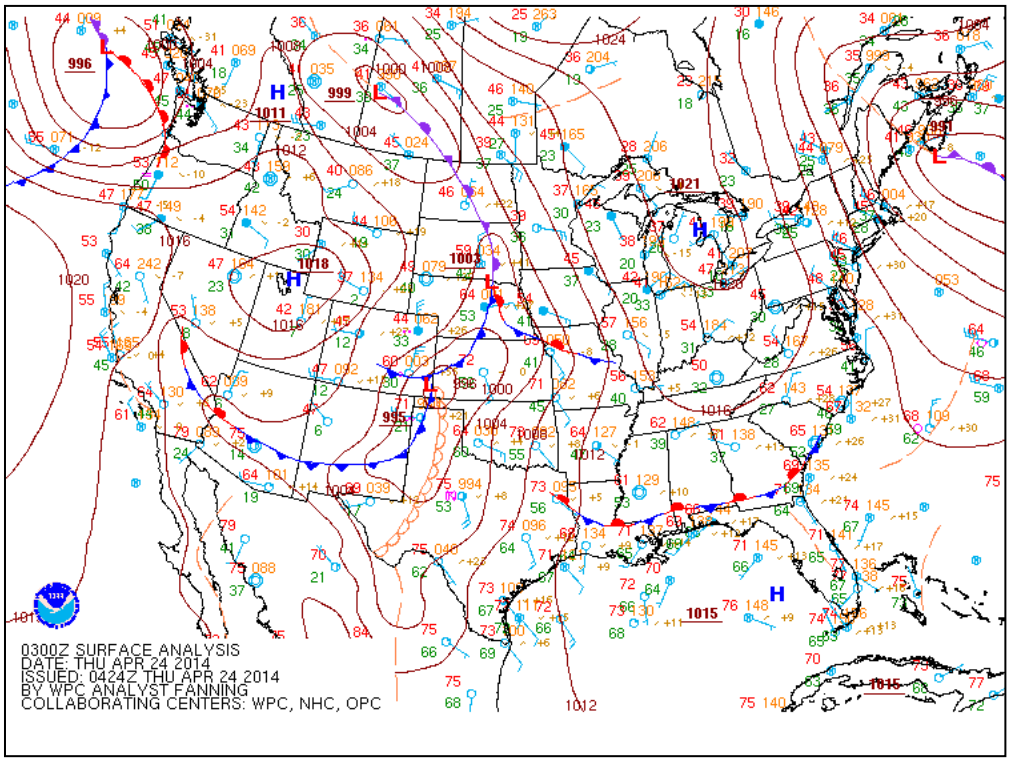


Figure 68: Surface Analysis for 3Z April 24, 2014, or 8:00 PM MST April 23, 2014. (Source: http://nomads.ncdc.noaa.gov/ncep/NCEP)

The synoptic weather conditions described above impacted a region that was in the midst of a severe to exceptional drought (Figure 69). Sustained drought conditions are known to make topsoil susceptible to high winds and produce blowing dust (see the following link from the National Climatic Data Center for more information: https://www.ncdc.noaa.gov/paleo/drought/drght_history.html). Figure 70 shows the total precipitation in inches from March 24, 2014 to April 22, 2014 for Colorado. Note that most of the area surrounding Lamar received less than 0.51 inches of precipitation during the 30-day period leading up to the April 23, 2014 dust event, particularly those locations upwind (north to northeast). Based on previous research 0.5 to 0.6 inches of precipitation over a 30-day period has been found to be the approximate threshold, below which, blowing dust exceedances at Lamar are more likely to occur when combined with high winds (see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2).

The U.S. Drought Monitor and 30-day precipitation totals indicate that soils in southeast Colorado near Lamar were dry enough to produce blowing dust when winds were at or above the thresholds for blowing dust on April 23, 2014.

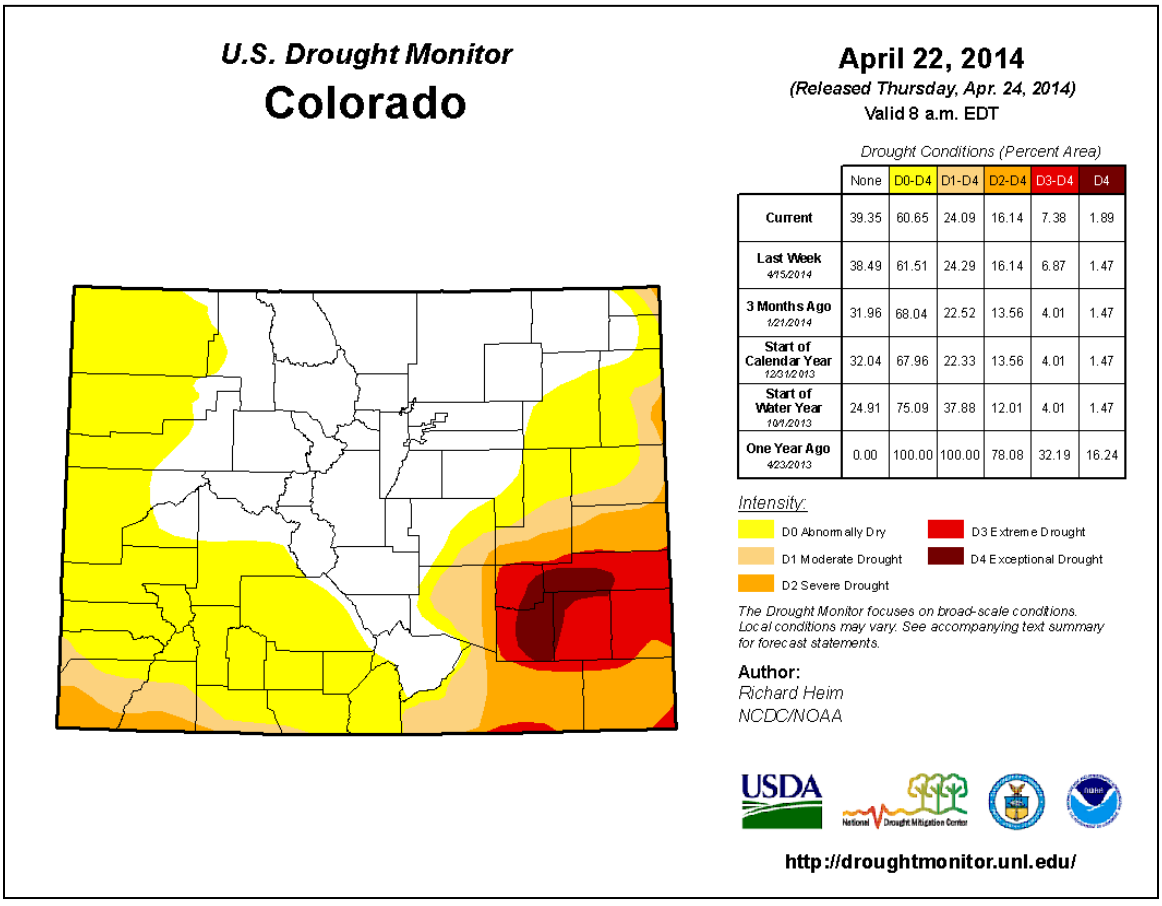


Figure 69: Drought conditions for Colorado at 5:00 AM MST April 22, 2014. (Source: http://droughtmonitor.unl.edu/MapsAndData/MapArchive.aspx)

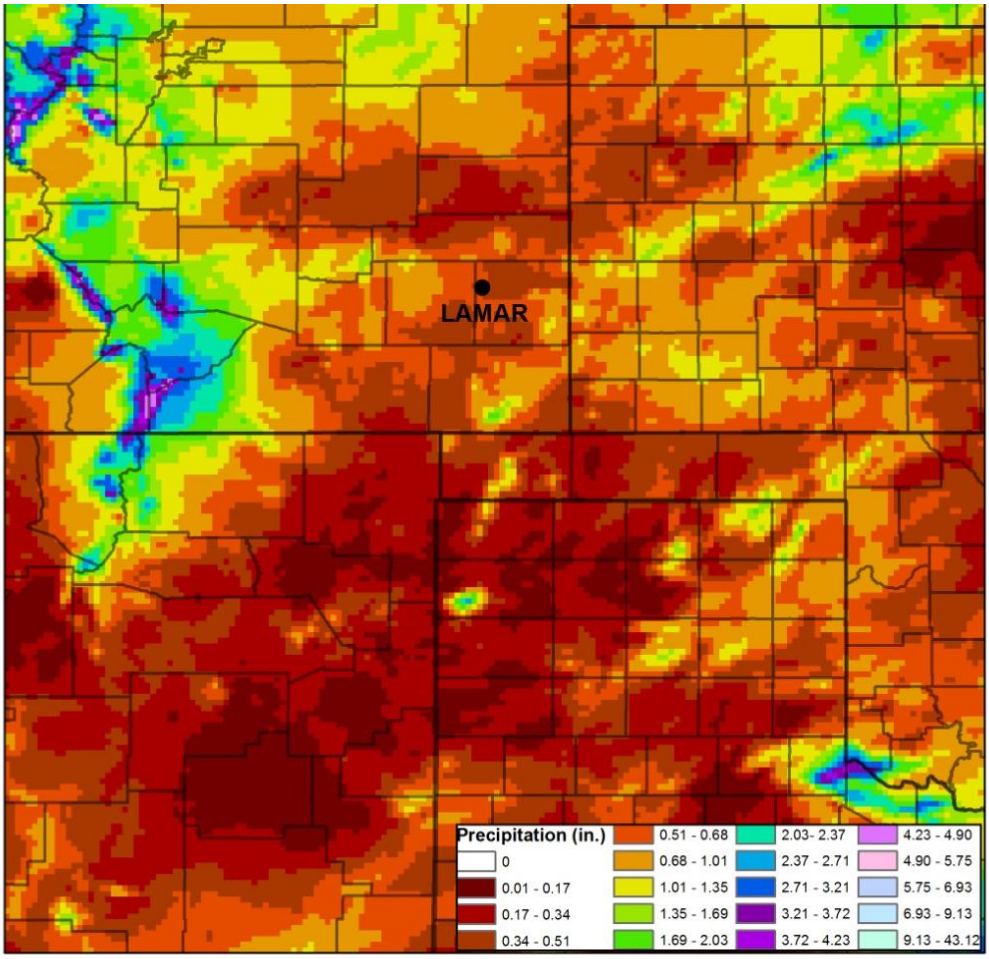


Figure 70: Total precipitation in inches for Colorado, March 24, 2014 – April 22, 2014. (Source: http://prism.nacse.org/recent/)

Based on the developing weather conditions and the drought-stricken soils described above, the blowing dust of April 23, 2014 was anticipated by local agencies. The Colorado Department of Public Health and Environment (CDPHE) along with the National Weather Service (NWS) office in Pueblo issued forecast products and advisories pertaining to blowing dust conditions in southeast Colorado. At 10:00 AM MST on April 23 the CDPHE issued a Blowing Dust Advisory for southeast Colorado, including the Lamar area. Text from that advisory includes:

> "Strong gusty winds will bring a threat for blowing dust to portions of east-central and southeast Colorado beginning late Wednesday afternoon and continuing through Wednesday evening." and, "After a cold front passes, blowing dust will likely become more widespread between 7 PM and 10 PM...spreading southward into Crowley, Kiowa, Bent, Prowers, Baca and far eastern Las Animas counties." (Source: http://www.colorado.gov/airquality/forecast_archive.aspx?seeddate=04%2f23%2f2014)

And from the Pueblo NWS Area Forecast Discussion at 2:59 PM MST:

> "Also localized areas of blowing dust will be possible into this evening and have depicted this in impending grids/zones. A short-fuse blowing dust highlight may become necessary

later this afternoon/evening if blowing dust becomes more widespread than currently anticipated." (Source: http://mesonet.agron.iastate.edu/wx/afos/)

Observations and forecasts issued by local agencies confirm that blowing dust was anticipated across southeast Colorado on April 23, 2014.

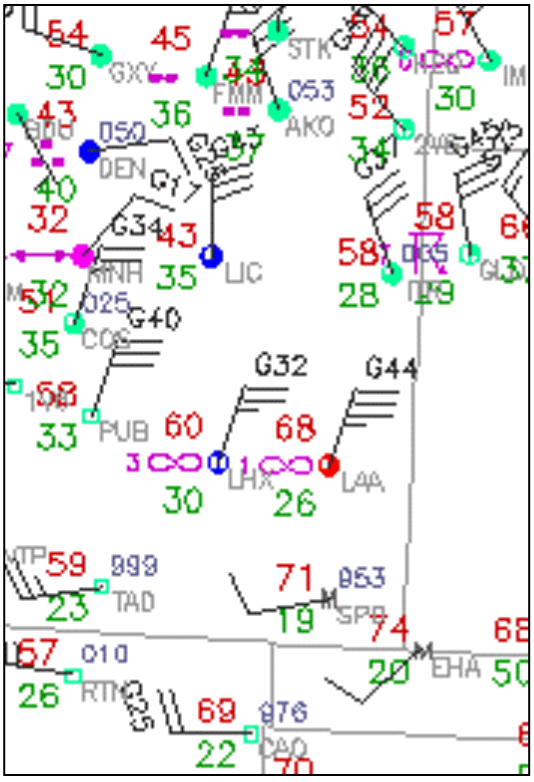
In order to fully evaluate the synoptic meteorological scenario of April 23, 2014, regional surface weather maps are provided showing individual station observations during the height of the event in question. Figure 71 presents weather observations for eastern Colorado and adjacent states at (a) 7:43 PM MST, and (b) 10:43 PM MST on April 23. On the map in Figure 71(a) the station observation for Lamar (LAA) shows winds sustained at 35 knots (40 mph), gusts to 44 knots (51 mph), and a reduced visibility of 1 statute mile with the weather symbol of infinity (∞). The infinity sign is the weather symbol for haze. Haze is often reported during dust storms, and in dry and windy conditions haze typically refers to blowing dust (see the following link for the description of haze published by the National Oceanic and Atmospheric Administration (NOAA): http://www.crh.noaa.gov/lmk/?n=general_glossary). Also note that 50 miles to the west and directly upwind from Lamar, La Junta (LHX) was reporting sustained winds of 25 knots (29 mph), gusts to 32 knots (36 mph), haze and visibility reduced to 3 statute miles. This observation indicates that this dust event was likely regional in scale and not solely confined to the Lamar area.

Three hours later at 10:43 PM MST (Figure 71 (b)), visibility in Lamar continued to be obscured at 3 statute miles with haze and the wind remained strong (sustained at 30 knots (35 mph) with gusts to 44 knots (51 mph)). The Lamar observations at 7:43 PM and 10:43 PM MST are consistent with blowing dust conditions in southeast Colorado (30 mph sustained winds, 40 mph gusts; see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2). La Junta also continued to receive very gusty winds and highly restricted visibility at this time (sustained winds of 40 mph, gusts to 53 mph with visibility of 0.75 of a statute mile).

Hourly surface observations, in table form, from Lamar and La Junta provide supporting evidence that there was an extended period of high winds and haze (blowing dust) in southeast Colorado on April 23. Table 18 lists observations for the PM_{10} exceedance location of Lamar while observations for La Junta can be found in Table 19. Observations that are climatologically consistent with blowing dust conditions (see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2) are highlighted in yellow. Both of these weather observation sites experienced many hours of reduced visibility along with sustained wind speeds and gusts at or above the thresholds for blowing dust.

Surface weather maps and hourly observations show that a regional dust storm occurred under north to northeasterly flow in the wake of a cold front. This data provides clear evidence of blowing dust and winds well above the threshold speeds for blowing dust on April 23, 2014.

a)



b)

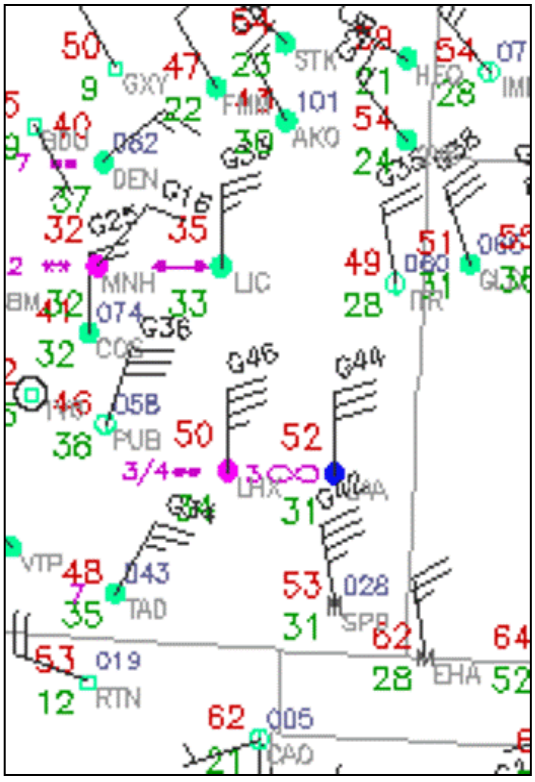


Figure 71: High Plains regional surface analysis for (a) 7:43 PM MST and (b) 10:43 PM MST, April 23, 2014.
(Source: http://www.mmm.ucar.edu/imagearchive/)

Table 18: Weather observations for Lamar, Colorado, on April 23, 2014 (Source: http://mesowest.utah.edu/)

Time MST April 23, 2014	Temperature Degrees F	Relative Humidity in %	Wind Speed in mph	Wind Gust in mph	Wind Direction in Degrees	Weather	Visibility in miles
0:53	65	43	21		200		10
1:53	64	45	23	32	170		10
2:53	63	45	24	30	190		10
3:53	64	45	24		200		10
4:53	62	48	16		200		10
5:53	63	48	18		210		9
6:53	68	42	28		210		9
7:53	72	35	23	30	220		9
8:53	75	28	21		230		10
9:53	78	15	23		240		10
10:53	80	11	22	28	230		10
11:53	85	9	18	27	240		10
12:53	87	8	22	39	210		10
13:53	87	7	12	29	230		10
14:53	87	7	25	36	240		10
15:53	84	8	16		250		10
16:53	85	7	22		260		10
17:53	79	10	23	32	280		9
18:53	73	13	14		280		10
19:22	68	21	35	46	20	haze	3
19:27	68	21	40	51	20	haze	2
19:45	63	25	32	48	10	haze	2
19:53	62	26	30	46	20	haze	2
20:04	61	30	24	41	20	haze	3
20:42	58	36	28	47	10	haze	2
20:49	57	36	38	48	10	haze	2
20:53	56	42	39	51	360	haze	2
21:02	55	45	40	53	360	haze	1
21:13	54	47	39	58	10	haze	2
21:27	52	50	38	55	360	haze	1
21:34	52	50	45	59	360	haze	1
21:40	52	50	44	55	10	haze	1
21:51	52	50	31	56	10	haze	2
21:53	51	52	36	52	10	haze	2
22:01	51	50	31	53	10	haze	2
22:12	52	46	32	45	10	haze	2
22:32	52	44	33	51	360	haze	3
22:42	52	44	33	52	360	haze	3
22:53	51	48	29	51	360	haze	3
23:10	50	48	32	50	10		3
23:17	49	54	24	43	10		4
23:53	48	56	30	44	10	haze	6

Table 19: Weather observations for La Junta, Colorado, on April 23, 2014 (Source: http://mesowest.utah.edu/)

Time MST April 23, 2014	Temperature Degrees F	Relative Humidity in %	Wind Speed in mph	Wind Gust in mph	Wind Direction in Degrees	Weather	Visibility in miles
10:53							
11:53	81	10	14	24	220		10
12:53	83	8	13	27	240		10
13:53	84	8	16	24	250		10
14:53	84	8	27	32	240		8
15:33	83	8	30	39	240	haze	1.75
15:44	82	8	23	31	260	haze	3
15:48	82	9	29	36	260	haze	1.75
15:53	82	8	29	36	270	haze	1.5
16:06	82	9	22	30	260	haze	3
16:12	83	8	28	35	270	haze	1.75
16:33	79	10	25		270	haze	2.5
16:42	78	10	33	39	260	haze	1
16:50	79	10	31	39	260	haze	0.75
16:53	78	10	27	37	260	haze	1
17:06	77	11	25	37	260	haze	1.5
17:09	77	11	24		260	haze	3
17:53	76	11	25		260	haze	5
18:53	72	13	32	38	270	haze	3
18:59	72	14	30	38	290	haze	1.75
19:10	63	31	31	38	360	haze	1.5
19:17	61	33	27	38	350	haze	1.25
19:33	60	32	28	37	20	haze	3
19:53	60	32	27	37	10	haze	5
20:20	57	42	38	45	360	haze	1
20:22	57	44	39	48	10	haze	0.5
20:33	54	53	41	53	10	lt rain	0.25
20:43	53	54	33	44	10	haze	1.25
20:53	52	57	31	45	360	haze	1.5
21:08	51	56	35	46	10	haze	1
21:23	51	54	39	48	360	lt rain	0.5
21:35	51	52	35	48	20	haze	0.75
21:42	50	52	38	48	20	haze	1
21:49	50	54	40	50	10	haze	1.25
21:53	50	52	32	50	10	haze	1.5
22:16	50	54	32	46	10	haze	3
22:25	50	54	44	53	360	haze	1.5
22:27	50	54	43	53	360	lt rain	0.75
22:51	48	57	28	48	360	lt rain	1.25
22:53	48	61	24	44	360	haze	2
23:01	45	76	33	41	350	lt rain	9
23:53	43	82	38	52	30	lt rain	10

Radar imagery provides strong supporting evidence that a regional dust storm was taking place on April 23, 2014. The Pueblo radar image at 6:14 PM MST, April 23 (Figure 72) shows a suspected line of dust (circled in red) approaching Lamar and La Junta from the north. This band of blowing dust was likely produced by several factors; including the cold front passage described earlier combined with strong outflow winds from post-frontal thunderstorms which were impacting northeast Colorado. Figure 73 displays the 1-km radar mosaic from the central Rockies at 4:25 PM MST and shows one particularly intense thunderstorm in northeast Colorado (circled in red) with discernible areas of outflow visible to its south (green arrow). These areas of outflow would continue to move southward and remained intact nearly two hours later in Figure 72. Also note that the radar return from Figure 72 has a distinct bow echo pattern which is often associated with strong, sometimes damaging, winds that spread outward from the bottom of storms (for additional information on bow echoes from the Storm Prediction Center: http://www.spc.noaa.go/misc/AbtDerechos/bowechoprot.htm). Considering the extent of the drought in southeast Colorado and the relatively low dBZ values on the radar return, it is reasonable to assume that this bow echo is indeed lofted dust.

By 7:34 PM MST the bow echo signature had disappeared from the Pueblo radar (Figure 74). Had the blowing dust dissipated? By referring back to La Junta observations from Table 19 we can certainly see that this was not the case. At 7:33 PM MST (1 minute before the radar image of Figure 74) La Junta reported sustained winds of 28 knots (32 mph), gusts to 37 knots (43 mph) with haze and visibility reduced to 3 statute miles, suggesting that blowing dust was indeed present. The likely reason that radar echoes were not visible in La Junta is due to the gap in NEXRAD coverage in southeast Colorado, with the lowest radar returns available ranging from 6,000 to 10,000 ft. above ground level (Figure 75). The radar beam could very well have been overshooting any blowing dust close to the surface in La Junta.

For that same reason, it appears that the radar did capture blowing dust aloft over Lamar. In Figure 74 we can see numerous radar returns in the 5-15 dBZ range near Lamar. These radar echoes were moving from southwest to northeast, which was the prevalent wind direction at the 700 mb level at that time (Figure 65). By referring back to Table 18 we can see that at 7:27 PM and 7:45 PM MST (the time period encompassing Figure 74), Lamar reported sustained winds of 32-40 knots (36-46 mph), gusts of 48-51 knots (55-59 mph), haze and visibility highly reduced to 2 statute miles. Therefore, the combination of radar imagery with surface observations suggests that a wall of dust stretching from the surface to at least 6,000 ft. above ground level realistically could have been impacting Lamar during the evening hours of April 23, 2014.

Radar imagery in conjunction with surface observations clearly reveals that a dust storm was taking place throughout southeast Colorado on April 23, 2014. This collection of data, combined with other evidence in this report, indicates that this dust storm was a natural, regional event and therefore not controllable or preventable.

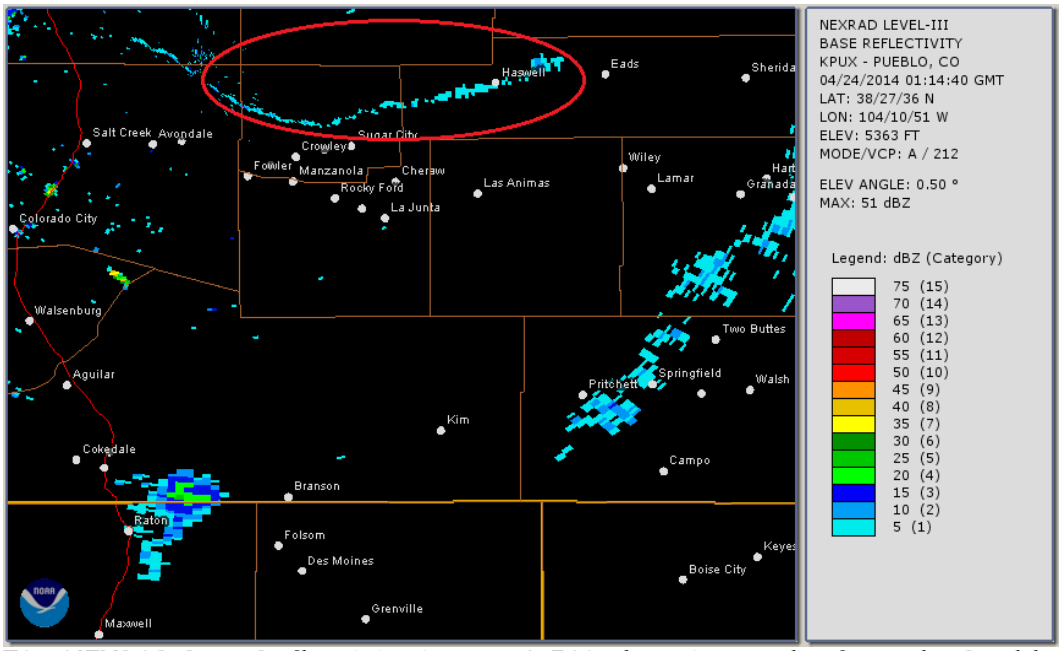


Figure 72: NEXRAD Base Reflectivity image, 0.50º elevation angle, from the Pueblo, CO radar at 6:14 PM MST (114Z, April 24), April 23, 2014.
(Source: http://www.ncdc.noaa.gov/nexradinv/)

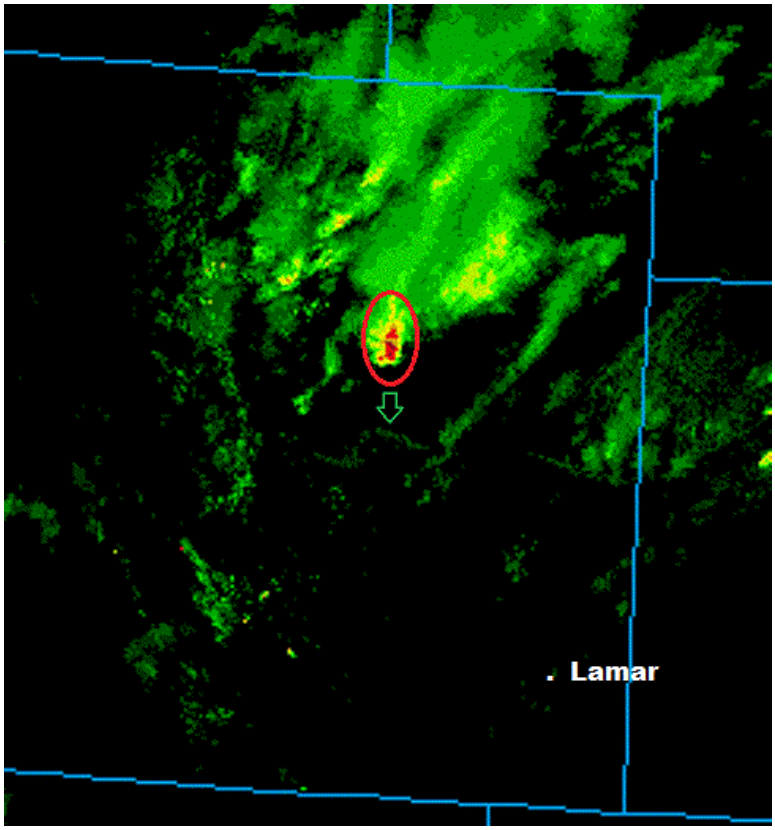


Figure 73: NEXRAD 1-km mosaic image of the central Rockies, 4:25 PM MST (2325Z), April 23, 2014.
(Source: http://www2.mmm.ucar.edu/imagearchive/)

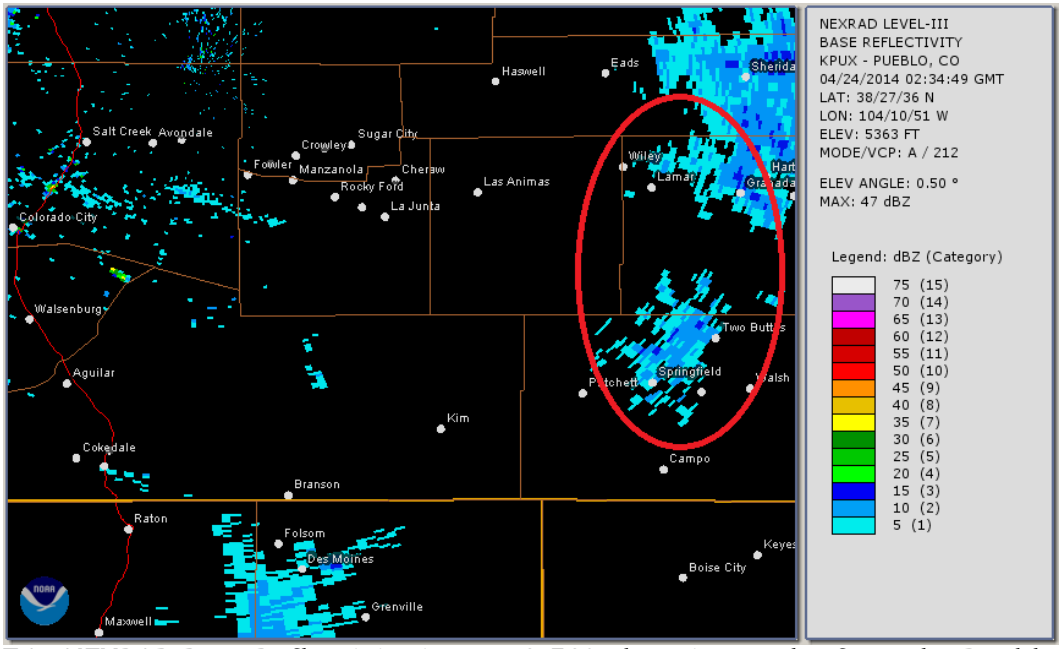


Figure 74: NEXRAD Base Reflectivity image, 0.50º elevation angle, from the Pueblo, CO radar at 7:34 PM MST (254Z, April 24), April 23, 2014.
(Source: http://www.ncdc.noaa.gov/nexradinv/)

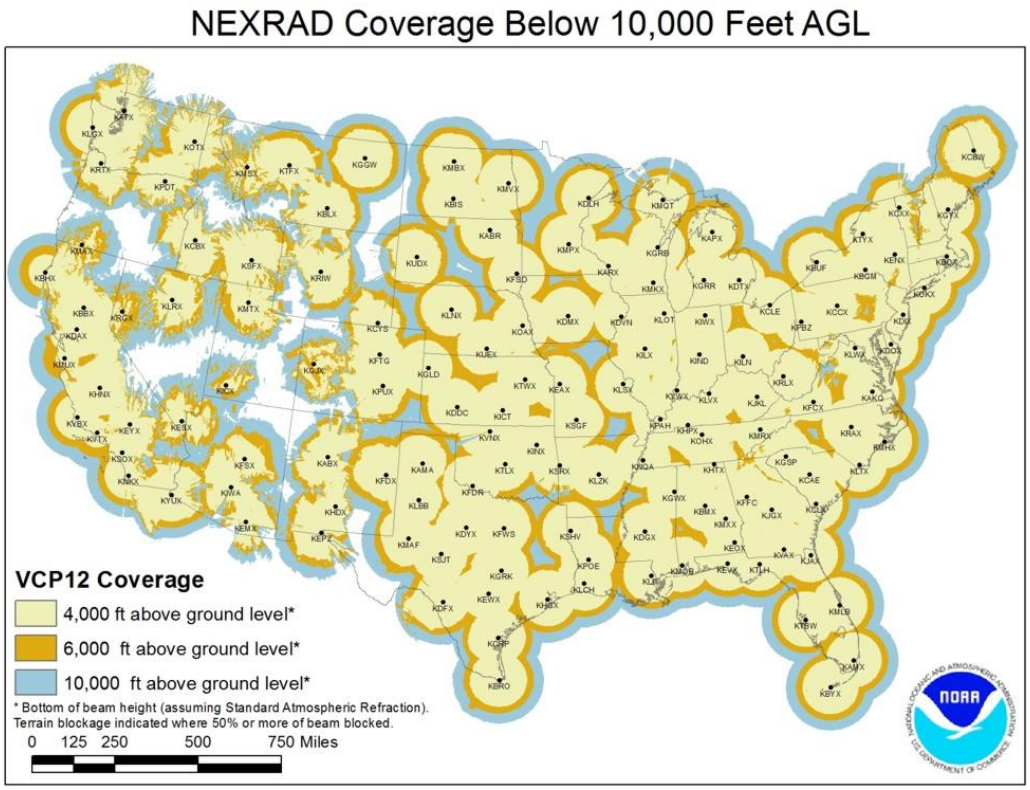


Figure 75: NEXRAD coverage below 10,000 ft. above ground level.
(Source: http://www.roc.noaa.gov/WSR88D/Maps.aspx)

2.8 April 29, 2014 Meteorological Analysis

On April 29 of 2014, a powerful spring storm system caused an exceedance of the 24-hour PM_{10} standard in Lamar, Colorado, at the Municipal Building monitor with a concentration of 321 $\mu g/m^3$. This highly elevated reading and the location of the monitor is plotted on a map of the Greater Lamar area in Figure 76. The exceedance in Lamar was the result of intense surface winds which were produced by a very strong upper-level trough that was moving across the central United States. The surface winds were predominantly out of a north to northwesterly direction which moved over dry soils in eastern Colorado, producing significant blowing dust.

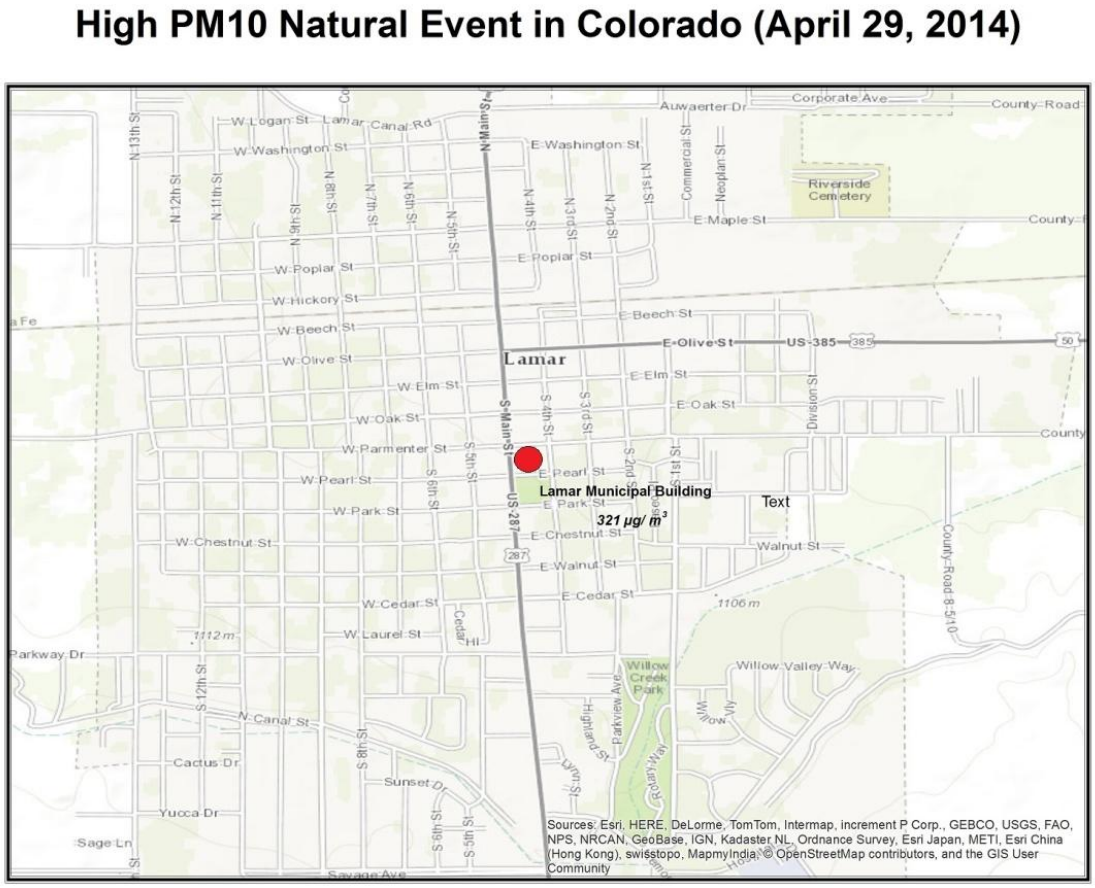


Figure 76: 24-hour PM_{10} concentration for the Lamar Municipal Building monitor, April 29, 2014.
(Source: http://webapps.datafed.net/datafed.aspx?dataset=AQS_D&parameter=pm10)

The upper-level trough associated with this storm system is shown on the North American 700 mb height analysis map at 5:00 AM MST, April 29, 2014 in Figure 77. The 700 mb level is located roughly 3 kilometers above mean sea level (MSL). This chart shows that an intense low pressure system was present at the 700 mb level at the onset of the blowing dust event of April 29 and that it was moving over the central United States.

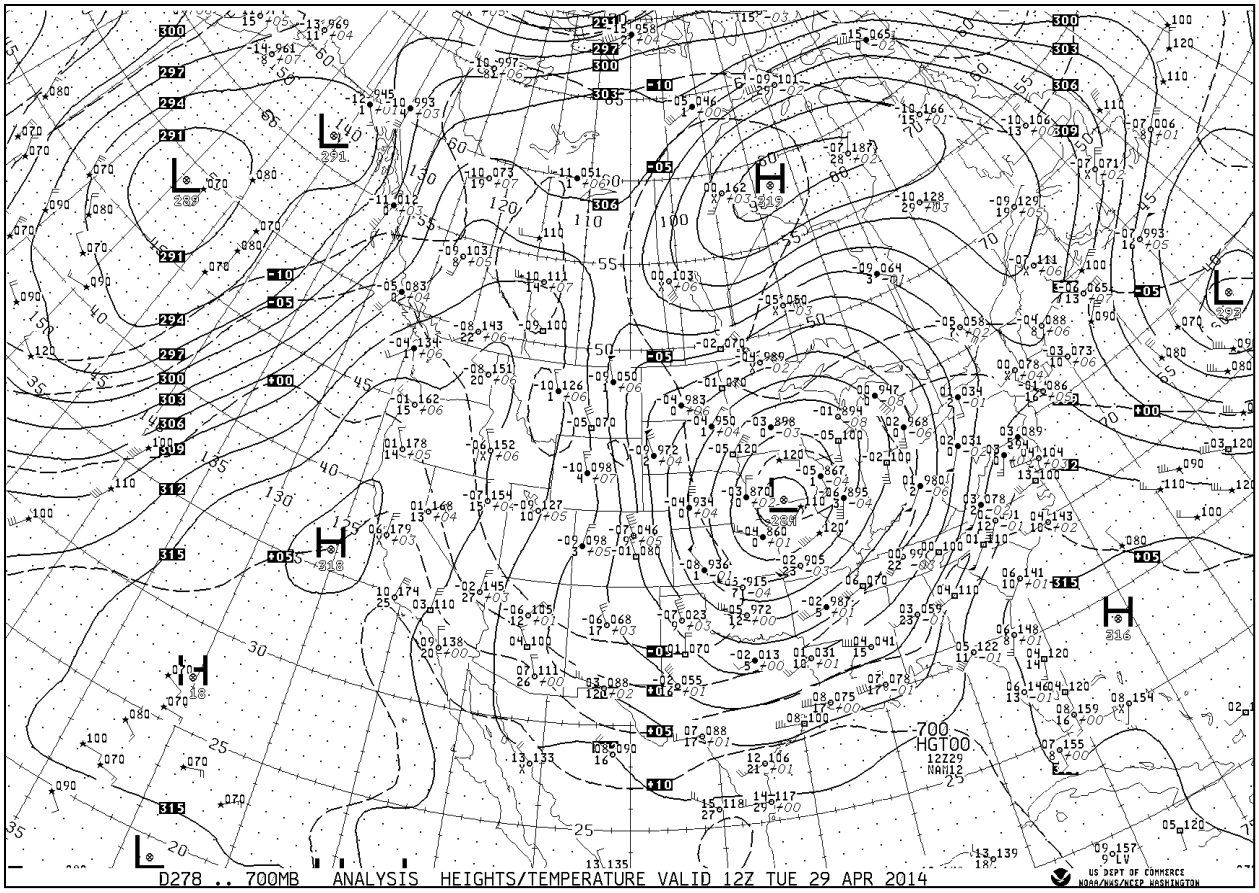


Figure 77: 700 mb (about 3 kilometers above mean sea level) analysis for 12Z April 29, 2014, or 5:00 AM MST April 29, 2014.
(Source: http://nomads.ncdc.noaa.gov/ncep/NCEP)

Eastern Colorado was on the western side of this slow moving, upper-level low where the winds were exceptionally strong. The North American Regional Reanalysis (NARR) 700 mb height analysis map of eastern Colorado shown in Figure 78 reveals that wind speeds over Lamar and upwind (north) ranged from 60-90 kts (69-103 mph) at 5:00 AM MST, April 29, 2014. By viewing Figure 79 we can see that relatively deep atmospheric mixing was occurring over eastern Colorado at the same time the 700 mb jet streak was overhead. Mixing of 3-5 km above MSL over Lamar and areas upwind would have been sufficient to transfer momentum to the surface from the zone of extremely strong winds that were present at 700 mb (about 3 km above MSL).

Twelve hours later at 5:00 PM MST, high winds and deep mixing continued over eastern Colorado. Figure 80 and Figure 81, respectively, show that 700 mb winds over and upwind of Lamar remained strong at 45-65 kts (52-75 mph) and mixing remained sufficiently deep at 4-6 km above MSL. This long period of very gusty winds mixing down to the surface was likely a key aspect to the PM_{10} exceedance in Lamar on April 29, 2014.

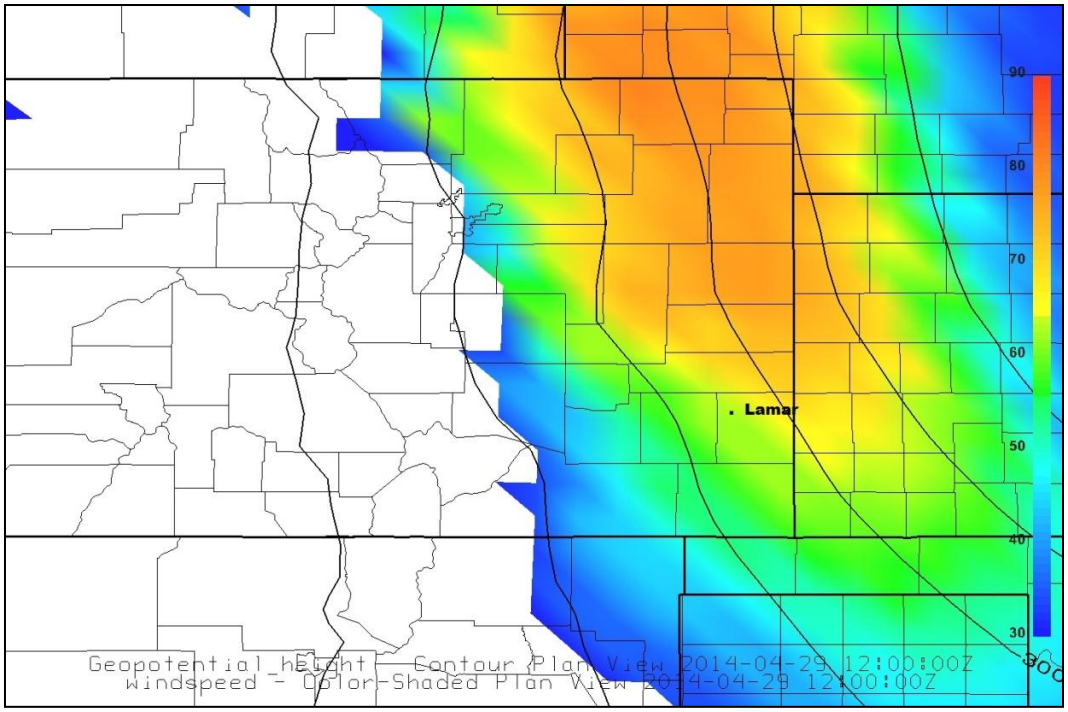


Figure 78: NARR 700 mb analysis for 12Z April 29, 2014, or 5:00 AM MST April 29, 2014 showing wind speeds in knots. Only speeds above 30 knots are shown.
(Source: http://nomads.ncdc.noaa.gov/data.php?name=access#hires_weather_datasets)

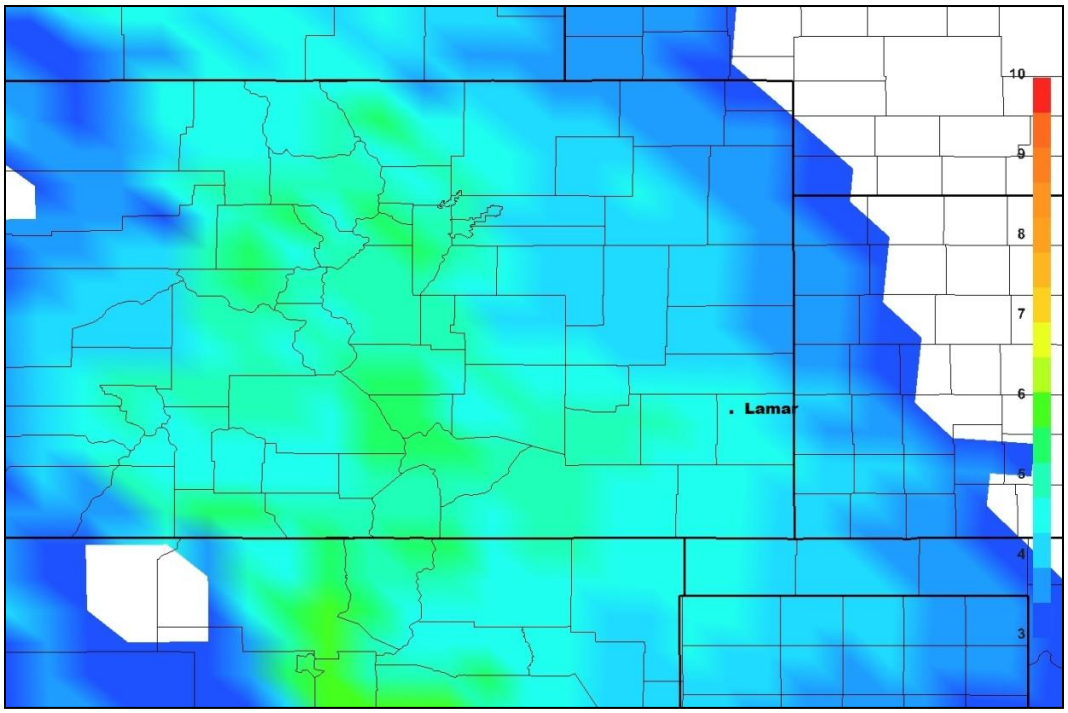


Figure 79: Height of the mixed layer in kilometers above mean sea level from the NARR at 12Z April 29, 2014, or 5:00 AM MST April 29, 2014. Only mixing heights above 3 kilometers are shown.
(Source: http://nomads.ncdc.noaa.gov/data.php?name=access#hires_weather_datasets)

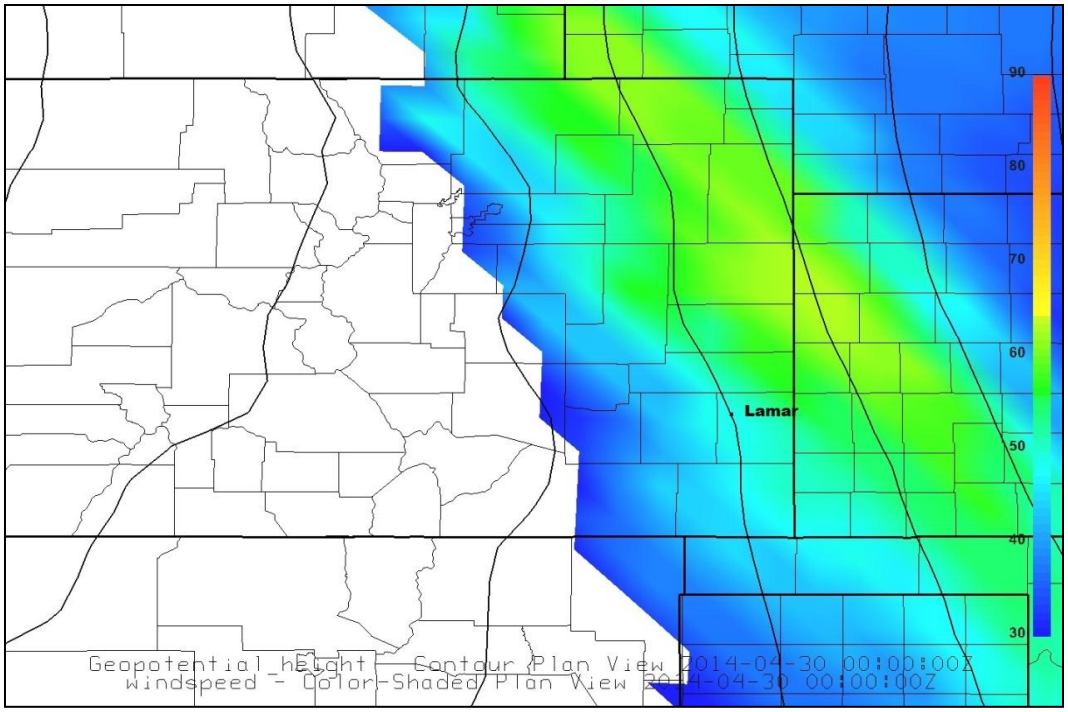


Figure 80: NARR 700 mb analysis for 0Z April 30, 2014, or 5:00 PM MST April 29, 2014 showing wind speeds in knots. Only speeds above 30 knots are shown.
(Source: http://nomads.ncdc.noaa.gov/data.php?name=access#hires_weather_datasets)

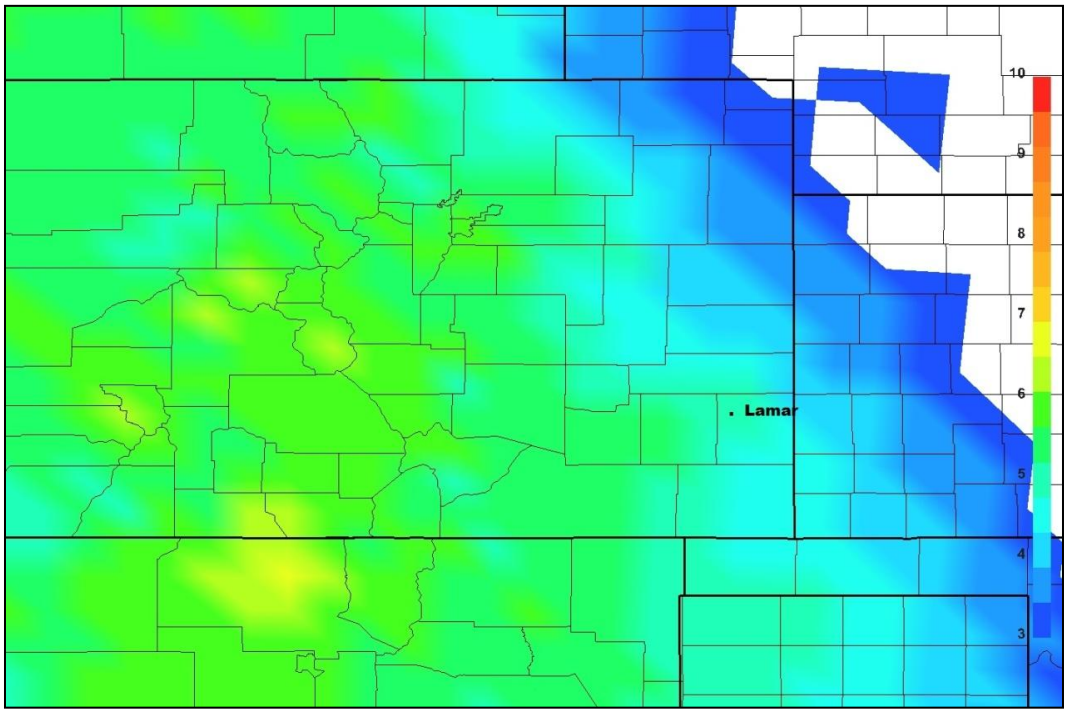


Figure 81: Height of the mixed layer in kilometers above mean sea level from the NARR at 0Z April 30, 2014, or 5:00 PM MST April 29, 2014. Only mixing heights above 3 kilometers are shown.
(Source: http://nomads.ncdc.noaa.gov/data.php?name=access#hires_weather_datasets)

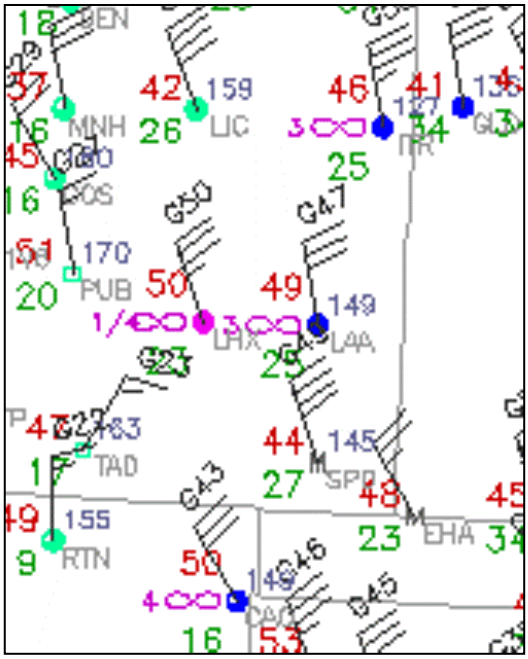
In order to fully evaluate the synoptic meteorological scenario of April 29, 2014, regional surface weather maps are provided showing individual station observations during the height of the event in question. Figure 82 presents weather observations for eastern Colorado and adjacent states at (a) 9:13 AM MST, and (b) 3:43 PM MST on April 29. On the map in Figure 82(a) the station observation for Lamar (LAA) shows winds sustained at 30 knots (35 mph), gusts to 47 knots (54 mph), and a reduced visibility of 3 statute miles with the weather symbol of infinity (∞). The infinity sign is the weather symbol for haze. Haze is often reported during dust storms, and in dry and windy conditions haze typically refers to blowing dust (see the following link for the description of haze published by the National Oceanic and Atmospheric Administration (NOAA): http://www.crh.noaa.gov/lmk/?n=general_glossary). Also note that 50 miles to the west of Lamar, La Junta (LHX) was reporting sustained winds of 35 knots (40 mph), gusts to 50 knots (58 mph), haze and visibility reduced to ¼ of a statute mile. Additionally, in Burlington (ITR, 85 miles north-northeast of Lamar) sustained winds were also at 35 knots (40 mph), gusts were recorded at 53 knots (61 mph) with haze and visibility obscured at 3 statute miles. These observations indicate that this dust event was regional in scale and not solely confined to the Lamar area.

Over 6 hours later at 3:43 PM MST (Figure 82 (b)), visibility in Lamar continued to be obscured at 3 statute miles with haze and the wind remained very strong (sustained at 35 knots (40 mph) with gusts to 45 knots (52 mph)). The Lamar observations at 9:13 AM and 3:43 PM MST are consistent with blowing dust conditions in southeast Colorado (30 mph sustained winds, 40 mph gusts; see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2). It should be noted that blowing dust conditions continued in both La Junta and Burlington at 3:43 PM MST with sustained winds and gusts well in excess of the climatology thresholds stated above.

Hourly surface observations, in table form, from Lamar, La Junta and Burlington provide supporting evidence that there was an extended period of high winds and haze (blowing dust) in eastern Colorado on April 29. Table 20 lists observations for the PM_{10} exceedance location of Lamar while observations for La Junta and Burlington can be found in Table 21 and Table 22, respectively. Observations that are climatologically consistent with blowing dust conditions (see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2) are highlighted in yellow. Collectively, these three weather observation sites experienced many hours of reduced visibility along with sustained wind speeds and gusts at or well above the thresholds for blowing dust.

Surface weather maps and hourly observations show that a regional dust storm occurred under exceptionally strong north to northwesterly flow. This data provides clear evidence of blowing dust and winds well above the threshold speeds for blowing dust on April 29, 2014.

a)



b)

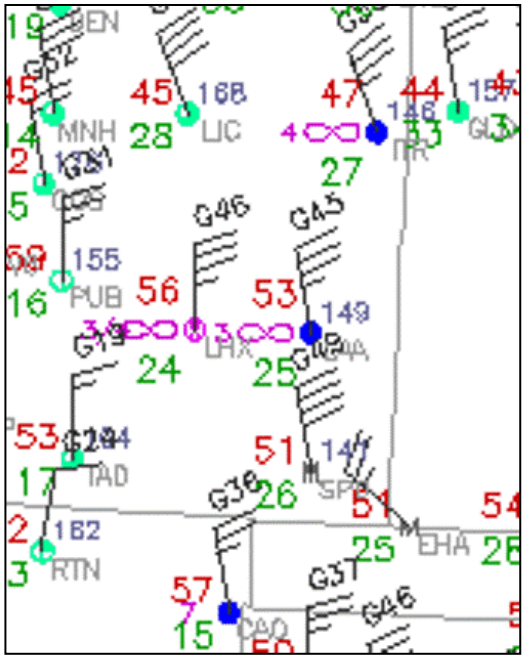


Figure 82: High Plains regional surface analysis for (a) 9:13 AM MST and (b) 3:43 PM MST, April 29, 2014.
(Source: http://www.mmm.ucar.edu/imagearchive/)

Table 20: Weather observations for Lamar, Colorado, on April 29, 2014 (Source: http://mesowest.utah.edu/)

Time MST April 29, 2014	Temperature Degrees F	Relative Humidity in %	Wind Speed in mph	Wind Gust in mph	Wind Direction in Degrees	Weather	Visibility in miles
3:53	46	43	22	31	320		10
4:42	46	47	32	40	320		8
4:53	45	51	32	44	330		8
5:53	46	47	32	44	330	haze	5
6:53	47	44	35	44	340	haze	6
7:53	48	39	43	52	350	haze	4
8:53	49	39	37	54	350	haze	3
9:13	49	37	38	50	350	haze	3
9:33	50	36	36	47	350	haze	3
9:53	54	34	40	51	360	haze	3
10:03	54	35	39	63	340	haze	3
10:09	53	35	45	59	350	haze	3
10:30	53	32	44	62	350	haze	2
10:51	52	37	44	54	340	haze	3
10:53	52	36	46	54	340	haze	3
11:02	53	32	40	61	340	haze	3
11:25	49	48	38	61	350		3
11:33	55	32	48	58	350	haze	4
11:46	51	39	45	62	350	haze	2
11:53	47	58	33	62	350		2
12:01	53	43	35	50	350		7
12:10	53	32	40	59	350	haze	3
12:16	52	35	37	53	350	haze	3
12:29	54	34	32	50	350	haze	5
12:50	52	35	38	51	340	haze	2
12:53	53	33	39	50	340	haze	2
13:07	52	38	37	46	360	haze	3
13:14	52	38	38	51	340	haze	3
13:20	54	40	37	52	340	haze	2
13:30	55	35	37	47	340	haze	3
13:53	56	33	41	50	340	haze	5
14:32	56	30	38	52	350	haze	3
14:53	53	33	38	52	350	haze	3
15:53	54	32	41	55	350	haze	3
16:31	53	36	33	47	360	haze	4
16:53	51	38	38	51	350	haze	4
17:15	50	41	37	56	350	haze	4
17:53	50	39	29	48	360	haze	5
18:05	48	46	28	36	360	haze	5
18:53	45	53	31	40	350		9
19:53	43	60	23	31	350		9

Table 21: Weather observations for La Junta, Colorado, on April 29, 2014 (Source: http://mesowest.utah.edu/)

Time MST April 29, 2014	Temperature Degrees F	Relative Humidity in %	Wind Speed in mph	Wind Gust in mph	Wind Direction in Degrees	Weather	Visibility in miles
6:53	45	45	33	41	340	haze	1.75
7:02	46	42	37	43	340	haze	1
7:11	47	40	33	47	340	haze	0.5
7:23	48	39	37	50	340	haze	0.5
7:53	48	39	45	56	350	lt rain	0.25
8:04	49	39	33	47	350	haze	0.5
8:19	49	37	46	56	340	haze	0.25
8:31	49	36	46	55	340	haze	0.25
8:50	50	34	44	51	350	haze	0.25
8:53	50	34	43	52	340	haze	0.25
9:00	50	34	43	58	340	haze	0.25
9:30	51	32	37	52	350	haze	0.25
9:53	52	29	43	56	350	haze	0.25
10:28	52	31	39	53	350	haze	0.5
10:35	54	28	43	53	350	haze	0.25
10:53	55	27	45	54	360	haze	0.25
11:02	54	27	47	56	350	haze	0.25
11:18	54	27	36	51	350	haze	0.5
11:53	56	24	46	54	360	haze	0.25
12:53	58	24	39	52	350	haze	0.5
13:40	58	23	40	53	350	haze	0.25
13:53	58	24	39	52	360	haze	0.5
14:53	58	24	41	45	350	haze	1
15:00	58	25	46	52	360	haze	0.5
15:21	57	27	40	52	360	haze	0.5
15:30	56	29	41	51	10	haze	1
15:38	56	29	43	53	360	haze	0.75
15:48	55	33	40	52	360	haze	1
15:53	55	32	35	52	360	haze	0.75
15:58	56	31	38	50	360	haze	1
16:05	55	30	41	50	360	haze	0.75
16:16	55	31	41	51	350	haze	0.5
16:31	54	34	35	48	360	haze	1.25
16:39	54	30	43	48	360	haze	1
16:42	54	31	41	52	360	haze	0.75
16:53	54	32	36	51	10	haze	0.75
16:56	52	36	36	47	10	haze	1.25
17:02	52	38	39	51	20	haze	3
17:04	52	38	43	51	10	haze	1.75
17:08	51	39	44	56	10	haze	0.5
17:18	50	41	38	50	10	haze	1.25
17:30	49	46	39	50	10	haze	2.5

Table 22: Weather observations for Burlington, Colorado, on April 29, 2014 (Source: http://mesowest.utah.edu/)

Time MST April 29, 2014	Temperature Degrees F	Relative Humidity in %	Wind Speed in mph	Wind Gust in mph	Wind Direction in Degrees	Weather	Visibility in miles
0:53	42	57	36	41	320		10
1:53	44	53	39	56	320		10
2:53	42	59	39	61	340		9
3:53	40	65	33	47	340		10
4:53	40	62	35	48	340		10
5:53	42	50	39	56	350	haze	6
6:53	42	50	47	62	340	haze	3
7:01	42	50	44	61	340	haze	1.75
7:12	43	49	32	60	340	haze	3
7:40	43	49	46	64	340	haze	1.75
7:53	44	47	46	68	340	haze	1
8:16	44	47	40	60	340	haze	2.5
8:39	45	45	39	59	340	haze	3
8:53	46	43	40	61	350	haze	3
9:15	46	43	37	60	350	haze	2.5
9:36	45	43	40	59	350	haze	3
9:53	46	42	50	64	350	haze	3
10:00	47	40	46	64	350	haze	1.75
10:15	45	45	45	62	340	haze	2
10:29	45	45	38	58	350	haze	3
10:38	46	42	39	58	350	haze	2.5
13:53	45	53	38	53	340		7
14:27	48	42	40	59	350	haze	2.5
14:38	47	44	40	56	350	haze	4
14:53	47	45	41	61	340	haze	4
15:53	46	49	44	51	340		7
16:53	43	55	32	44	350		10
17:53	38	82	25	39	350	lt rain	6
18:53	36	85	20	33	350	lt snow	8
19:53	37	82	18		350		10
20:10	37	82	18		360		10
20:39	35	82	22	32	360	lt snow	6
20:53	35	78	22	33	360		9
21:53	33	88	15	23	350	lt snow	9
22:09	33	88	17	24	350	lt snow	9

Satellite generated data products from April 29, 2014 provide further evidence that dust caused the PM_{10} exceedance in Lamar. Figure 83 displays the Atmospheric Infrared Sounder (AIRS) Dust Score zoomed on southeast Colorado based on the MODIS Aqua satellite image from 1:30 PM MST on April 29 (see the following link for more information on Dust Score and other AIRS variables: http://disc.sci.gsfc.nasa.gov/nrt/data-holdings/airs-nrt-products). The tan pixels represent dust scores greater than 360, which is indicative of dust particles. It should be noted that at the time of this image Lamar was in the midst of an extended period of high winds and reduced visibility, suggesting that a dust storm was indeed occurring in southeast Colorado at 1:30 PM MST. By referring back to Table 20, at 1:30 PM MST Lamar reported sustained winds of 37 mph, gusts to 47 mph with haze and visibility reduced to 3 statute miles. This is an observation consistent with blowing dust conditions in southeast Colorado (30 mph sustained winds, 40 mph gusts; see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2).

Eleven minutes before the MODIS image of Figure 83, webcam imagery was able to capture blowing dust at Gobbler's Knob (20 miles south of Lamar on Figure 83). Figure 84 clearly shows a considerable amount of airborne dust with the horizon almost completely obscured. This confirms that dust was widespread across southeast Colorado on April 29, 2014.

The National Oceanic and Atmospheric Administration (NOAA) Satellite Services Division was in agreement with the conclusion that blowing dust was occurring in eastern Colorado. The Smoke Text Product from NOAA at 7:00 PM MST on April 29, 2014 stated:

> "An expansive area of dust is moving from the central plains south into the Texas Panhandle this evening. Through sunset, the dust is seen reaching from eastern Colorado down through central Texas." (Source: http://www.ssd.noaa.gov/PS/FIRE/DATA/SMOKE/2014/2014D300316.html)

Additionally, the Pueblo office of the National Weather Service issued a Dust Storm Warning for southeast Colorado while the Colorado Department of Public Health and Environment issued a Blowing Dust Advisory in anticipation of the blowing dust event of April 29, 2014. Text from these advisories includes:

> "Wrap around north flow around a deep storm system over the upper Midwest will produce high winds and widespread blowing dust through this afternoon." (Source: http://mesonet.agron.iastate.edu/wx/afos/)

> "Extremely gusty winds will produce areas of blowing dust to portions of eastern Colorado for much of Tuesday." (Source: http://www.colorado.gov/airquality/forecast_archive.aspx?seeddate=04%2f29%2f2014)

And to further confirm the presence of a dust storm in southeast Colorado, a trained weather spotter reported blowing dust with visibility reduced to ½ of a statue mile near Sheridan Lake (approximately 35 miles northeast of Lamar):

PRELIMINARY LOCAL STORM REPORT
NATIONAL WEATHER SERVICE PUEBLO CO
143 PM MDT TUE APR 29 2014

..TIME... ...EVENT... ...CITY LOCATION... ...LAT.LON...
..DATE... ....MAG.... ..COUNTY LOCATION..ST.. ...SOURCE....
..REMARKS..

0845 AM BLOWING DUST 4 E SHERIDAN LAKE 38.47N 102.21W
04/29/2014 KIOWA CO TRAINED SPOTTER

1/2 MILE VSBY

(Source: http://mesonet.agron.iastate.edu/wx/afos/)

Satellite-derived products combined with reports, advisories and webcam imagery from southeast Colorado on April 29 clearly reveal that a regional dust storm was anticipated and did take place which was not controllable or preventable.

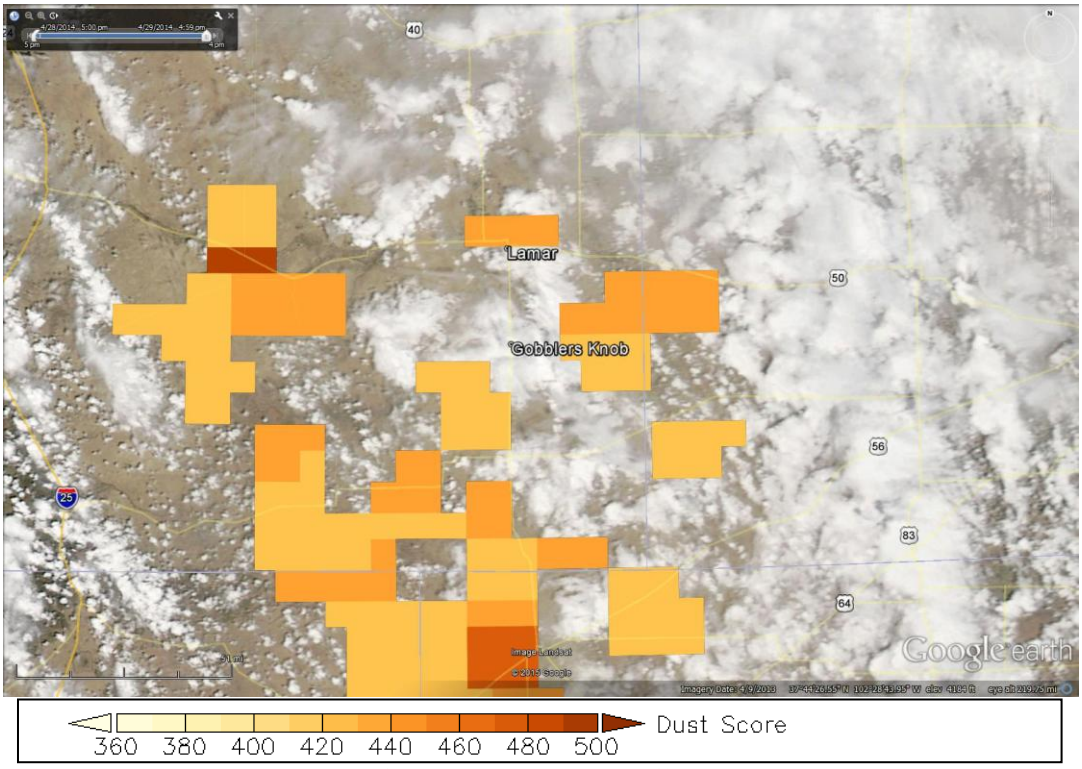


Figure 83: AIRS Dust Score from the MODIS Aqua satellite image at 1:30 PM MST (2030Z) April 29, 2014.
(Source: http://www.earthdata.nasa.gov/labs/worldview)

Figure 84: Gobblers Knob webcam image at 1:19 PM MST April 29, 2014. (Source: http://www.cotrip.org/speed.htm)

The synoptic weather conditions described above impacted a region that was in the midst of a severe to exceptional drought (Figure 85). Sustained drought conditions are known to make topsoil susceptible to high winds and produce blowing dust (see the following link from the National Climatic Data Center for more information: https://www.ncdc.noaa.gov/paleo/drought/drght_history.html). Figure 86 shows the total precipitation in inches from March 30, 2014 to April 28, 2014 for Colorado. Note the large area upwind of Lamar (northerly) that received less than 0.5 inches of precipitation during the 30-day period leading up to the April 29 dust event in Lamar. Based on previous research 0.5 to 0.6 inches of precipitation over a 30-day period has been found to be the approximate threshold, below which, blowing dust exceedances at Lamar are more likely to occur when combined with high winds (see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2).

The U.S. Drought Monitor and 30-day precipitation totals indicate that soils in eastern Colorado near Lamar were dry enough to produce blowing dust when winds were above the thresholds for blowing dust. This information, combined with other evidence provided in this report, proves that this dust storm was a natural, regional event that was not reasonably controllable or preventable.

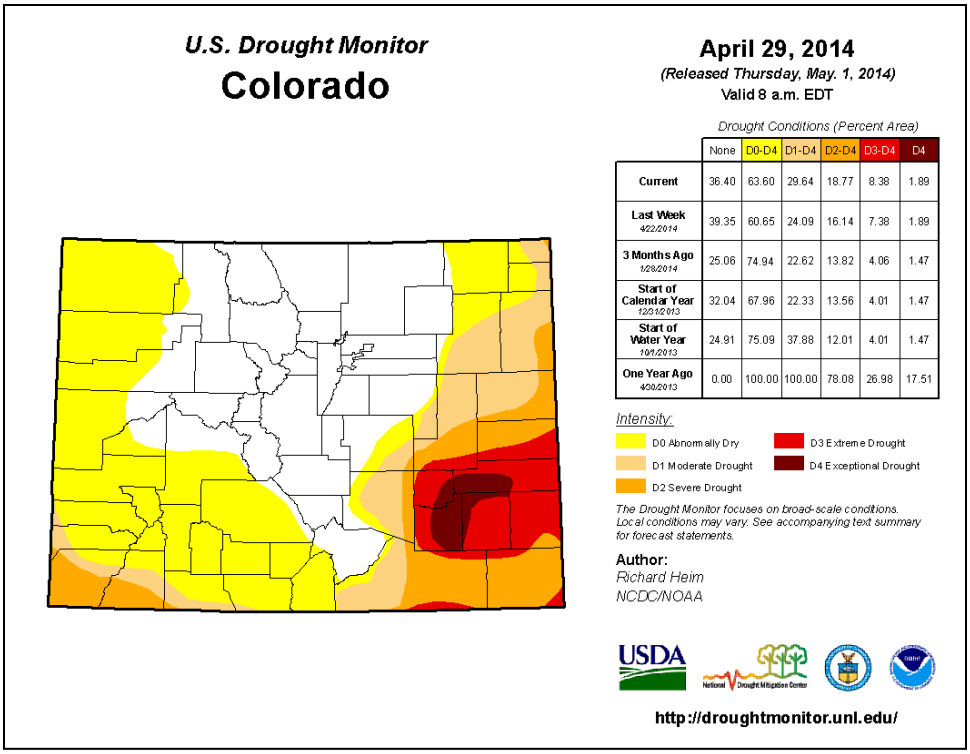


Figure 85: Drought conditions for Colorado at 5:00 AM MST April 29, 2014. (Source: http://droughtmonitor.unl.edu/MapsAndData/MapArchive.aspx)

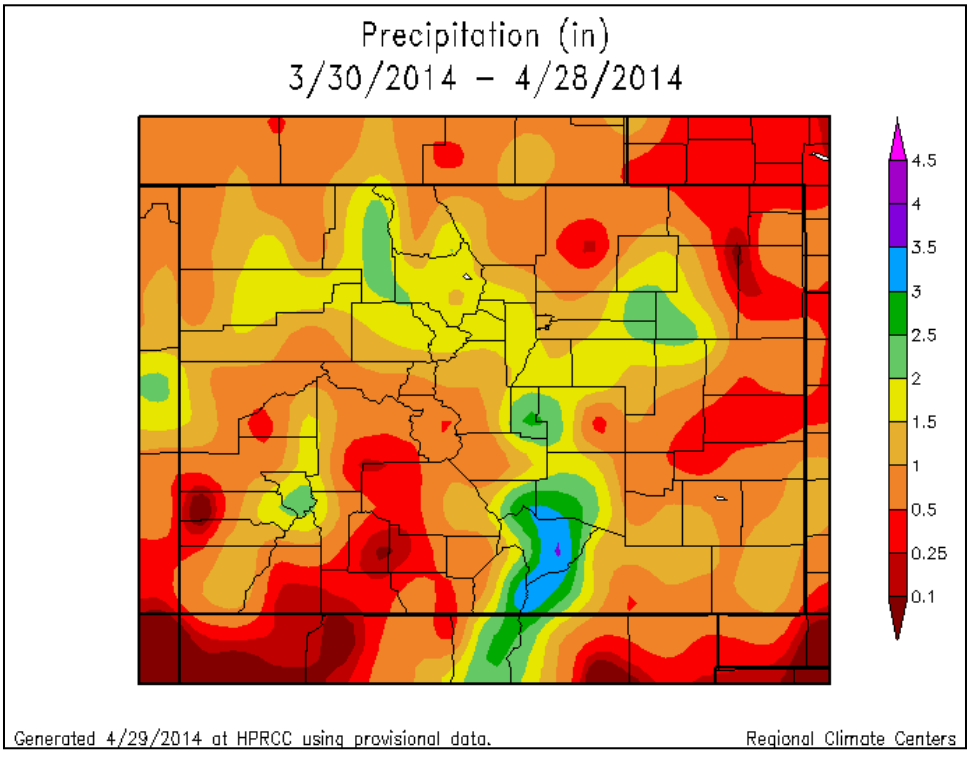


Figure 86: Total precipitation in inches for eastern Colorado and adjacent states, March 30, 2014 – April 28, 2014. (Source: [http://www.hprcc.unl.edu/maps/current/)](http://www.hprcc.unl.edu/maps/current/)

2.9 November 10, 2014 Meteorological Analysis

On November 10 of 2014, a powerful late autumn storm system caused an exceedance of the 24-hour PM_{10} standard in Lamar, Colorado, at the Municipal Building monitor with a concentration of 298 $\mu g/m^3$. This highly elevated reading and the location of the monitor is plotted on a map of the Greater Lamar area in Figure 87. The exceedance in Lamar was the result of intense surface winds in the wake of a passing cold front. These surface features were associated with a strong upper-level trough that was moving across the western United States. The surface winds were predominantly out of a north to northeasterly direction which moved over dry soils in eastern Colorado, producing significant blowing dust.

Figure 87: 24-hour PM_{10} concentration for the Lamar Municipal Building monitor, November 10, 2014.
(Source: http://webapps.datafed.net/datafed.aspx?dataset=AQS_D&parameter=pm10)

The upper-level trough associated with this storm system is shown on the 700 mb and 500 mb height analysis maps at 5:00 AM MST, November 10, 2014 in Figure 88 and Figure 89, respectively. The 700 mb level is located roughly 3 kilometers above mean sea level (MSL) while the 500 mb level is approximately 6 kilometers above MSL. These two charts show that a deep trough of low pressure was present at both the 700 and 500 mb level just a few hours before the blowing dust event of November 10, 2014, and that it was moving over the western United States. This is a typical upper-air pattern for blowing dust events in Colorado (see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2).

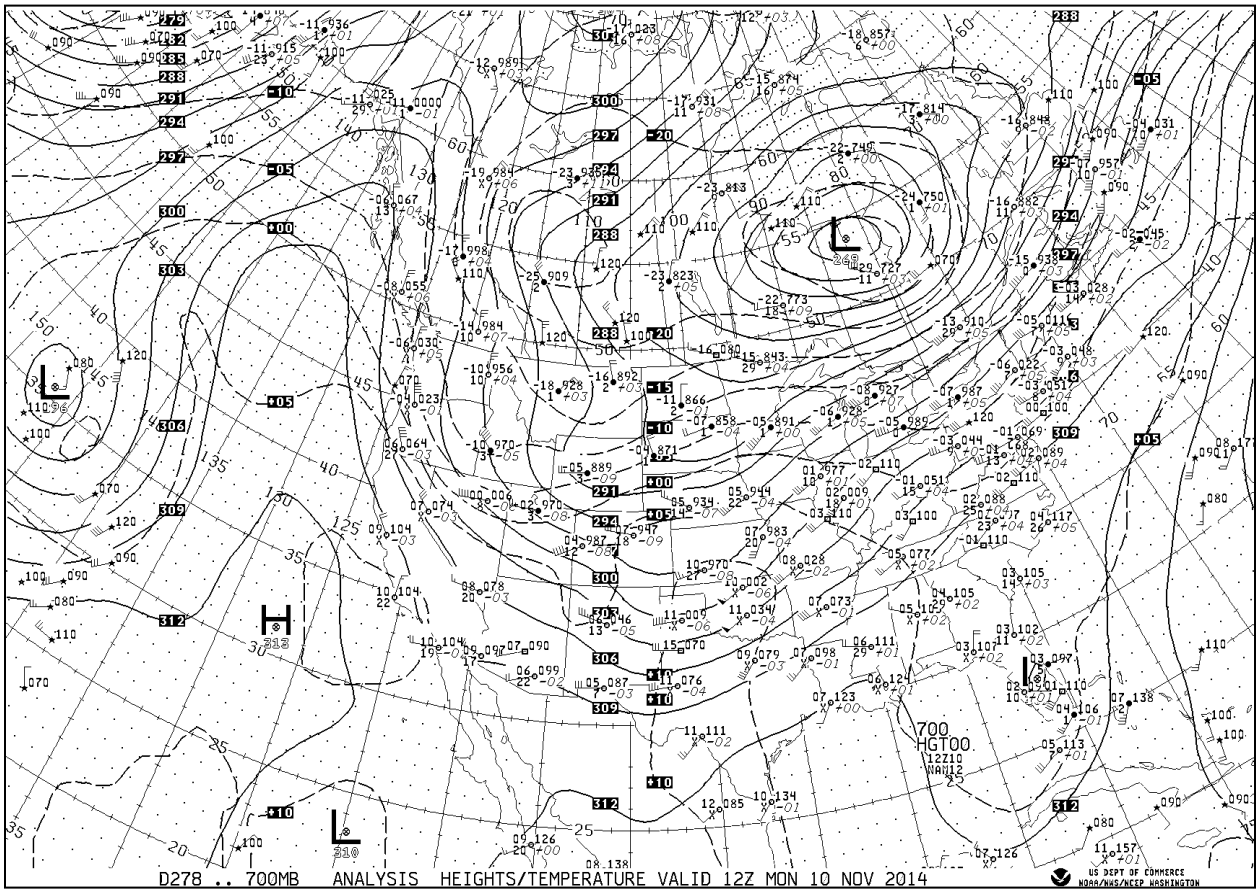


Figure 88: 700 mb (about 3 kilometers above mean sea level) analysis for 12Z November 10, 2014, or 5:00 AM MST November 10, 2014.
(Source: http://nomads.ncdc.noaa.gov/ncep/NCEP)

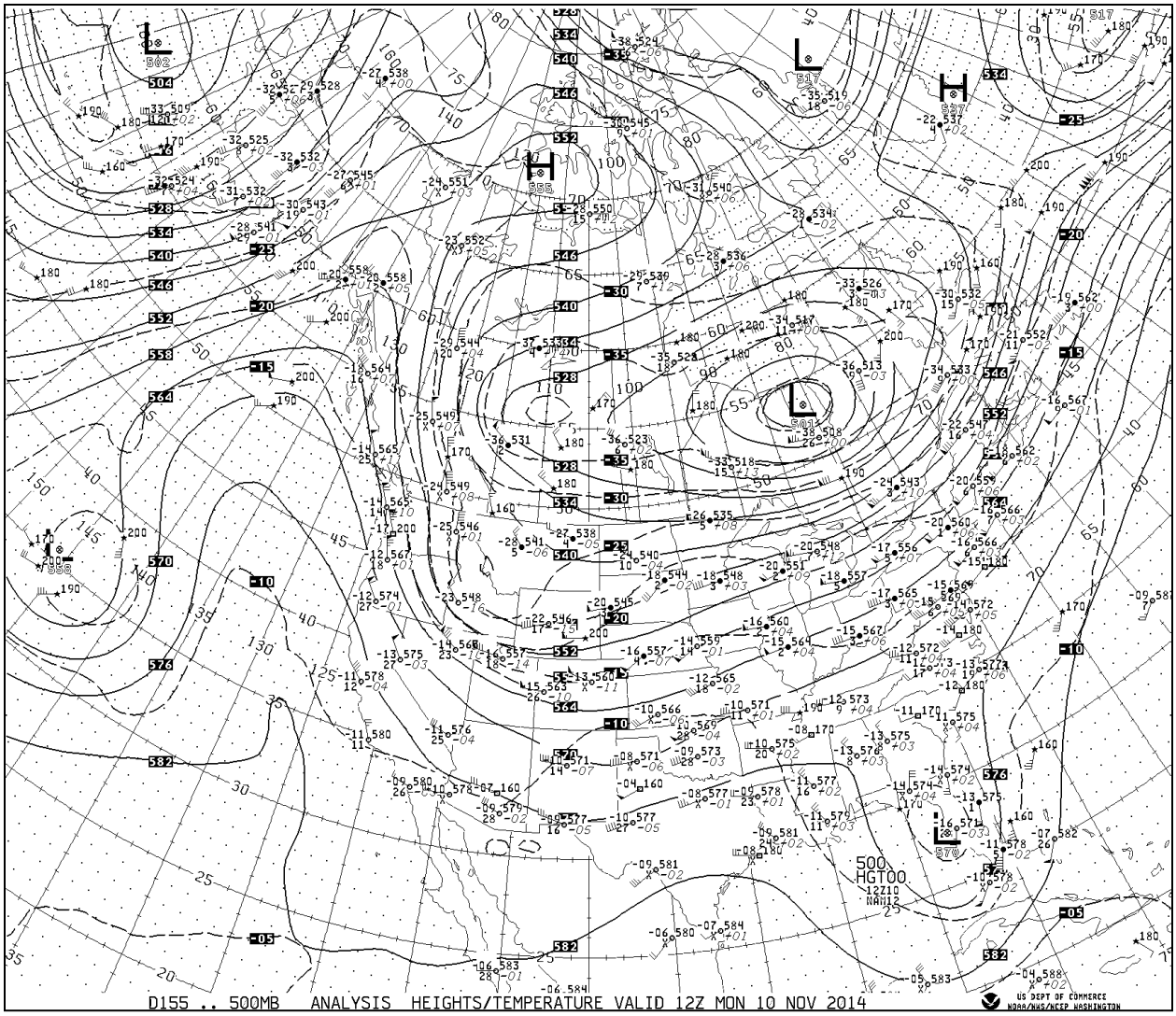


Figure 89: 500 mb (about 6 kilometers above mean sea level) analysis for 12Z November 10, 2014, or 5:00 AM MST November 10, 2014.
(Source: http://nomads.ncdc.noaa.gov/ncep/NCEP)

The surface weather associated with the storm system of November 10, 2014 is presented in Figure 90 and Figure 91. Significant surface features at 11:00 AM MST, November 10, 2014 (Figure 90) included a strong cold front that was moving southward through eastern Colorado. By 5:00 PM MST (Figure 91) the cold front had cleared eastern Colorado, leaving behind a significant amount of "bunching" of isobars. This indicates that a strong pressure gradient was in place. Wind speed is directly proportional to the pressure gradient, so a higher pressure gradient will produce stronger winds (see the following link for additional information on pressure gradient and its relationship to wind speed from the National Oceanic and Atmospheric Administration (NOAA): http://www.srh.noaa.gov/jetstream/synoptic/wind.htm). The strong pressure gradient was in response to a building ridge of high pressure in eastern Montana and Wyoming interacting with a strong area of low pressure in the Texas Panhandle.

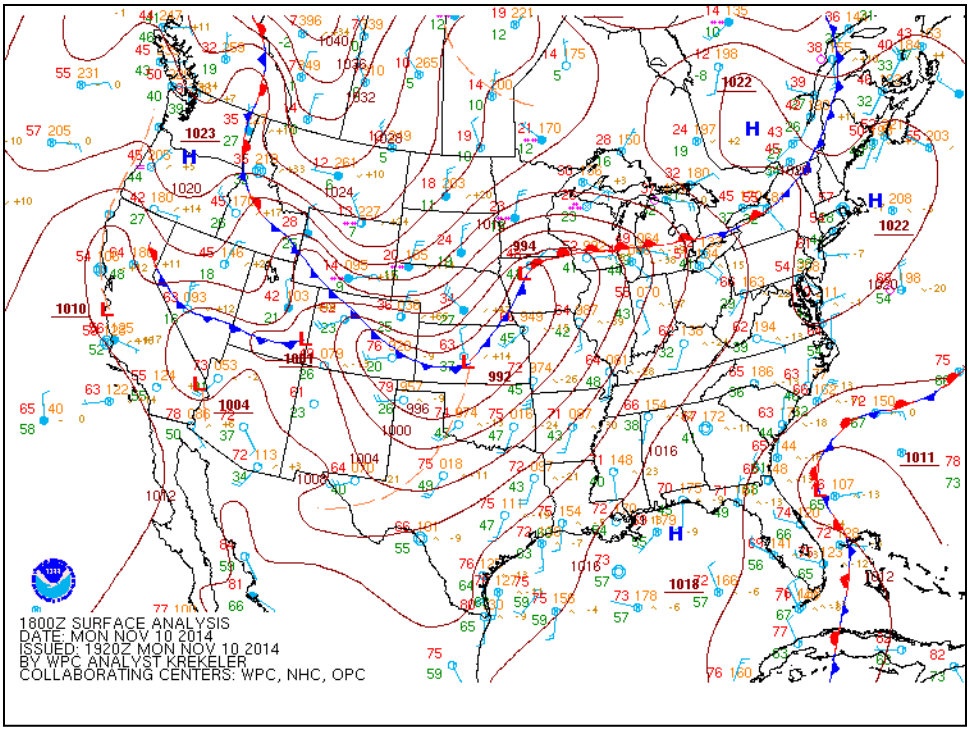


Figure 90: Surface Analysis for 18Z November 10, 2014, or 11:00 AM MST November 10, 2014.
(Source: http://nomads.ncdc.noaa.gov/ncep/NCEP)

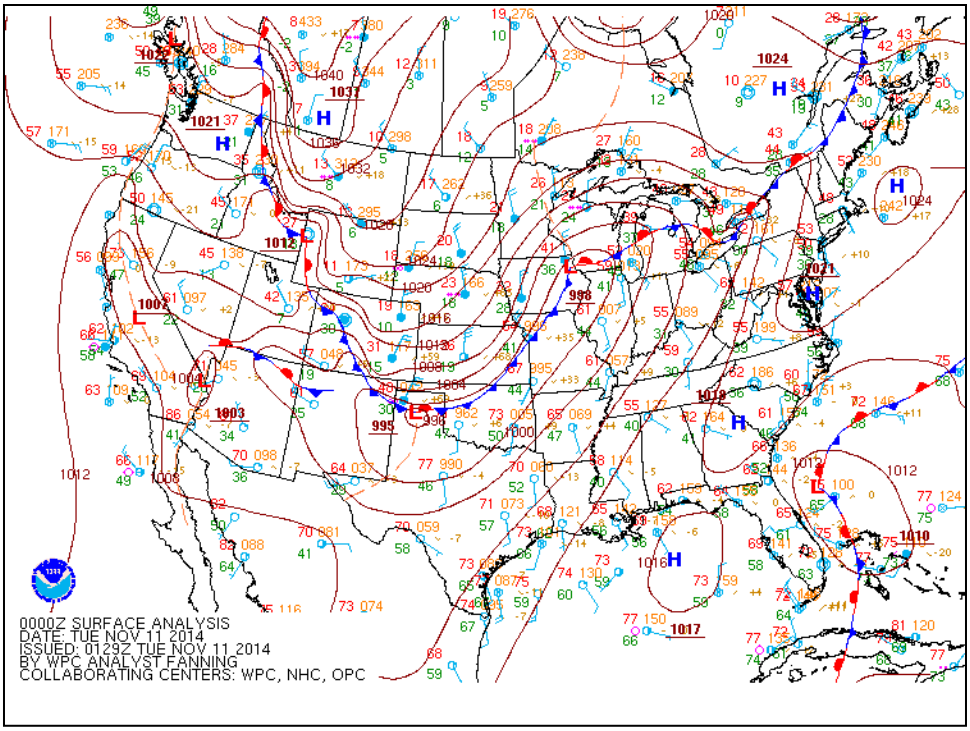


Figure 91: Surface Analysis for 0Z November 11, 2014, or 5:00 PM MST November 10, 2014.
(Source: http://nomads.ncdc.noaa.gov/ncep/NCEP)

In order to fully evaluate the synoptic meteorological scenario of November 10, 2014, a regional surface weather map is provided showing individual station observations during the height of the event in question. Figure 92 presents weather observations for eastern Colorado and adjacent states at 1:43 PM MST, November 10. The station observation for Lamar (LAA) shows winds sustained at 30 knots (35 mph), gusts to 40 knots (46 mph), and a reduced visibility of 2 statute miles with the weather symbol of infinity (∞). The infinity sign is the weather symbol for haze. Haze is often reported during dust storms, and in dry and windy conditions haze typically refers to blowing dust (see the following link for the description of haze published by the National Oceanic and Atmospheric Administration (NOAA): http://www.crh.noaa.gov/lmk/?n=general_glossary). Also note that to the north and west of Lamar in nearby Burlington (ITR), La Junta (LHX) and Pueblo (PUB), similar weather conditions were reported with high winds, haze and poor visibility. This collection of weather observations indicates that a regional blowing dust event was indeed occurring on November 10, 2014.

Hourly surface observations, in table form, from Lamar and other regional weather stations provide supporting evidence that there was an extended period of high winds and haze (blowing dust) across eastern Colorado. Table 23 lists observations for the PM_{10} exceedance location of Lamar while Burlington, La Junta and Pueblo observations can be found in Table 24 through Table 26, respectively. Observations that are climatologically consistent with blowing dust conditions (see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2) are highlighted in yellow. Collectively, these four sites experienced many hours of reduced visibility along with sustained wind speeds and gusts at or above the thresholds for blowing dust.

Surface weather maps and hourly observations show that a regional dust storm occurred under north to northeasterly flow in the wake of a cold front. This data provides clear evidence of blowing dust and winds at or above the threshold speeds for blowing dust on November 10, 2014.

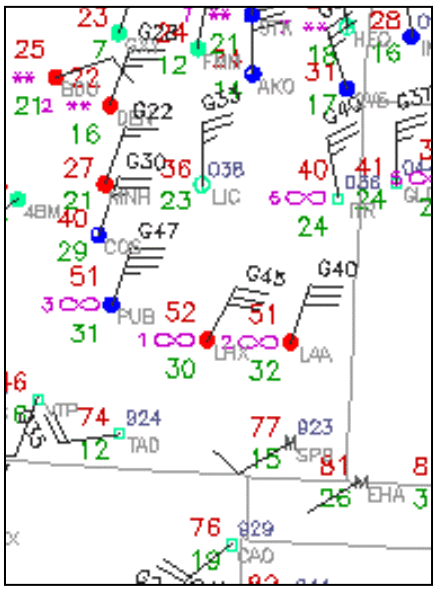


Figure 92: High Plains regional surface analysis for 1:43 PM MST, November 10, 2014. (Source: http://www.mmm.ucar.edu/imagearchive/)

Table 23: Weather observations for Lamar, Colorado, on November 10, 2014 (Source: http://mesowest.utah.edu/)

Time MST November 10, 2014	Temperature Degrees F	Relative Humidity in %	Wind Speed in mph	Wind Gust in mph	Wind Direction in Degrees	Weather	Visibility in miles
4:53	44	41	12		260		10
5:53	43	38	7		160		10
6:22	52	28	13		260		10
6:53	49	31	12		290		10
7:53	55	26	16		280		10
8:53	60	24	16		270		10
9:53	71	17	13		260		10
10:53	78	13	15		260		10
11:53	79	13	12		330		10
12:34	65	30	43	53	20	haze; squalls	2.5
12:39	61	35	33	53	30	haze	1.5
12:46	58	39	36	48	20	haze	1.75
12:53	55	43	33	48	20	haze	1.75
13:08	51	48	32	46	20	haze	2
13:41	49	48	33	44	20	haze	4
13:53	49	48	29	40	20	haze	4
14:20	47	45	32	46	30	haze	2.5
14:30	47	45	35	45	30	haze	3
14:53	45	45	28	43	20	haze	3
15:33	40	46	22	35	30	haze	2
15:53	38	46	28	36	10	haze	3
16:04	35	47	29	37	10	haze	2
16:21	33	49	25	36	20	haze	3
16:32	33	49	28	37	20	haze	2.5
16:44	32	49	27	38	10	haze	3
16:53	31	51	24	36	30	haze	2.5
17:00	30	53	25	37	30	haze	3
17:39	29	53	22	31	20	haze	5
17:53	28	55	24	35	10		7
18:53	27	55	22	32	10		9
19:07	24	74	25	35	10	lt snow	2
19:13	23	85	21	32	20	lt snow; fog	1.25
19:17	23	85	18	28	10	lt snow; fog	1
19:24	23	88	13		10	mod snow; ice fog	0.5
19:36	22	84	24	30	20	mod snow; ice fog	0.5

Table 24: Weather observations for Burlington, Colorado, on November 10, 2014 (Source: http://mesowest.utah.edu/)

Time MST November 10, 2014	Temperature Degrees F	Relative Humidity in %	Wind Speed in mph	Wind Gust in mph	Wind Direction in Degrees	Weather	Visibility in miles
3:53	44	36	12		260		10
4:53	44	38	13		260		10
5:53	45	36	10		270		10
6:53	40	44	8		300		10
7:53	40	44	8		270		10
8:53	42	43	6		260		10
9:53	42	44	9		280		10
10:53	51	33	7		280		10
11:21	63	22	9		360		10
11:28	61	27	23	29	20		10
11:53	48	51	31	45	10	haze	4
12:09	40	67	31	41	10	haze	6
12:26	40	67	28	40	360		7
12:53	39	64	30	40	360		10
13:53	40	59	31	40	10		8
14:53	40	57	33	44	360	haze	5
15:45	40	53	31	46	350	haze	6
15:53	35	52	32	46	360		9
16:43	29	51	36	47	10	haze	4
16:53	25	60	31	41	350		10
17:37	25	57	32	41	360		10
17:41	23	59	35	50	350	haze	6
17:53	22	62	33	50	350		8
18:09	20	77	30	40	360	lt snow	3
18:16	20	77	29	40	360	lt snow	1.75
18:53	20	81	28	37	360	lt snow	1.5
19:53	20	77	24	37	360	lt snow	3
20:53	20	77	18	35	350	lt snow	6
21:15	20	67	28	37	350		10
21:53	20	65	24	33	360		10
22:08	19	64	24	30	360		10

Table 25: Weather observations for La Junta, Colorado, on November 10, 2014 (Source: http://mesowest.utah.edu/)

Time MST November 10, 2014	Temperature Degrees F	Relative Humidity in %	Wind Speed in mph	Wind Gust in mph	Wind Direction in Degrees	Weather	Visibility in miles
0:53	52	29	16		260		10
1:53	54	26	13		260		10
2:53	48	35	13		270		10
3:53	44	40	12		280		10
4:53	47	34	14		260		10
5:53	50	29	14		270		10
6:53	56	24	18		250		10
7:53	59	25	12		290		10
8:53	66	19	21	25	250		10
9:53	71	16	21		240		10
10:53	76	12	16	22	260		10
11:53	78	12	9		310		10
12:38	74	15	41	56	30	haze; squalls	2.5
12:42	61	31	45	58	30	haze; squalls	1
12:46	59	34	39	58	20	haze; squalls	0.75
12:53	58	36	40	53	20	haze	1
13:06	54	41	36	53	20	haze	0.75
13:27	52	43	37	52	30	haze	1.25
13:53	51	41	35	47	20	haze	2.5
14:13	50	41	32	45	20	haze	3
14:37	48	42	35	48	20	haze	2
14:53	47	40	30	47	10	haze	3
15:29	41	42	22	44	20	haze	4
15:48	37	44	30	40	30	haze	4
15:53	37	44	23	37	20	haze	4
16:19	35	45	28	36	20	haze	6
16:53	31	51	24	35	20		8
17:11	31	49	21	29	350	haze	6
17:25	30	48	22	27	10		9
17:53	30	48	20	32	10		10

Table 26: Weather observations for Pueblo, Colorado, on November 10, 2014 (Source: http://mesowest.utah.edu/)

Time MST November 10, 2014	Temperature Degrees F	Relative Humidity in %	Wind Speed in mph	Wind Gust in mph	Wind Direction in Degrees	Weather	Visibility in miles
0:53	44	31	8		260		10
1:53	40	36	6		280		10
2:53	40	34	9		260		10
3:53	37	40	8		260		10
4:53	39	42	0				10
5:53	40	39	10		270		10
6:53	41	38	9		280		10
7:53	49	31	0				10
8:53	56	26	5		220		10
9:53	66	19	4		100		10
10:53	71	14	7		160		10
11:53	73	12	0				10
12:53	63	30	47	56	30	lt rain; squalls	3
12:56	59	36	51	61	30	lt rain; squalls	1.75
13:04	54	45	44	61	20	haze	2
13:25	52	46	44	59	30	haze	4
13:35	51	46	43	54	20	haze	3
13:53	47	49	39	53	20	haze	4
14:10	46	47	31	47	20		8
14:53	40	50	28	45	20	haze	6
15:13	38	52	33	41	40	haze	5
15:53	34	51	28	37	30	haze	5
16:53	30	44	16	29	40	haze	6
17:53	26	60	20		50	lt snow	8
18:47	25	63	24	29	50	lt snow	2.5
18:53	23	73	18	29	50	lt snow	1.25
19:08	23	74	16		60	lt snow	3
19:16	24	74	14		90	lt snow	4
19:53	24	74	10		90	lt snow	8
20:10	24	68	12		50	lt snow	7
20:53	24	65	9		80		10
21:53	24	62	9		70		10
22:53	23	63	7		70		10
23:53	23	58	10		80		10

Satellite imagery from November 10, 2014 provides strong evidence that dust caused the PM_{10} exceedance in Lamar. Specifically, the Moderate Resolution Imaging Spectroradiometer (MODIS) Aqua image clearly shows dust plumes blowing across southeast Colorado minutes before Lamar reported high winds, haze and reduced visibility. Additional information on MODIS can be found at the National Aeronautics and Space Administration (NASA) website (https://earthdata.nasa.gov/data/near-real-time-data/data/instrument/modis)

Figure 93 shows the MODIS Aqua satellite image zoomed on southeast Colorado at approximately 12:22 PM MST (1922Z). A wall of dust can be easily identified approaching Lamar and La Junta from the north-northeast. Twelve minutes after this MODIS Aqua image was generated, the surface observation for Lamar at 12:34 PM MST (Table 23) shows that sustained winds sharply increased to 43 mph along with wind gusts of 53 mph, haze and visibility reduced to 2 ½ statute miles. This is an observation that is consistent with blowing dust conditions in southeast Colorado (30 mph sustained winds, 40 mph gusts; see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2). Similarly in La Junta, at 12:38 PM MST (Table 25) the wind speed abruptly increased to 41 mph with gusts to 56 mph, haze and visibility obscured at 2.5 statute miles.

To confirm the presence of dust plumes on the MODIS imagery, a webcam image at Gobblers Knob (20 miles south of Lamar) is presented in Figure 94. This image was captured at 1:15 PM MST, which was 53 minutes after the MODIS Aqua image of Figure 93 and 31 minutes after Lamar's first observation indicating blowing dust. Figure 94 clearly shows a considerable amount of airborne dust with the horizon almost completely obscured.

The National Oceanic and Atmospheric Administration (NOAA) Satellite Services Division and the National Weather Service (NWS) office in Pueblo were in agreement with the conclusion that blowing dust was occurring in southeast Colorado. The Smoke Text Product from NOAA at 7:45 PM MST on November 10, 2014 stated:

> "There is a large and significant area of blowing dust that can be seen moving towards the south/southeast across southeastern Colorado and into northeastern New Mexico." (Source: http://www.ssd.noaa.gov/PS/FIRE/DATA/SMOKE/2014/2014K110313.html)

While the NWS Forecast Discussion at 3:50 PM MST stated:

> "Arctic front came through the eastern plains this afternoon…in typical fashion...ahead of schedule. 50-60 mph N to NE wind gusts along and behind FROPA...with blowing dust." (Source: http://mesonet.agron.iastate.edu/wx/afos/)

Additionally, the Colorado Department of Public Health and Environment (CDPHE) issued a Blowing Dust Advisory for southeast Colorado, including Lamar, at 1:00 PM MST. Included in the advisory text:

> "Strong gusty winds with a cold front will create areas of blowing dust through Monday evening." (Source: http://www.colorado.gov/airquality/forecast_archive.aspx?seeddate=11%2f10%2f2014)

Satellite products combined with reports, advisories and webcam imagery from southeast Colorado on November 10, 2014 clearly reveal that a dust storm occurred which was regional in scale and therefore not controllable or preventable.

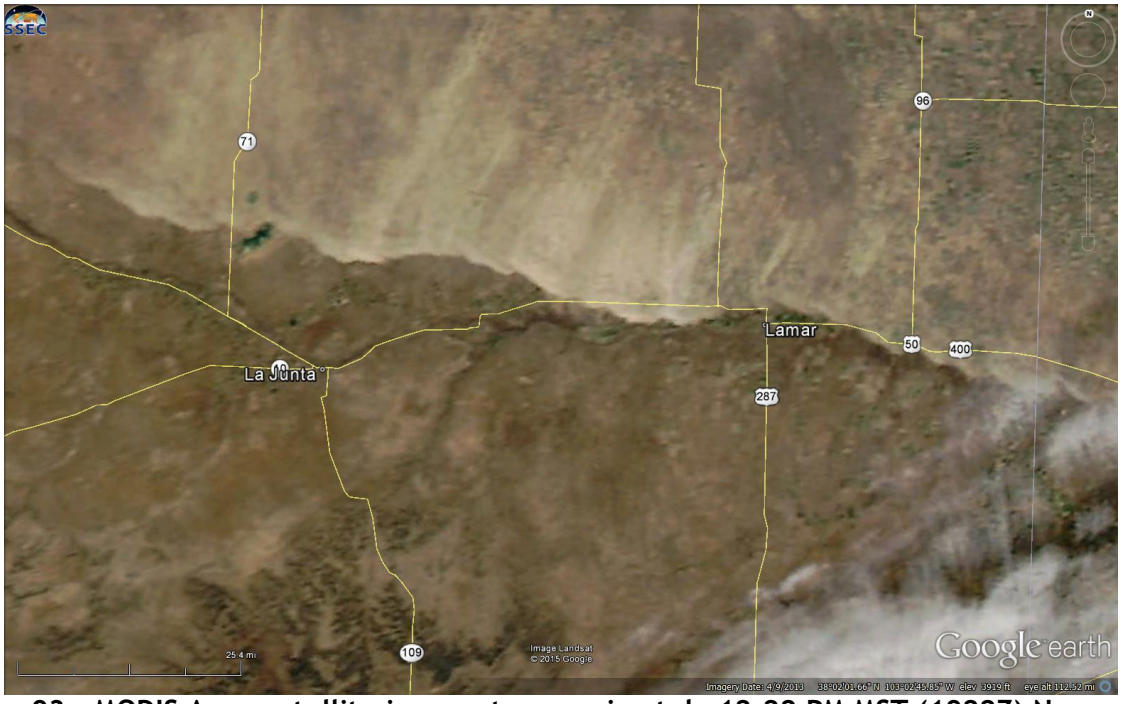


Figure 93: MODIS Aqua satellite image at approximately 12:22 PM MST (1922Z) November 10, 2014.
(Source: http://ge.ssec.wisc.edu/modis-today/index.php)

Figure 94: Gobblers Knob webcam image at 1:19 PM MST November 10, 2014.
(Source: http://amos.cse.wustl.edu/)

The synoptic weather conditions described above impacted a region that was in the midst of a severe drought (Figure 95). Sustained drought conditions are known to make topsoil susceptible to high winds and produce blowing dust (see the following link from the National Climatic Data Center for more information: https://www.ncdc.noaa.gov/paleo/drought/drght_history.html). Figure 96 shows the total precipitation in inches from October 11, 2014 to November 9, 2014 for eastern Colorado. Note that a large portion of eastern Colorado received less than 0.51 inches of precipitation during the 30-day period leading up to the November 10, 2014 dust event, particularly upwind from Lamar (north to northeasterly) where many areas received virtually no measureable precipitation. Based on previous research 0.5 to 0.6 inches of precipitation over a 30-day period has been found to be the approximate threshold, below which, blowing dust exceedances at Lamar are more likely to occur when combined with high winds (see the Lamar Blowing Dust Climatology available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2).

The U.S. Drought Monitor and 30-day precipitation totals indicate that soils in eastern Colorado, especially upwind from Lamar, were dry enough to produce blowing dust when winds were above the thresholds for blowing dust. This information, combined with other evidence provided in this report, proves that this dust storm was a natural, regional event that was not reasonably controllable or preventable.

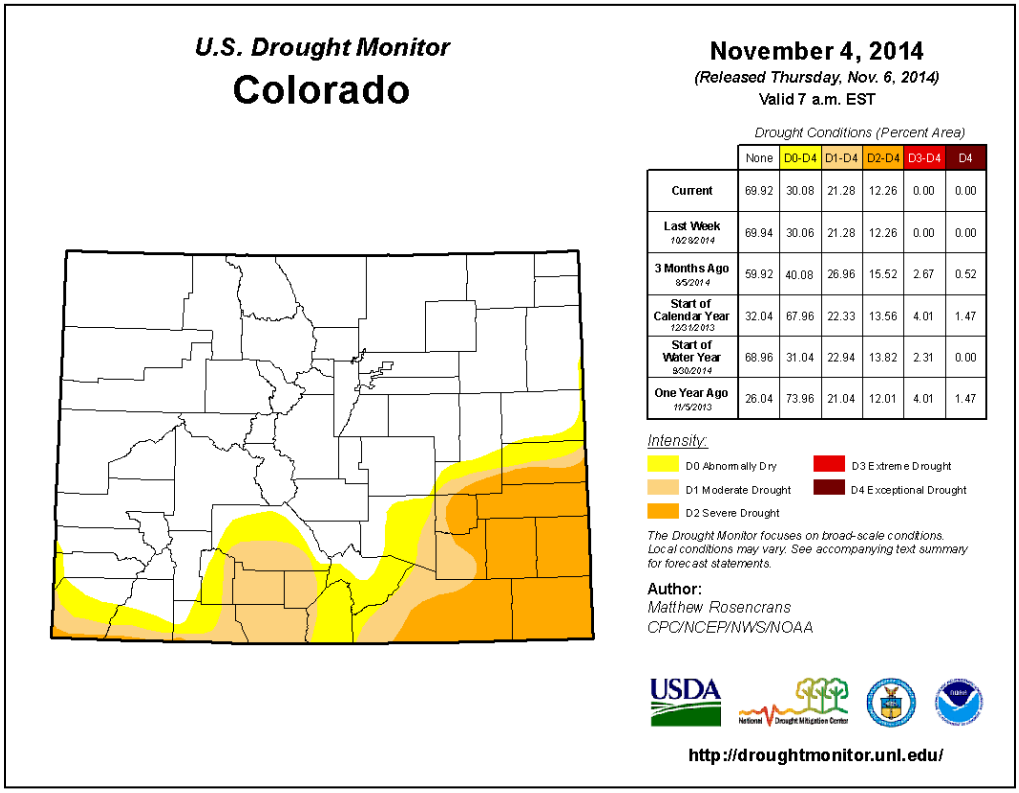


Figure 95: Drought conditions for Colorado at 5:00 AM MST November 4, 2014. (Source: http://droughtmonitor.unl.edu/MapsAndData/MapArchive.aspx)

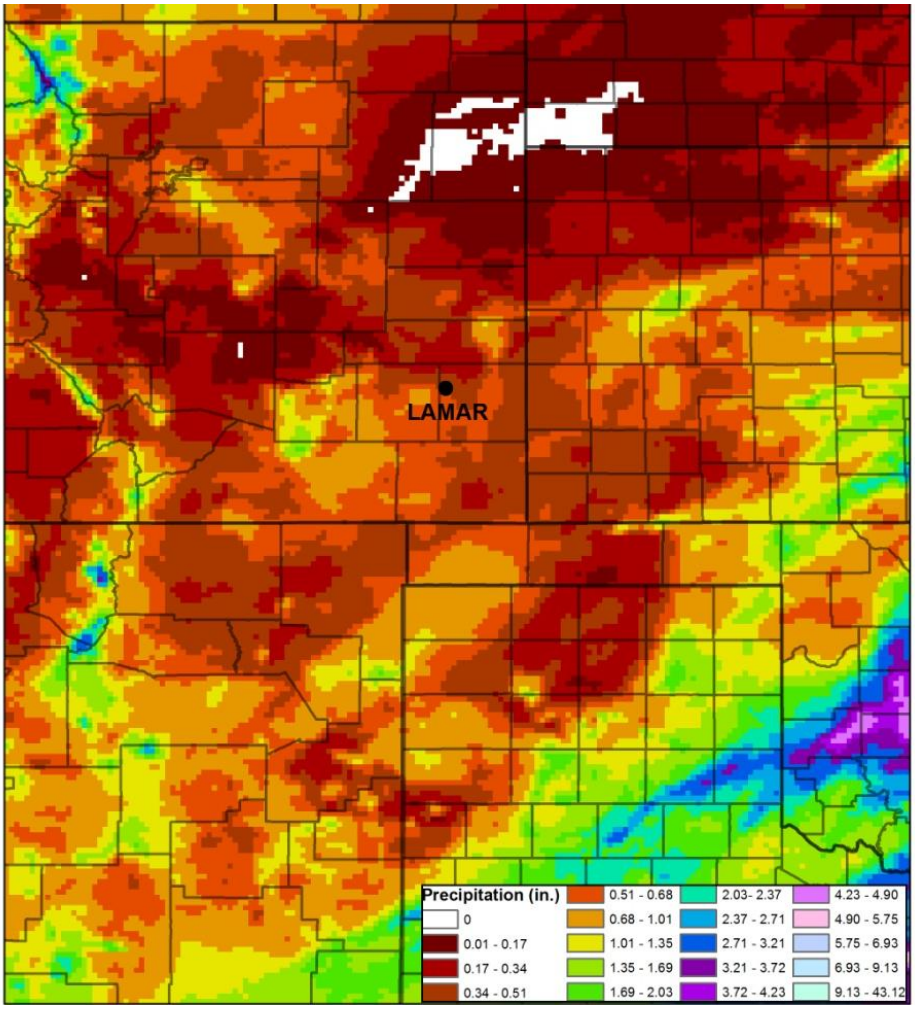


Figure 96: Total precipitation in inches for Colorado and adjacent states, October 11, 2014 – November 9, 2014.
(Source: http://prism.nacse.org)

3.0 Evidence - Ambient Air Monitoring Data and Statistics

Multiple intense fronts moved across south eastern Colorado in 2014. Several of these transported blowing dust into Lamar from source regions outside of the monitoring area. Ambient air monitoring data and statistics for each event are discussed further below.

3.1 March 11, 2014 Monitoring Data and Statistics

On March 11, 2014, a powerful late winter storm system moved across the western United States. Intense surface winds in the wake of the passing system transported blowing dust into Lamar. The strong winds following the system affected PM_{10} samples at the site in Lamar, Colorado. During this event a sample in excess of 150 $\mu g/m^3$ was recorded at Lamar Municipal Building 08-099-0002 (Lamar Muni, 387 $\mu g/m^3$).

3.1.1 Historical Fluctuations of PM_{10} Concentrations in Lamar

This evaluation of PM_{10} monitoring data for sites affected by the March 11, 2014, event was made using valid samples from PM_{10} samplers in Lamar from 2009 through August of 2014; APCD has been monitoring PM_{10} concentrations in Lamar since 1985. The overall data summary for the affected site is presented in Table 27, with all data values being presented in $\mu g/m^3$:

Table 27: March 11, 2014, Event Data Summary

	Lamar Municipal
3/11/2014	**387**
Mean	25.5
Median	19
Mode	14
St. Dev	38.5
Var.	1487.9
Minimum	1
Maximum	1220
Percentile	99.5%
Count	1997

The PM_{10} sample on March 11, 2014, at Lamar Municipal of 387 $\mu g/m^3$ exceeds the 99th percentile value for all evaluation criteria and is the 3rd largest sample of the dataset and the largest sample in any March. Both samples greater than the event sample are associated with high wind events. There are 1,997 samples in this dataset. The sample of March 11, 2014 clearly exceeds the typical samples for this site.

Figure 97 and Figure 98 graphically characterize the Lamar Municipal PM_{10} data. The first, Figure 97, is a simple time series; every sample in this dataset (2009 – 2014) greater than 150 $\mu g/m^3$ is identified. Note the overwhelming number of samples occupying the lower end of the graph; an interested reader can count the number of samples greater than 100 $\mu g/m^3$. Of the 1,997 samples in this data set less than 1% are greater than 100 $\mu g/m^3$.

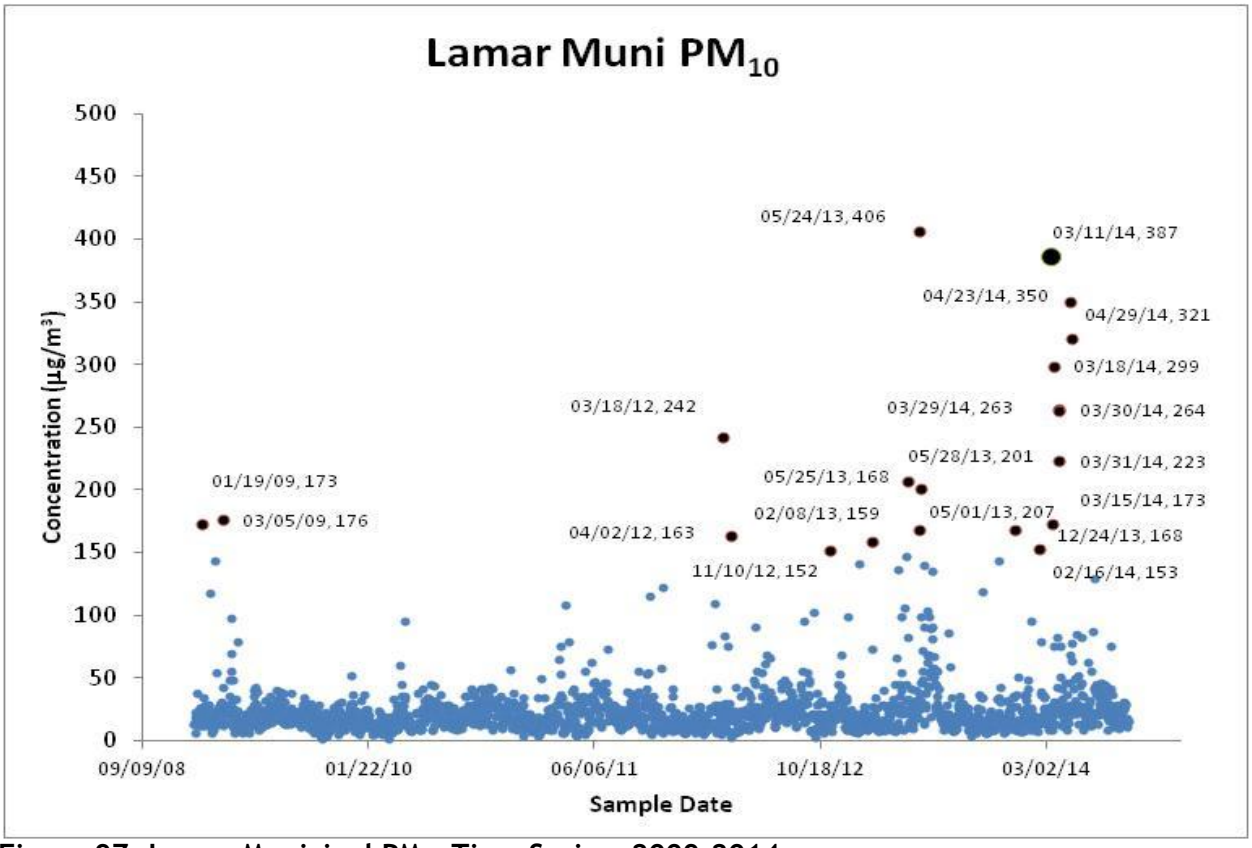


Figure 97: Lamar Municipal PM_{10} Time Series, 2009-2014

The monthly box-whisker plot in Figure 98, highlights the consistency of the majority of data from month to month. Note the greater variability (wider inner-quartile range) and greater range of the data through the winter and early spring months that's accompanied by typically greater monthly maxima. Recall, this time period experiences a greater number of days with meteorological conditions similar to those experienced on March 11, 2014. Although these high values affect the variability and central tendency (average) of the dataset they are not representative of what is typical at the site.

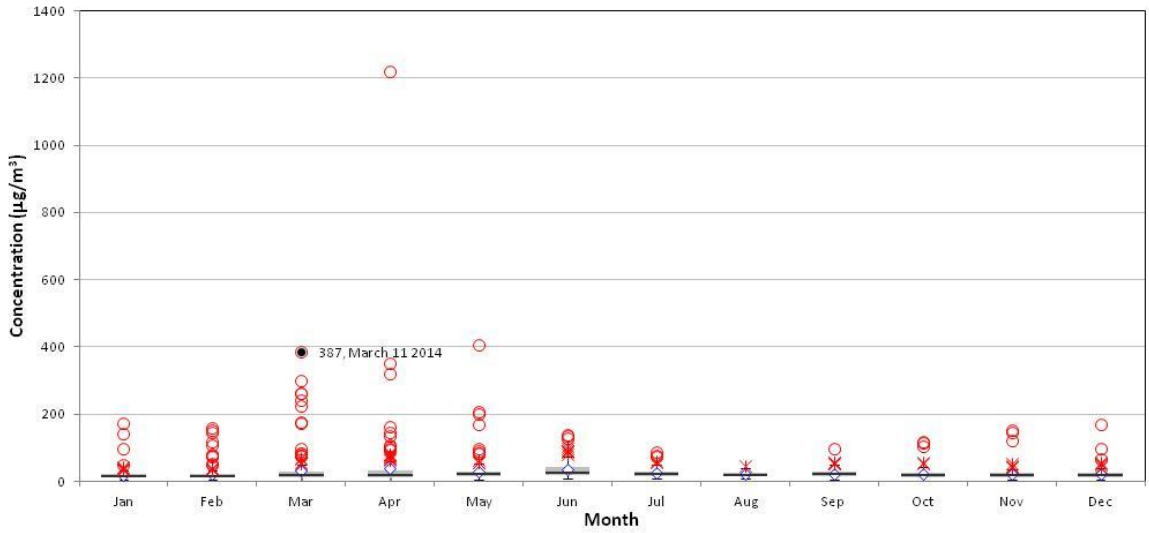


Figure 98: Lamar Municipal PM_{10} Box-Whisker Plot, 2009-2014

Note the degree to which the data in the months of fall through spring, beginning in October and extending through May, are skewed. The March mean (32.7 µg/m^3) is greater than the March median value (19 µg/m^3); the March mean is greater than nearly 83% of all samples in any March. The skew in the data is due to the presence of a handful of extreme values and can create the flawed perception that those months experiencing these high wind events are somehow 'dirtier' than other months of the year. Figure 98 suggests that typical, day to day PM_{10} concentrations exposures for the months of June and September are highest among all months. The sample of March 11, 2014, clearly exceeds the typical data at this site.

3.1.2 Wind Speed Correlations

Wind speeds in southeast Colorado increased mid morning of March 11, 2014 and stayed elevated through late afternoon, gusting to speeds in excess of 40 mph with sustained hourly averages in excess of 25 mph for eight hours. The two charts in Figure 99 display wind speed (mph) as a function of date from meteorological sites within the affected area for a number of days before and after the event.

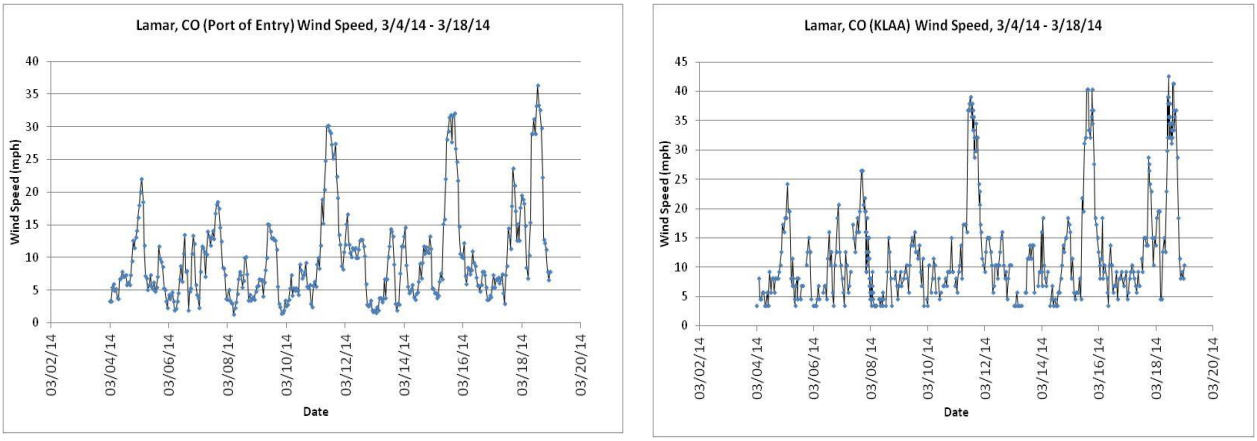


Figure 99: Wind Speed (mph), Lamar, 3/4/2014 – 3/18/2014

Figure 100 plots PM_{10} concentrations from the Lamar Municipal site for the period for seven days prior to and following the sample of March 11, 2014.

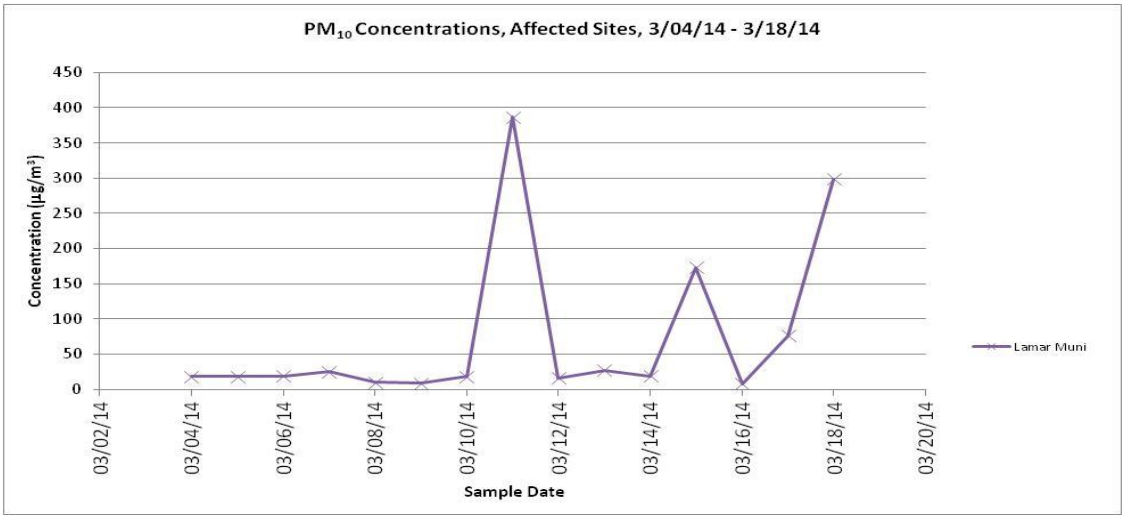


Figure 100: PM_{10} Concentrations, Lamar Municipal, 3/4/2014 – 3/18/2014

Figure 100 mimics the plots for wind speed, suggesting an association between the regional high winds and PM_{10} concentrations at the affected sites; even to the extent that high winds on March 15, 2014 and March 18, 2014 have an association with the high sample values on those days (173 µg/m^3 and 299 µg/m^3, both samples greater than the 99% value for the entire data set). Although the samples were affected to differing degrees by the event (possibly reflecting the variation in contribution from local sources) the elevated concentrations are clearly associated with the elevated wind speeds. The relationship between the two data sets would suggest that the regional high winds had an effect on PM_{10} samples in Lamar on March 11, 2014.

3.1.3 Percentiles

The monthly percentile plot in Figure 101 demonstrate a high degree of association between monthly median values and relatively high monthly percentile values, e.g. the Pearson's r value between the monthly 90th percentile value at Lamar Municipal and the monthly median is 0.65. As the percentile value decreases (i.e. 85%, 75%, etc) the correlation between those values and the monthly median values increases sharply.

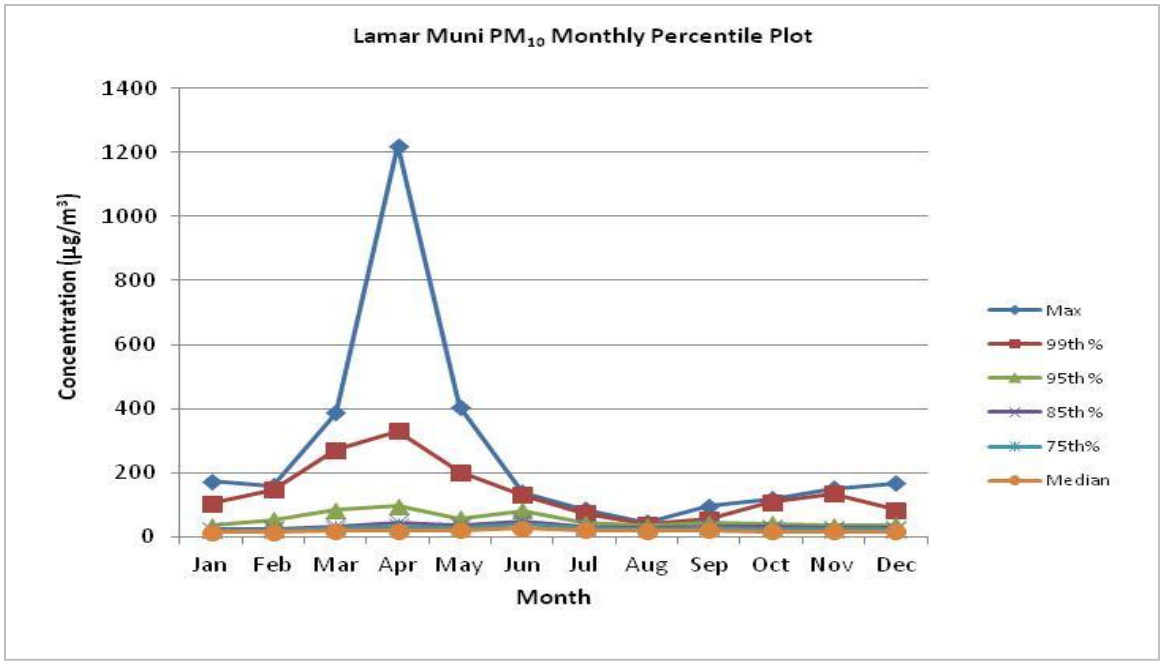


Figure 101: Monthly PM_{10} Percentile Plot

It is certainly the case that monthly median values are indicative of typical, day to day concentrations. Additionally, there is a range of samples that are a product of normal variation subject to typical, day to day local effects. This range may be restricted to percentile values that are well correlated with the median. For the data set of concern (Lamar Municipal) a conservative estimate of the percentile value that is reflective of typical, day to day variation is the 75th percentile value. Nearly all of the variation in the monthly 75th percentile value in this data set can be explained by the variation in monthly medians; for Lamar Municipal the correlation between the median and monthly 75th percentile values is r^2 = 0.9. A reasonable estimate of the contribution to the event from local sources for this data set may be the monthly 85th percentile values; the correlation between the median and the monthly 85th percentile values is r^2 = 0.80. If these percentile values are taken as an estimate of event PM_{10} due to local variation then the portion of the sample concentration remaining from these monthly percentile values would be the sample contribution due to the event.

Table 28 identifies various percentile values that are representative of the maximum contribution due to local sources for Lamar Municipal from all March data (2009 – 2014). In Table 28 the range estimate in the 'Est. Conc. Above Typical' column is derived using the difference between the actual sample value and the 85th percentile as the minimum (reasonable) event contribution estimate and the difference between the actual sample value and the 75th percentile as the maximum (conservative) event contribution estimate. This column represents the range of estimated contribution to the March 11, 2014 sample at Lamar Municipal due to the high wind event.

Table 28: Estimated Maximum Event PM_{10} Contribution, March 11, 2014

Site	Event Day Concentration ($\mu g/m^3$)	March Median ($\mu g/m^3$)	March Average ($\mu g/m^3$)	March 75th % ($\mu g/m^3$)	March 85th % ($\mu g/m^3$)	Est. Conc. Above Typical ($\mu g/m^3$)
Lamar Municipal	**387**	19	32.7	28	33	**354 – 359**

Clearly, there would have been no exceedance but for the additional contribution to the PM_{10} sample provided by the event.

3.2 March 15, 2014 Monitoring Data and Statistics

On March 15, 2014, a powerful late winter storm produced high winds in Southeast Colorado. Intense northerly surface winds blowing over dry disturbed soil in eastern Colorado resulted in blowing dust affecting PM_{10} samples at the site in Lamar, Colorado. During this event a sample in excess of 150 $\mu g/m^3$ was recorded at Lamar Municipal Building 08-099-0002 (Lamar Muni, 173 $\mu g/m^3$).

3.2.1 Historical Fluctuations of PM_{10} Concentrations in Lamar

This evaluation of PM_{10} monitoring data for sites affected by the March 15, 2014, event was made using valid samples from PM_{10} samplers in Lamar from 2009 through August of 2014; APCD has been monitoring PM_{10} concentrations in Lamar since 1985. The overall data summary for the affected site is presented in Table 29, with all data values being presented in $\mu g/m^3$:

Table 29: March 15, 2014, Event Data Summary

	Lamar Municipal
3/15/2014	**173**
Mean	25.5
Median	19
Mode	14
St. Dev	38.5
Var.	1487.9
Minimum	1
Maximum	1220
Percentile	99.5%
Count	1997

The PM_{10} sample on March 15, 2014, at Lamar Municipal of 173 $\mu g/m^3$ exceeds the 99^{th} percentile value for all evaluation criteria and is the 14^{th} largest sample of the dataset. All thirteen samples greater than the event sample are associated with high wind events. There are 1,997 samples in this dataset. The sample of March 15, 2014 clearly exceeds the typical samples for this site.

Figure 102 and Figure 103 graphically characterize the Lamar Municipal PM_{10} data. The first, Figure 102, is a simple time series; every sample in this dataset (2009 – 2014) greater than 150 µg/m^3 is identified. Note the overwhelming number of samples occupying the lower end of the graph; an interested reader can count the number of samples greater than 100 µg/m^3. Of the 1,997 samples in this data set less than 1% are greater than 100 µg/m^3.

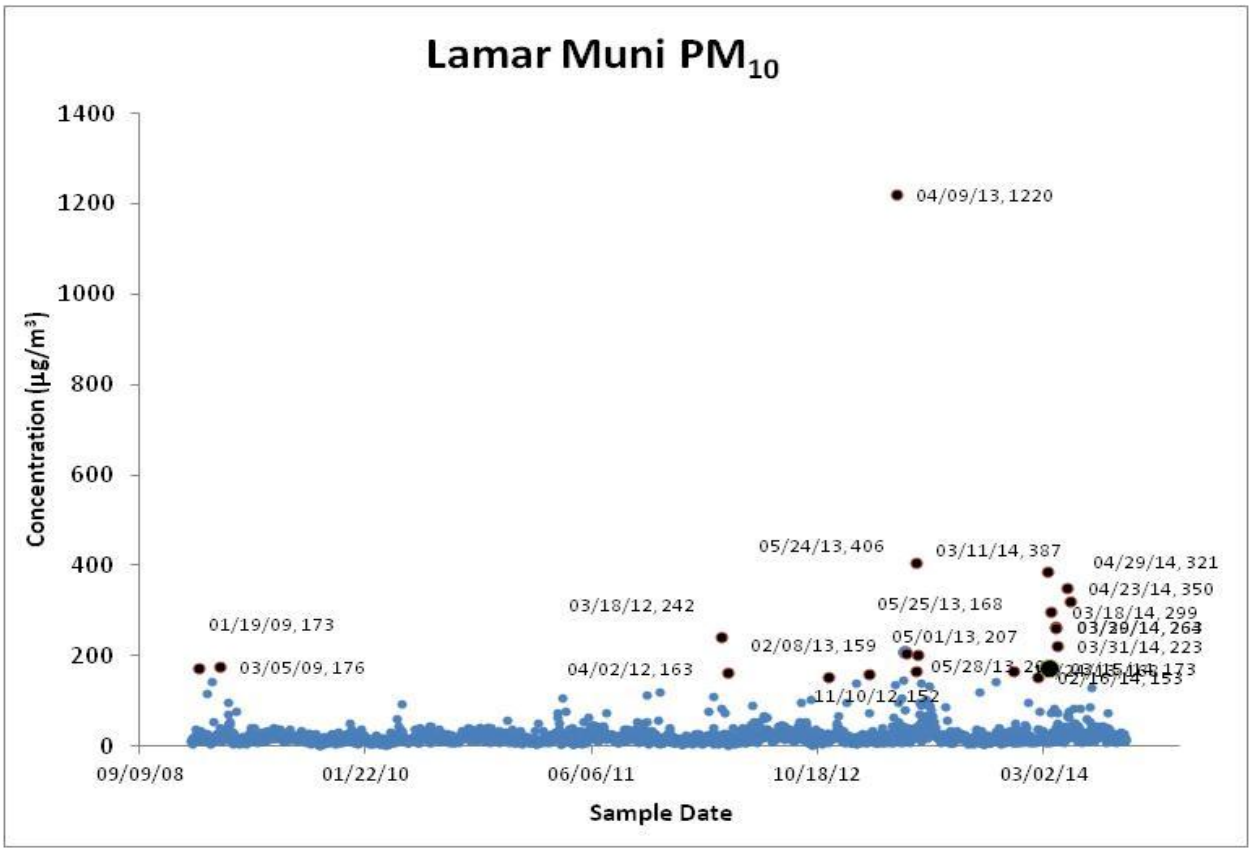


Figure 102: Lamar Municipal PM_{10} Time Series, 2009-2014

The monthly box-whisker plot in Figure 103 highlights the consistency of the majority of data from month to month. Note the greater variability (wider inner-quartile range) and greater range of the data through the winter and early spring months that's accompanied by typically greater monthly maxima. Recall, this time period experiences a greater number of days with meteorological conditions similar to those experienced on March 15, 2014. Although these high values affect the variability and central tendency (average) of the dataset they are not representative of what is typical at the site.

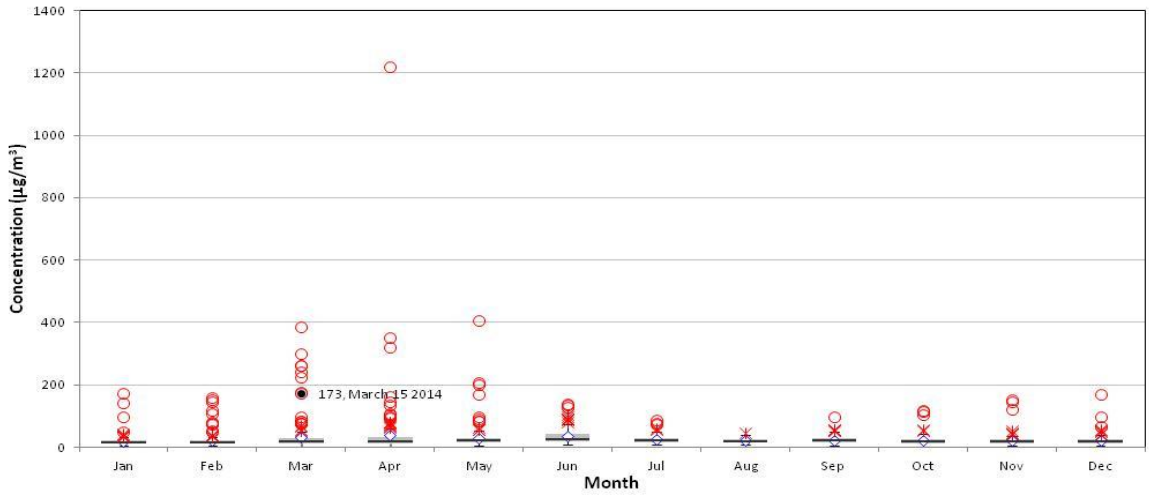


Figure 103: Lamar Municipal PM_{10} Box-Whisker Plot, 2009-2014

Note the degree to which the data in the months of fall through spring, beginning in October and extending through May, are skewed. The March mean (32.7 µg/m^3) is greater than the March median value (19 µg/m^3); the March mean is greater than nearly 83% of all samples in any March. The skew in the data is due to the presence of a handful of extreme values and can create the flawed perception that those months experiencing these high wind events are somehow 'dirtier' than other months of the year. Figure 103 suggests that typical, day to day PM_{10} concentrations exposures for the months of June and September are highest among all months. The sample of March 15, 2014, clearly exceeds the typical data at this site.

3.2.2 Wind Speed Correlations

Wind speeds in southeast Colorado increased early morning of March 15, 2014 and stayed elevated through late evening, gusting to speeds in excess of 50 mph. The two charts in Figure 104 display wind speed (mph) as a function of date from meteorological sites within the affected area for a number of days before and after the event.

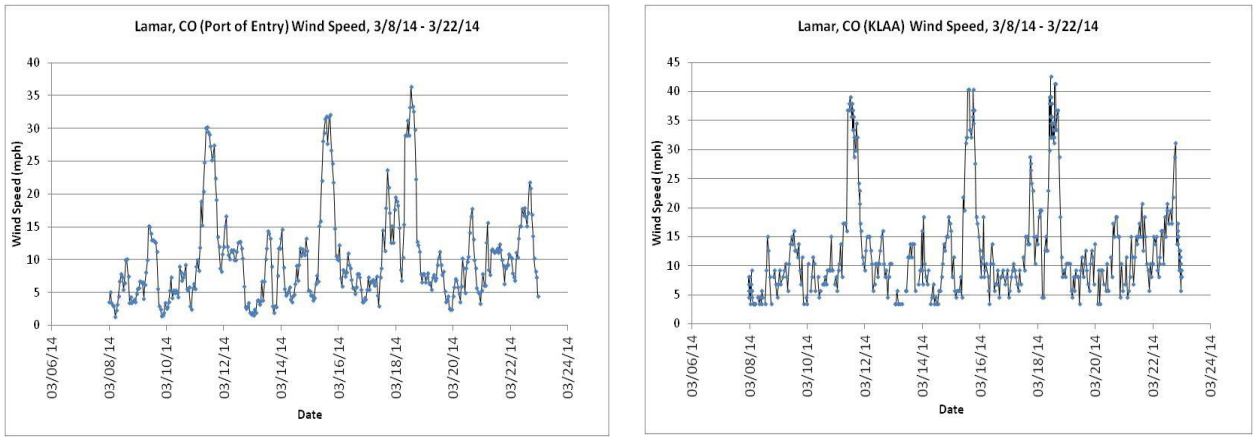


Figure 104: Wind Speed (mph), Lamar, 3/8/2014 – 3/22/2014

Figure 105 plots PM_{10} concentrations from the Lamar Municipal site for the period for seven days prior to and following the sample of March 15, 2014.

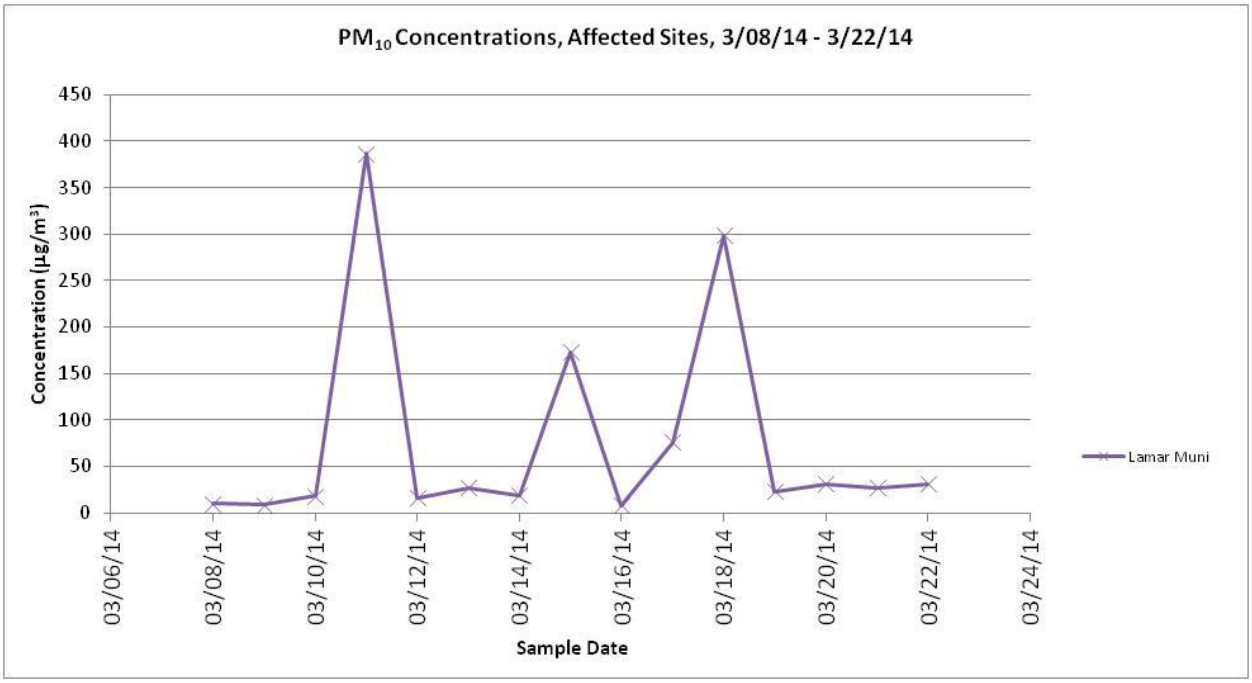


Figure 105: PM_{10} Concentrations, Lamar Municipal, 3/8/2014 – 3/22/2014

Figure 105 mimics the plots for wind speed, suggesting an association between the regional high winds and PM_{10} concentrations at the affected sites. Although the samples were affected to differing degrees by the event (possibly reflecting the variation in contribution from local sources) the elevated concentrations are clearly associated with the elevated wind speeds. The relationship between the two data sets would suggest that the regional high winds had an effect on PM_{10} samples in Lamar on March 15, 2014.

3.2.3 Percentiles

The monthly percentile plot in Figure 106 demonstrate a high degree of association between monthly median values and relatively high monthly percentile values, e.g. the Pearson's r value between the monthly 90^{th} percentile value at Lamar Municipal and the monthly median is 0.65. As the percentile value decreases (i.e. 85%, 75%, etc) the correlation between those values and the monthly median values increases sharply.

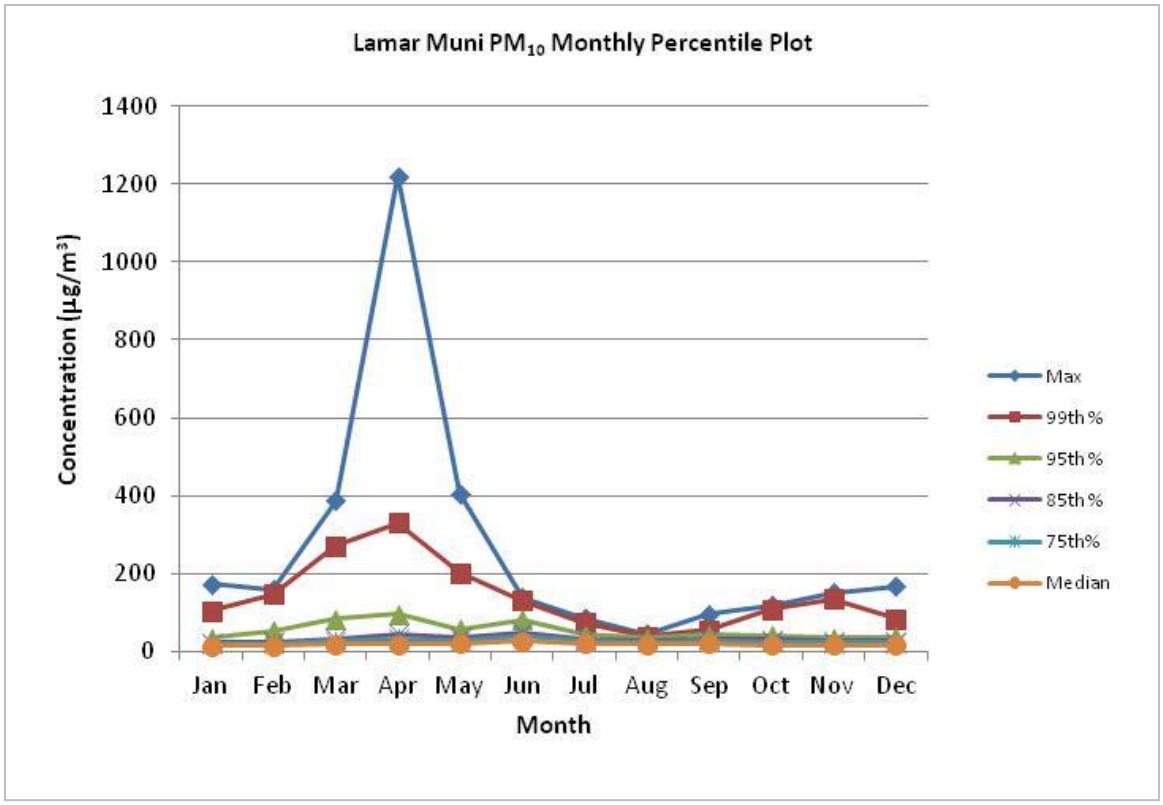


Figure 106: Monthly PM_{10} Percentile Plot

It is certainly the case that monthly median values are indicative of typical, day to day concentrations. Additionally, there is a range of samples that are a product of normal variation subject to typical, day to day local effects. This range may be restricted to percentile values that are well correlated with the median. For the data set of concern (Lamar Municipal) a conservative estimate of the percentile value that is reflective of typical, day to day variation is the 75th percentile value. Nearly all of the variation in the monthly 75th percentile value in this data set can be explained by the variation in monthly medians; for Lamar Municipal the correlation between the median and monthly 75th percentile value is r^2 = 0.9. A reasonable estimate of the contribution to the event from local sources for this data set may be the monthly 85th percentile values the correlation between the median and the monthly 85th percentile values is r^2 = 0.80. If these percentile values are taken as an estimate of event PM_{10} due to local variation then the portion of the sample concentration remaining from these monthly percentile values would be the sample contribution due to the event.

Table 30 identifies various percentile values that are representative of the maximum contribution due to local sources for Lamar Municipal from all March data (2009 – 2014). In Table 30 the range estimate in the 'Est. Conc. Above Typical' column is derived using the difference between the actual sample value and the 85th percentile as the minimum (reasonable) event contribution estimate and the difference between the actual sample value and the 75th percentile as the maximum (conservative) event contribution estimate. This column represents the range of estimated contribution to the March 15, 2014 sample at Lamar Municipal due to the high wind event.

Table 30: Estimated Maximum Event PM_{10} Contribution, March 15, 2014

Site	Event Day Concentration ($\mu g/m^3$)	March Median ($\mu g/m^3$)	March Average ($\mu g/m^3$)	March 75th % ($\mu g/m^3$)	March 85th % ($\mu g/m^3$)	Est. Conc. Above Typical ($\mu g/m^3$)
Lamar Municipal	**173**	19	32.7	28	33	**140 – 145**

Clearly, there would have been no exceedance but for the additional contribution to the PM_{10} sample provided by the event.

3.3 March 18, 2014 Monitoring Data and Statistics

On March 18, 2014, a powerful late winter storm caused intense surface winds in Southern Colorado. Strong and gusty winds moved over dry soils and transported blowing dust into Lamar. The strong winds affected PM_{10} samples at the site in Lamar, Colorado. During this event a sample in excess of 150 $\mu g/m^3$ was recorded at Lamar Municipal Building 08-099-0002 (Lamar Muni, 299 $\mu g/m^3$).

3.3.1 Historical Fluctuations of PM_{10} Concentrations in Lamar

This evaluation of PM_{10} monitoring data for sites affected by the March 18, 2014, event was made using valid samples from PM_{10} samplers in Lamar from 2009 through August of 2014; APCD has been monitoring PM_{10} concentrations in Lamar since 1985. The overall data summary for the affected site is presented in Table 31, with all data values being presented in $\mu g/m^3$:

Table 31: March 18, 2014, Event Data Summary

	Lamar Municipal
3/18/2014	**299**
Mean	25.5
Median	19
Mode	14
St. Dev	38.5
Var.	1487.9
Minimum	1
Maximum	1220
Percentile	99.5%
Count	1997

The PM_{10} sample on March 18, 2014, at Lamar Municipal of 299 $\mu g/m^3$ exceeds the 99th percentile value for all evaluation criteria and is the 6th largest sample of the dataset. The five samples greater than the event sample are associated with high wind events. There are 1,997 samples in this dataset. The sample of March 18, 2014 clearly exceeds the typical samples for this site.

Figure 107 and Figure 108 graphically characterize the Lamar Municipal PM_{10} data. The first, Figure 107, is a simple time series; every sample in this dataset (2009 – 2014) greater than 150 µg/m^3 is identified. Note the overwhelming number of samples occupying the lower end of the graph; an interested reader can count the number of samples greater than 100 µg/m^3. Of the 1,997 samples in this data set less than 1% are greater than 100 µg/m^3.

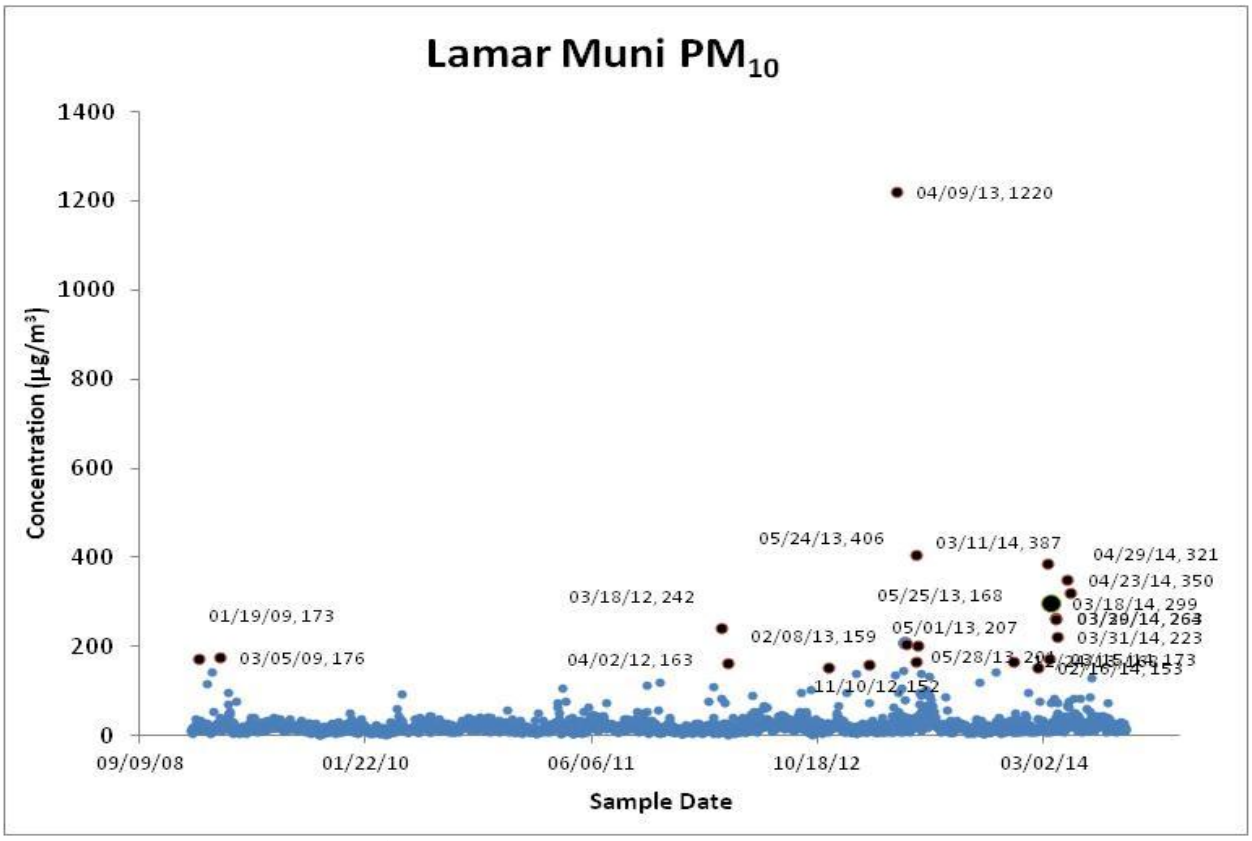


Figure 107: Lamar Municipal PM_{10} Time Series, 2009-2014

The monthly box-whisker plot, Figure 108, highlights the consistency of the majority of data from month to month. Note the greater variability (wider inner-quartile range) and greater range of the data through the winter and early spring months that's accompanied by typically greater monthly maxima. Recall, this time period experiences a greater number of days with meteorological conditions similar to those experienced on March 18, 2014. Although these high values affect the variability and central tendency (average) of the dataset they are not representative of what is typical at the site.

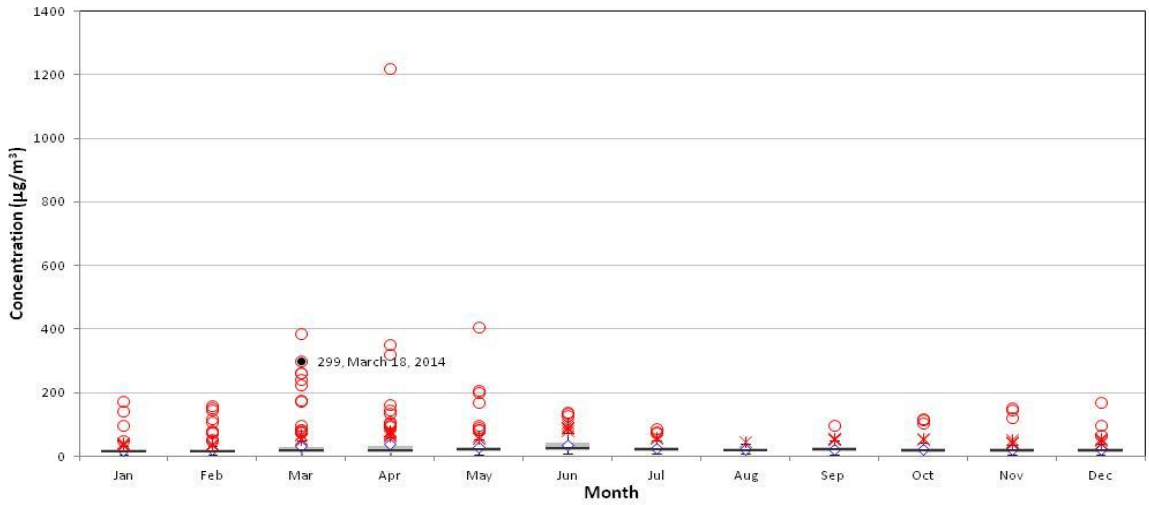


Figure 108: Lamar Municipal PM_{10} Box-Whisker Plot, 2009-2014

Note the degree to which the data in the months of fall through spring, beginning in October and extending through May, are skewed. The March mean (32.7 µg/m^3) is greater than the March median value (19 µg/m^3); the March mean is greater than nearly 83% of all samples in any March. The skew in the data is due to the presence of a handful of extreme values and can create the flawed perception that those months experiencing these high wind events are somehow 'dirtier' than other months of the year. Figure 108 suggests that typical, day to day PM_{10} concentrations exposures for the months of June and September are highest among all months. The sample of March 18, 2014, clearly exceeds the typical data at this site.

3.3.2 Wind Speed Correlations

Wind speeds in southeast Colorado increased early morning of March 18, 2014 and stayed elevated through late evening, gusting to speeds in excess of 50mph. The two charts in Figure 109 display wind speed (mph) as a function of date from meteorological sites within the affected area for a number of days before and after the event.

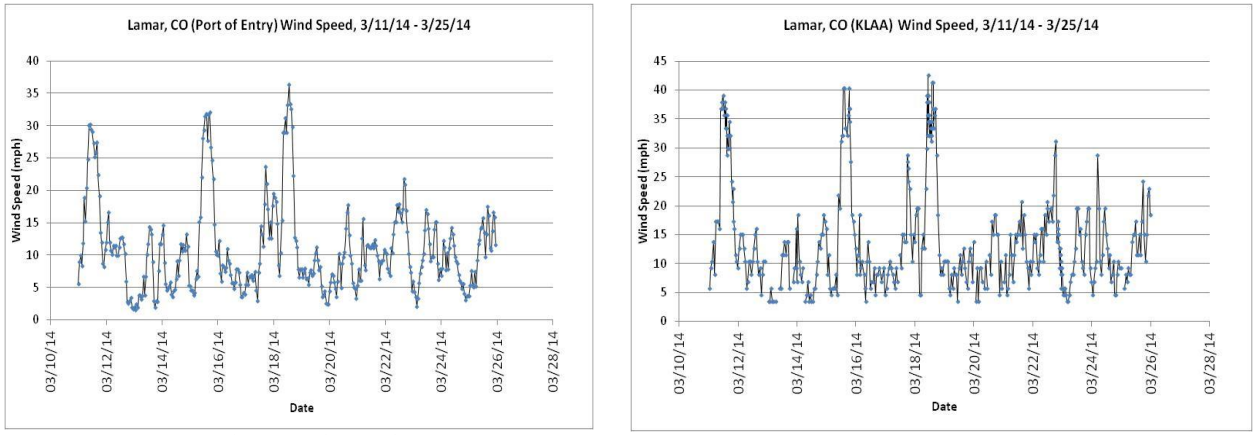


Figure 109: Wind Speed (mph), Lamar, 3/11/2014 – 3/25/2014

Figure 110 plots PM_{10} concentrations from the Lamar Municipal site for the period for seven days prior to and following the sample of March 18, 2014.

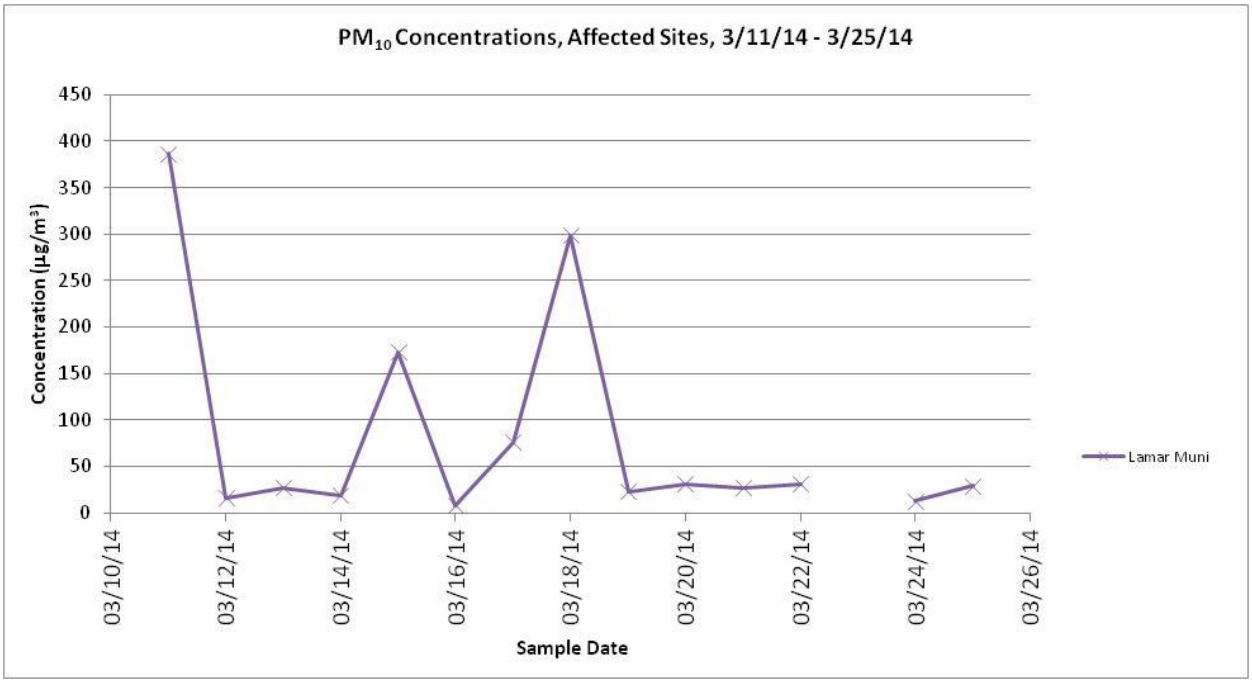


Figure 110: PM_{10} Concentrations, Lamar Municipal, 3/11/2014 – 3/25/2014

Figure 110 mimics the plots for wind speed, suggesting an association between the regional high winds and PM_{10} concentrations at the affected sites. Although the samples were affected to differing degrees by the event (possibly reflecting the variation in contribution from local sources) the elevated concentrations are clearly associated with the elevated wind speeds. The relationship between the two data sets would suggest that the regional high winds had an effect on PM_{10} samples in Lamar on March 18, 2014.

3.3.3 Percentiles

The monthly percentile plot in Figure 111 demonstrate a high degree of association between monthly median values and relatively high monthly percentile values, e.g. the Pearson's r value between the monthly 90^{th} percentile value at Lamar Municipal and the monthly median is 0.65. As the percentile value decreases (i.e. 85%, 75%, etc) the correlation between those values and the monthly median values increases sharply.

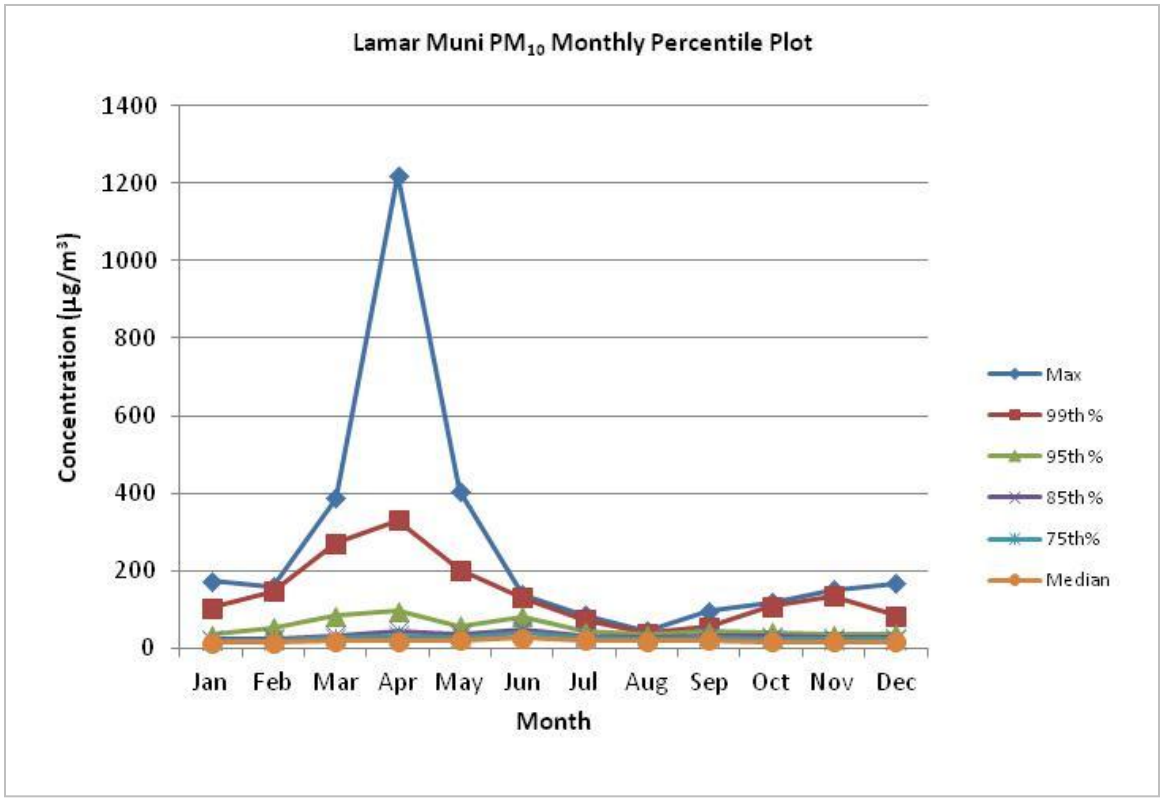


Figure 111: Monthly PM_{10} Percentile Plot

It is certainly the case that monthly median values are indicative of typical, day to day concentrations. Additionally, there is a range of samples that are a product of normal variation subject to typical, day to day local effects. This range may be restricted to percentile values that are well correlated with the median. For the data set of concern (Lamar Municipal) a conservative estimate of the percentile value that is reflective of typical, day to day variation is the 75th percentile value. Nearly all of the variation in the monthly 75th percentile value in this data set can be explained by the variation in monthly medians; for Lamar Municipal the correlation between the median and monthly 75th percentile value is r^2 = 0.9. A reasonable estimate of the contribution to the event from local sources for this data set may be the monthly 85th percentile value, the correlation between the median and the monthly 85th percentile values is r^2 = 0.80. If these percentile values are taken as an estimate of event PM_{10} due to local variation then the portion of the sample concentration remaining from these monthly percentile values would be the sample contribution due to the event.

Table 32 identifies various percentile values that are representative of the maximum contribution due to local sources for Lamar Municipal from all March data (2009 – 2014). In Table 32 the range estimate in the 'Est. Conc. Above Typical' column is derived using the difference between the actual sample value and the 85th percentile as the minimum (reasonable) event contribution estimate and the difference between the actual sample value and the 75th percentile as the maximum (conservative) event contribution estimate. This column represents the range of estimated contribution to the March 18, 2014 sample at Lamar Municipal due to the high wind event.

Table 32: Estimated Maximum Event PM_{10} Contribution, March 18, 2014

Site	Event Day Concentration ($\mu g/m^3$)	March Median ($\mu g/m^3$)	March Average ($\mu g/m^3$)	March 75th % ($\mu g/m^3$)	March 85th % ($\mu g/m^3$)	Est. Conc. Above Typical ($\mu g/m^3$)
Lamar Municipal	**299**	19	32.7	28	33	**266 - 271**

Clearly, there would have been no exceedance but for the additional contribution to the PM_{10} sample provided by the event.

3.4 March 29, 2014 Monitoring Data and Statistics

On March 29, 2014, intense surface winds produced by a strong upper-level trough moving across the western United States affected PM_{10} samples at the site in Lamar, Colorado. The intense winds were predominantly out of a south to southwest direction moved over dry soils producing significant blowing dust. During this event a sample in excess of 150 $\mu g/m^3$ was recorded at Lamar Municipal Building 08-099-0002 (Lamar Muni, 263 $\mu g/m^3$).

3.4.1 Historical Fluctuations of PM_{10} Concentrations in Lamar

This evaluation of PM_{10} monitoring data for sites affected by the March 29, 2014, event was made using valid samples from PM_{10} samplers in Lamar from 2009 through August of 2014; APCD has been monitoring PM_{10} concentrations in Lamar since 1985. The overall data summary for the affected site is presented in Table 33, with all data values being presented in $\mu g/m^3$:

Table 33: March 29, 2014, Event Data Summary

	Lamar Municipal
3/29/2014	**263**
Mean	25.5
Median	19
Mode	14
St. Dev	38.5
Var.	1487.9
Minimum	1
Maximum	1220
Percentile	99.5%
Count	1997

The PM_{10} sample on March 29, 2014, at Lamar Municipal of 263 $\mu g/m^3$ exceeds the 99th percentile value for all evaluation criteria and is the 8th largest sample of the dataset. The seven samples greater than the event sample are associated with high wind events. There are 1,997 samples in this dataset. The sample of March 29, 2014 clearly exceeds the typical samples for this site.

Figure 112 and Figure 113 graphically characterize the Lamar Municipal PM_{10} data. The first, Figure 112, is a simple time series; every sample in this dataset (2009 – 2014) greater than 150 µg/m^3 is identified. Note the overwhelming number of samples occupying the lower end of the graph; an interested reader can count the number of samples greater than 100 µg/m^3. Of the 1,997 samples in this data set less than 1% are greater than 100 µg/m^3.

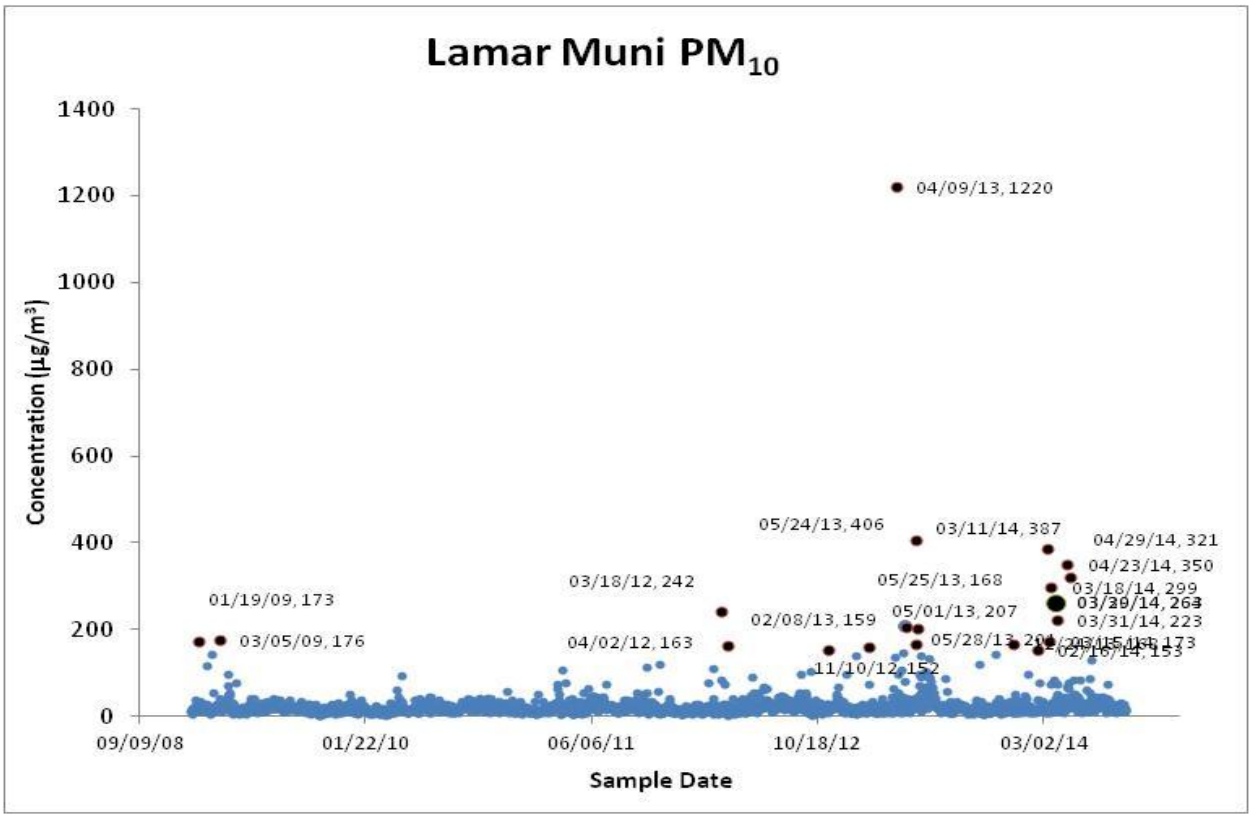


Figure 112: Lamar Municipal PM_{10} Time Series, 2009-2014

The monthly box-whisker plot in Figure 113 highlights the consistency of the majority of data from month to month. Note the greater variability (wider inner-quartile range) and greater range of the data through the winter and early spring months that's accompanied by typically greater monthly maxima. Recall, this time period experiences a greater number of days with meteorological conditions similar to those experienced on March 29, 2014. Although these high values affect the variability and central tendency (average) of the dataset they are not representative of what is typical at the site.

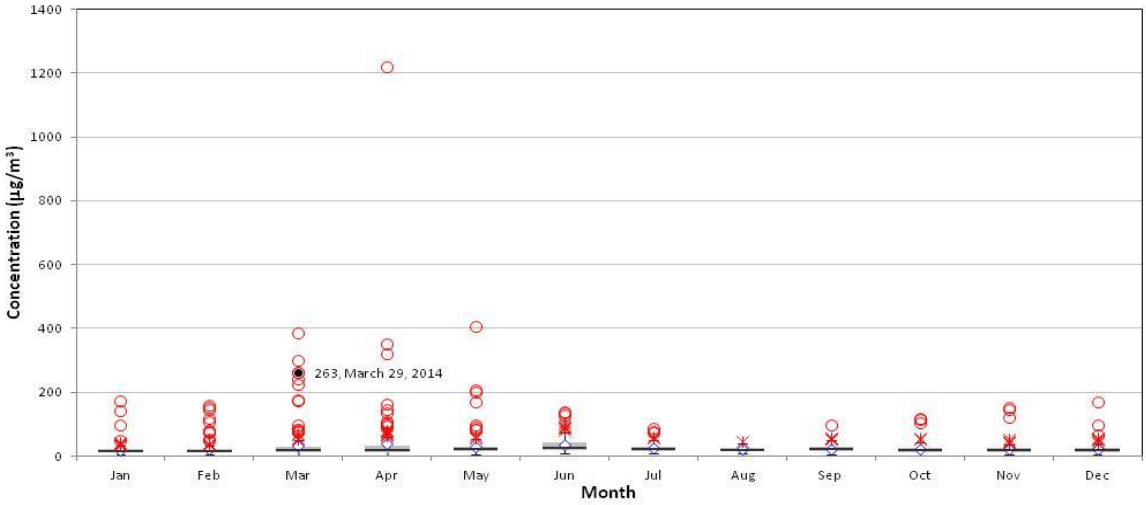


Figure 113: Lamar Municipal PM_{10} Box-Whisker Plot, 2009-2014

Note the degree to which the data in the months of fall through spring, beginning in October and extending through May, are skewed. The March mean (32.7 µg/m^3) is greater than the March median value (19 µg/m^3); the March mean is greater than nearly 83% of all samples in any March. The skew in the data is due to the presence of a handful of extreme values and can create the flawed perception that those months experiencing these high wind events are somehow 'dirtier' than other months of the year. Figure 113 suggests that typical, day to day PM_{10} concentrations exposures for the months of June and September are highest among all months. The sample of March 29, 2014, clearly exceeds the typical data at this site.

3.4.2 Wind Speed Correlations

Wind speeds in southeast Colorado increased early morning of March 29, 2014 and stayed elevated through late evening, gusting to speeds in excess of 50 mph. The following two charts (Figure 114) display wind speed (mph) as a function of date from meteorological sites within the affected area for a number of days before and after the event.

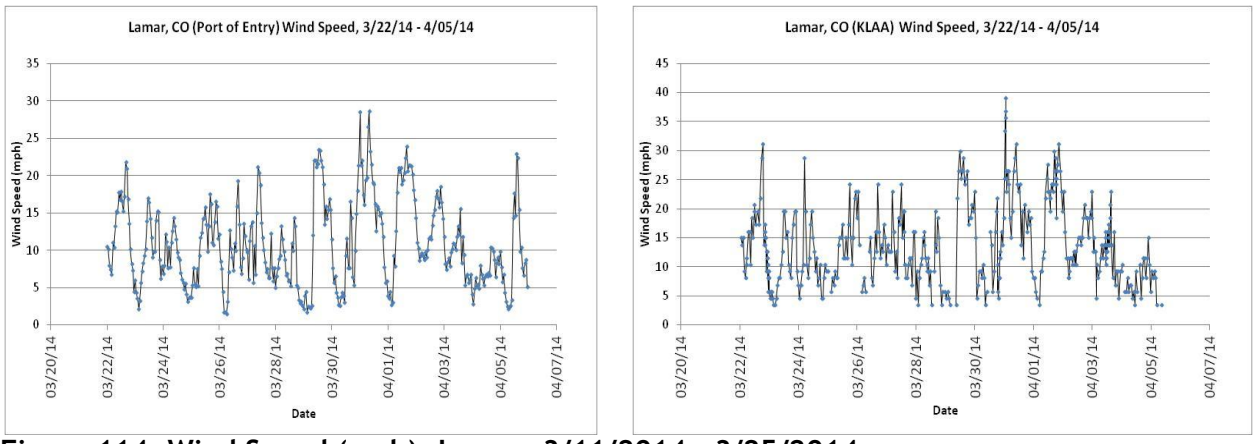


Figure 114: Wind Speed (mph), Lamar, 3/11/2014 – 3/25/2014

Figure 115 plots PM_{10} concentrations from the Lamar Municipal site for the period for seven days prior to and following the sample of March 29, 2014.

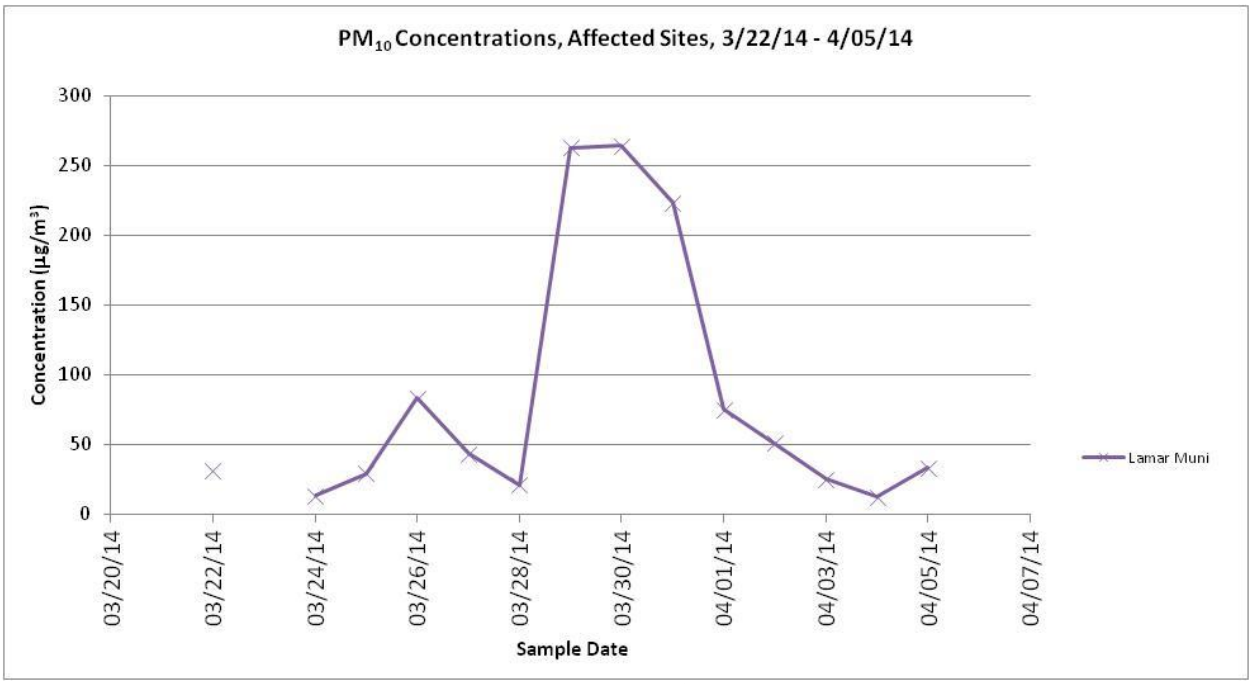


Figure 115: PM_{10} Concentrations, Lamar Municipal, 3/11/2014 – 3/25/2014

Figure 115 mimics the plots for wind speed, suggesting an association between the regional high winds and PM_{10} concentrations at the affected sites. Although the samples were affected to differing degrees by the event (possibly reflecting the variation in contribution from local sources) the elevated concentrations are clearly associated with the elevated wind speeds. The relationship between the two data sets would suggest that the regional high winds had an effect on PM_{10} samples in Lamar on March 29, 2014.

3.4.3 Percentiles

The monthly percentile plot in Figure 116 demonstrate a high degree of association between monthly median values and relatively high monthly percentile values, e.g. the Pearson's r value between the monthly 90^{th} percentile value at Lamar Municipal and the monthly median is 0.65. As the percentile value decreases (i.e. 85%, 75%, etc) the correlation between those values and the monthly median values increases sharply.

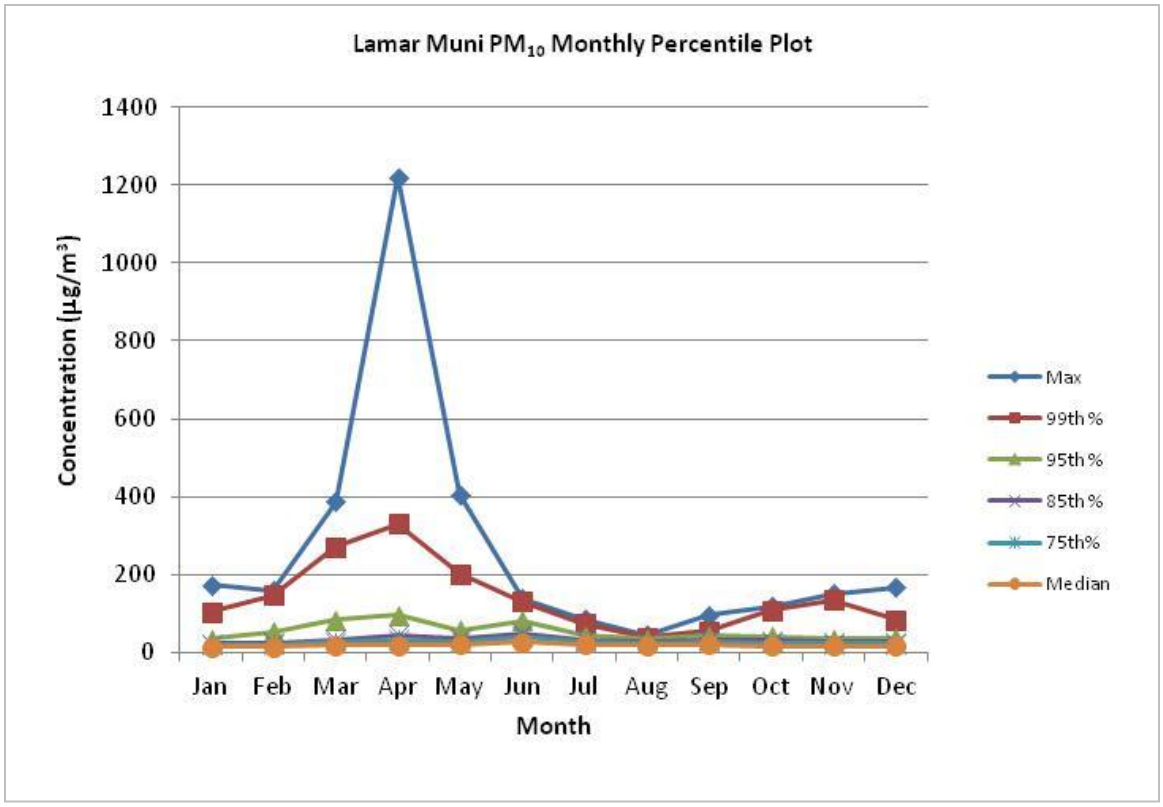


Figure 116: Monthly PM_{10} Percentile Plot

It is certainly the case that monthly median values are indicative of typical, day to day concentrations. Additionally, there is a range of samples that are a product of normal variation subject to typical, day to day local effects. This range may be restricted to percentile values that are well correlated with the median. For the data set of concern (Lamar Municipal) a conservative estimate of the percentile value that is reflective of typical, day to day variation is the 75th percentile value. Nearly all of the variation in the monthly 75th percentile values in this data set can be explained by the variation in monthly medians; for Lamar Municipal these the correlation between the median and monthly 75th percentile values is r^2 = 0.9. A reasonable estimate of the contribution to the event from local sources for this data set may be the monthly 85th percentile values the correlation between the median and the monthly 85th percentile values is r^2 = 0.80. If these percentile values are taken as an estimate of event PM_{10} due to local variation then the portion of the sample concentration remaining from these monthly percentile values would be the sample contribution due to the event.

Table 34 identifies various percentile values that are representative of the maximum contribution due to local sources for Lamar Municipal from all March data (2009 – 2014). In Table 34 the range estimate in the 'Est. Conc. Above Typical' column is derived using the difference between the actual sample value and the 85th percentile as the minimum (reasonable) event contribution estimate and the difference between the actual sample value and the 75th percentile as the maximum (conservative) event contribution estimate. This column represents the range of estimated contribution to the March 29, 2014 sample at Lamar Municipal due to the high wind event.

Table 34: Estimated Maximum Event PM_{10} Contribution, March 29, 2014

Site	Event Day Concentration ($\mu g/m^3$)	March Median ($\mu g/m^3$)	March Average ($\mu g/m^3$)	March 75th % ($\mu g/m^3$)	March 85th % ($\mu g/m^3$)	Est. Conc. Above Typical ($\mu g/m^3$)
Lamar Municipal	**263**	19	32.7	28	33	**230 – 235**

Clearly, there would have been no exceedance but for the additional contribution to the PM_{10} sample provided by the event.

3.5 March 30, 2014 Monitoring Data and Statistics

On March 30, 2014, a powerful spring storm moved across southeast Colorado. The storm generated strong surface winds moving over dry soils affected PM_{10} samples at multiple sites across southern Colorado. During this event, a sample in excess of 150 $\mu g/m^3$ was recorded at Lamar Municipal Building 08-099-0002 (Lamar Muni, 207 $\mu g/m^3$).

3.5.1 Historical Fluctuations of PM_{10} Concentrations in Lamar

This evaluation of PM_{10} monitoring data for the Lamar site affected by the March 30, 2014, event was made using valid samples from PM_{10} samplers in Lamar from 2009 through August of 2014; APCD has been monitoring PM_{10} concentrations in this area since 1985. The overall data summary for the affected sites is presented in Table 35, with all data values being presented in $\mu g/m^3$:

Table 35: March 30, 2014, Event Data Summary

	Lamar Municipal
03/30/2014	**264**
Mean	25.5
Median	19
Mode	14
St. Dev	38.6
Var.	1488.0
Minimum	1
Maximum	1220
Percentile	99.5%
Count	1997

The PM_{10} sample on March 30, 2014, at Lamar Municipal of 264 $\mu g/m^3$ exceeds the 99th percentile value for all evaluation criteria and is the 7th largest sample of all samples from 2009 through August, 2014. All six samples greater than the event sample are associated with high wind events. There are 1,997 samples in this dataset. The sample of March 30, 2014 clearly exceeds the typical samples for this site.

Figure 117 and Figure 118 graphically characterize the Lamar Municipal PM_{10} data. The first, Figure 117, is a simple time series; every sample in this dataset (2009 – 2014) greater than 150 µg/m^3 is identified. Note the overwhelming number of samples occupying the lower end of the graph; an interested reader can count the number of samples greater than 100 µg/m^3. Of the 1,997 samples in this data set less than 1% are greater than 100 µg/m^3.

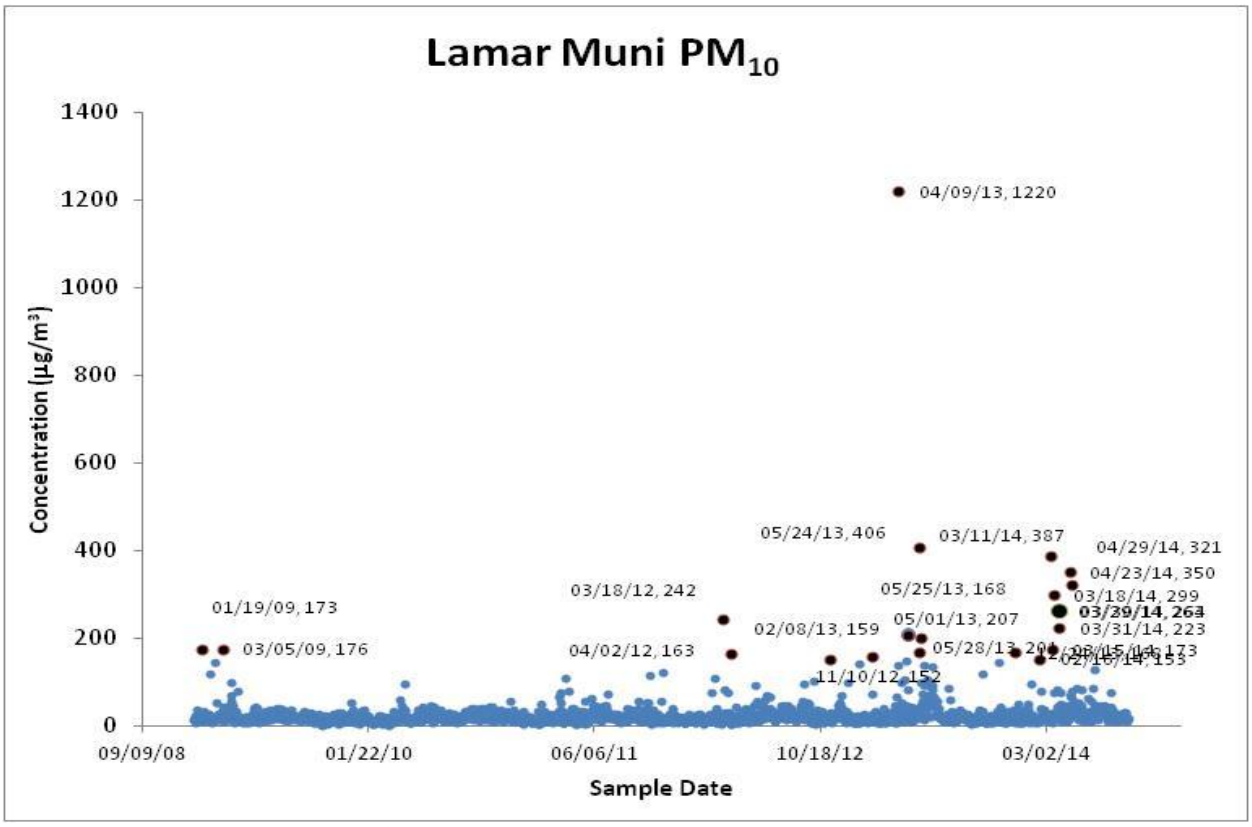


Figure 117: Lamar Municipal PM_{10} Time Series, 2009-2014

The monthly box-whisker plot in Figure 118 highlights the consistency of the majority of data from month to month. Note the greater variability (wider inner-quartile range) and greater range of the data through the winter and early spring months that's accompanied by typically greater monthly maxima. Recall, this time period experiences a greater number of days with meteorological conditions similar to those experienced on March 30, 2014. Although these high values affect the variability and central tendency (average) of the dataset they are not representative of what is typical at the site.

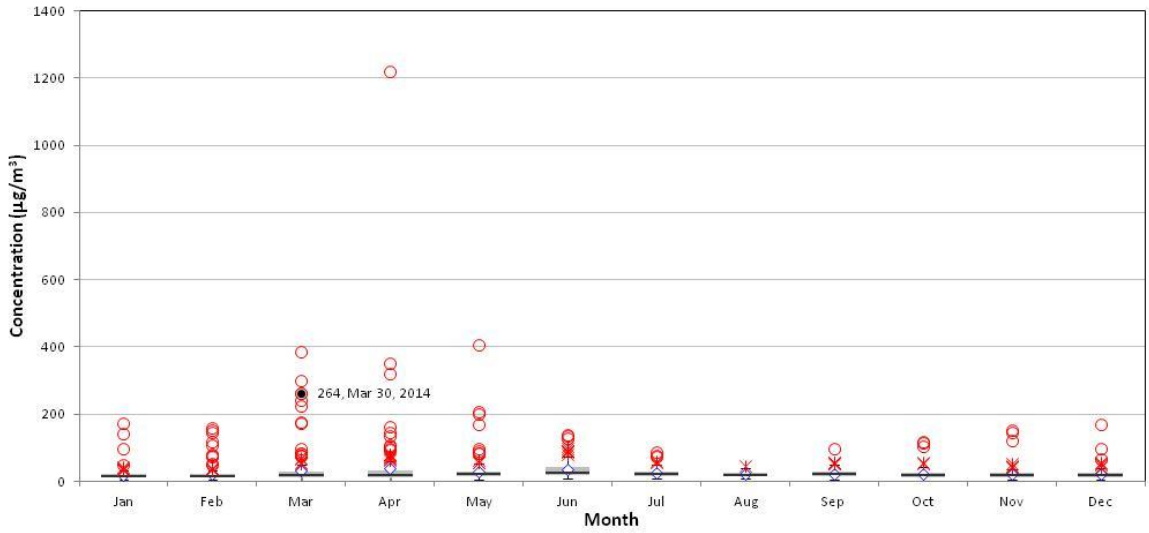


Figure 118: Lamar Municipal PM_{10} Box-Whisker Plot, 2009-2014

Note the degree to which the data in the months of fall through spring, beginning in October and extending through March, are skewed. The March mean (32.7 µg/m^3) is greater than the March median value (19 µg/m^3) and is greater than the 73% of all samples in any March. The skew in the data is due to the presence of a handful of extreme values and can create the flawed perception that those months experiencing these high wind events are somehow 'dirtier' than other months of the year. Figure 118 suggests that typical, day to day PM_{10} concentrations exposures for the month of June and September are highest among all months. The sample of March 30, 2014, clearly exceeds the typical data at this site.

3.5.2 Wind Speed Correlations

Wind speeds in southeast Colorado increased late in the evening of May 30, 2014, and stayed elevated through the late morning of March 30, 2014, gusting to speeds in excess of 40 mph. The two charts in Figure 119 display wind speed (mph) as a function of date from meteorological sites within the affected areas for a number of days before and after the event.

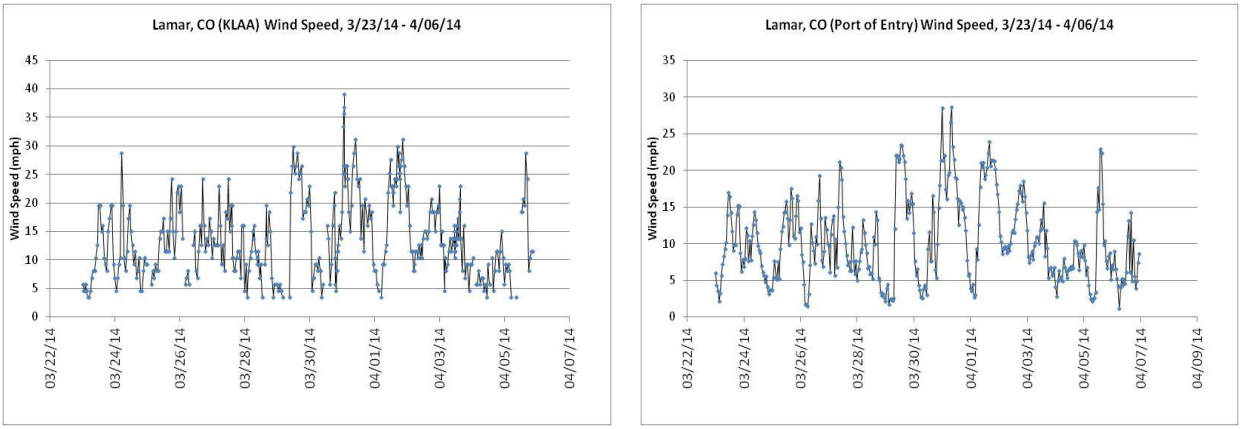


Figure 119: Wind Speed (mph), Lamar, 4/24/2013 – 5/08/2013

Figure 120 plots PM_{10} concentrations from the Lamar Municipal and other affected sites for the period for seven days prior to and following the samples of March 30, 2014. It should be noted that two Alamosa monitors and the monitor in Pueblo also reported exceedances on March 30, 2014 and are included in Figure 120 for comparison purposes only. These additional exceedances in Alamosa and Pueblo will be discussed in a separate Exceptional Event Technical Support Document.

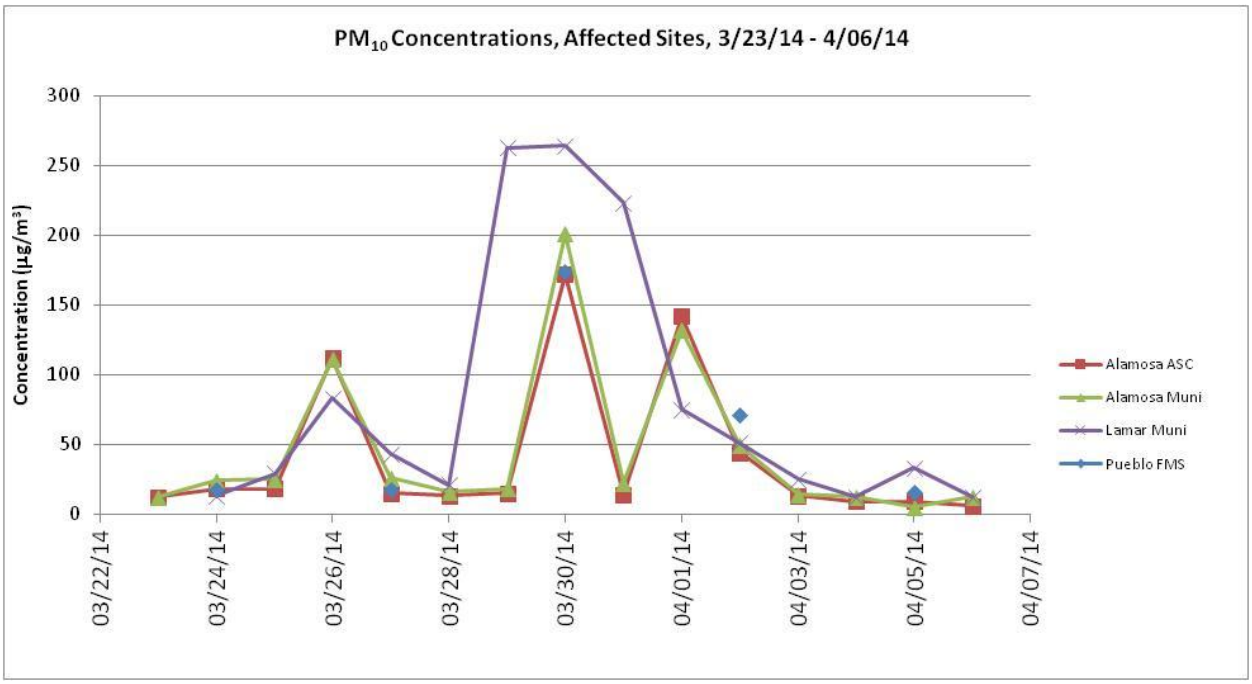


Figure 120: PM_{10} Concentrations, Affected Sites, 4/24/2013 – 05/08/2013

Figure 120 mimics the plots for wind speed, suggesting an association between the regional high winds and PM_{10} concentrations at the affected sites. Although the samples were affected to differing degrees by the event (possibly reflecting the variation in contribution from local sources) the elevated concentrations are clearly associated with the elevated wind speeds. Given the spatial dislocation of the sites the relationship between the two data sets would suggest that the regional high winds had an effect on PM_{10} samples in Lamar on March 30, 2014.

3.5.3 Percentiles

The monthly percentile plot in Figure 121 demonstrate a high degree of association between monthly median values and relatively high monthly percentile values, e.g. the Pearson's r value between the monthly 90^{th} percentile value at Lamar Municipal and the monthly median is 0.57. As the percentile value decreases (i.e. 85%, 75%, etc) the correlation between those values and the monthly median values increases sharply.

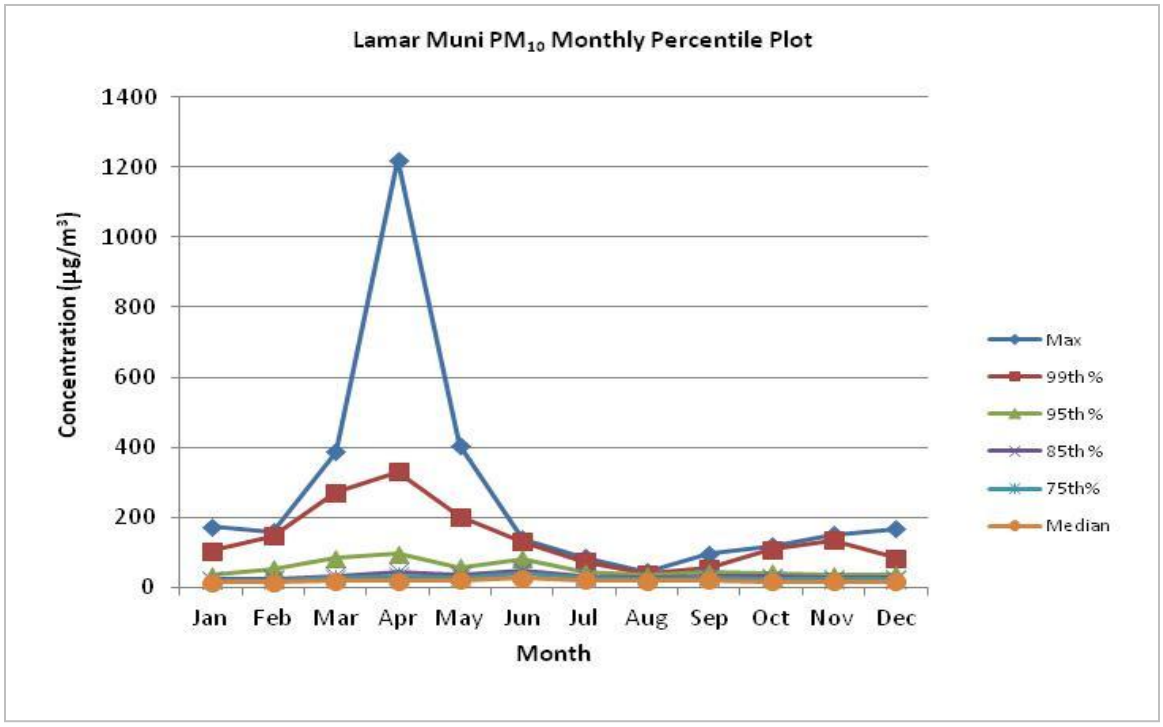


Figure 121: Monthly PM_{10} Percentile Plot

It is certainly the case that monthly median values are indicative of typical, day to day concentrations. Additionally, there is a range of samples that are a product of normal variation subject to typical, day to day local effects. This range may be restricted to percentile values that are well correlated with the median. For the data set of concern (Lamar Municipal) a conservative estimate of the percentile value that is reflective of typical, day to day variation is the 75th percentile value. Nearly all of the variation in the monthly 75th percentile value of this data set can be explained by the variation in monthly medians; for this site the correlation between the median and monthly 75th percentile value was an $r^2 = 0.9$ (Lamar Municipal). A reasonable estimate of the contribution to the event from local sources for this data set may be the monthly 85th percentile value; for this site the correlation between the median and the monthly 85th percentile value is an $r^2 = 0.80$ (Lamar Municipal). If this percentile value is taken as an estimate of event PM_{10} due to local variation then the portion of the sample concentration remaining from this monthly percentile value would be the sample contribution due to the event.

Table 36 identifies various percentile values that are representative of the maximum contribution due to local sources for the Lamar site from all March data. In Table 36 the range estimate in the 'Est. Conc. Above Typical' column is derived using the difference between the actual sample value and the 85th percentile as the minimum (reasonable) event contribution estimate and the difference between the actual sample value and the 75th percentile as the maximum (conservative) event contribution estimate. This column represents the range of estimated contribution to the March 30, 2014 sample at the site listed in the table due to the high wind event.

Table 36: Estimated Maximum Event PM_{10} Contribution, March 30, 2014

Site	Event Day Concentration ($\mu g/m^3$)	March Median ($\mu g/m^3$)	March Average ($\mu g/m^3$)	March 75th % ($\mu g/m^3$)	March 85th % ($\mu g/m^3$)	Est. Conc. Above Typical ($\mu g/m^3$)
Lamar Municipal	**264**	19	32.7	28	33	**231 – 236**

Clearly, there would have been no exceedance but for the additional contribution to the PM_{10} sample provided by the event.

3.6 March 31, 2014 Monitoring Data and Statistics

On March 31, 2014, a powerful spring storm across Southern Colorado, strong and gusty post-frontal winds transported blowing dust into Lamar. The strong winds affected PM_{10} samples at the site in Lamar, Colorado. During this event a sample in excess of 150 $\mu g/m^3$ was recorded at Lamar Municipal Building 08-099-0002 (Lamar Muni, 223 $\mu g/m^3$).

3.6.1 Historical Fluctuations of PM_{10} Concentrations in Lamar

This evaluation of PM_{10} monitoring data for sites affected by the March 31, 2014, event was made using valid samples from PM_{10} samplers in Lamar from 2009 through August of 2014; APCD has been monitoring PM_{10} concentrations in Lamar since 1985. The overall data summary for the affected site is presented in Table 37, with all data values being presented in $\mu g/m^3$:

Table 37: March 31, 2014, Event Data Summary

	Lamar Municipal
3/31/2014	**223**
Mean	25.5
Median	19
Mode	14
St. Dev	38.5
Var.	1487.9
Minimum	1
Maximum	1220
Percentile	99.5%
Count	1997

The PM_{10} sample on March 31, 2014, at Lamar Municipal of 223 $\mu g/m^3$ exceeds the 99^{th} percentile value for all evaluation criteria and is the 10^{th} largest sample of the dataset. The nine samples greater than the event sample are associated with high wind events. There are 1,997 samples in this dataset. The sample of March 31, 2014 clearly exceeds the typical samples for this site.

(Figure 122 and Figure 123 graphically characterize the Lamar Municipal PM_{10} data. The first, Figure 122, is a simple time series; every sample in this dataset (2009 – 2014) greater than 150 µg/m^3 is identified. Note the overwhelming number of samples occupying the lower end of the graph; an interested reader can count the number of samples greater than 100 µg/m^3. Of the 1,997 samples in this data set less than 1% are greater than 100 µg/m^3.

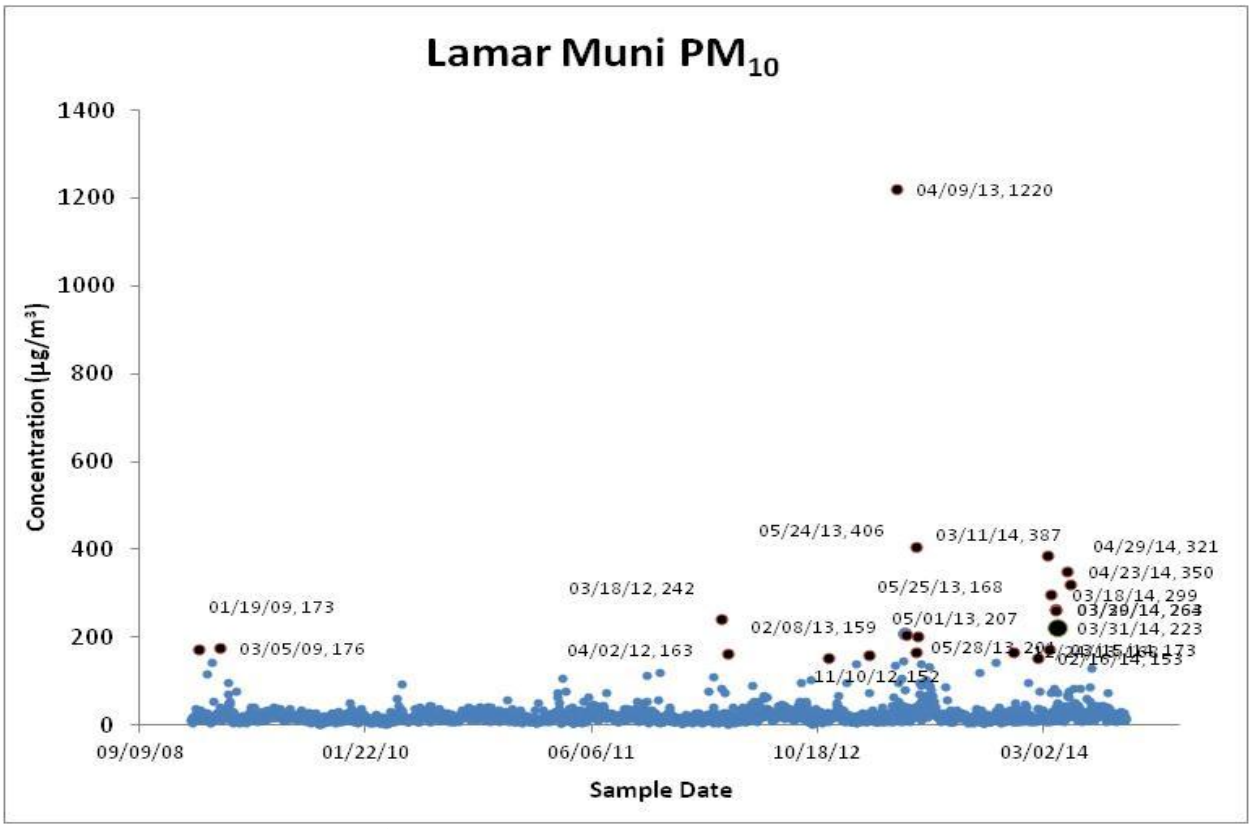


Figure 122: Lamar Municipal PM_{10} Time Series, 2009-2014

The monthly box-whisker plot in Figure 123 highlights the consistency of the majority of data from month to month. Note the greater variability (wider inner-quartile range) and greater range of the data through the winter and early spring months that's accompanied by typically greater monthly maxima. Recall, this time period experiences a greater number of days with meteorological conditions similar to those experienced on March 31, 2014. Although these high values affect the variability and central tendency (average) of the dataset they are not representative of what is typical at the site.

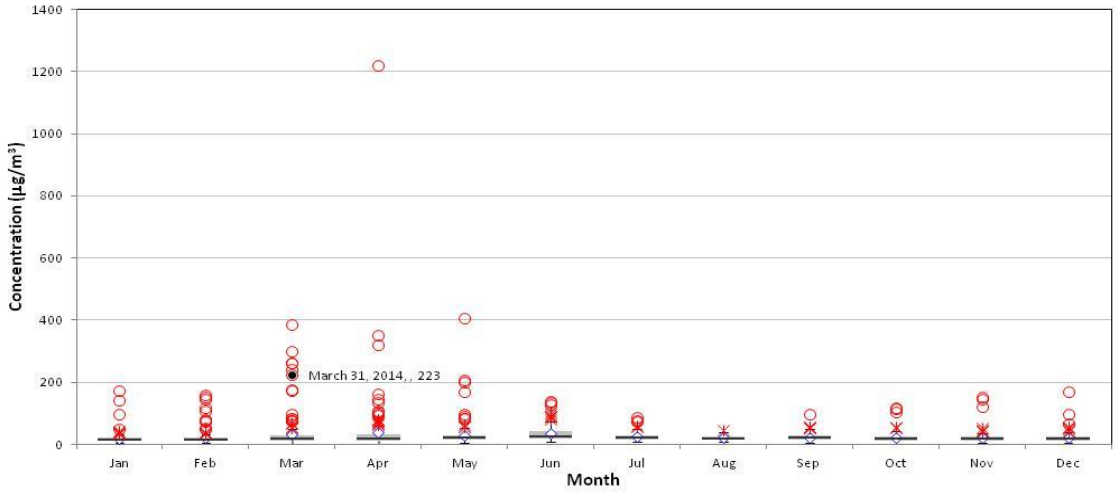


Figure 123: Lamar Municipal PM_{10} Box-Whisker Plot, 2009-2014

Note the degree to which the data in the months of fall through spring, beginning in October and extending through May, are skewed. The March mean (32.7 µg/m^3) is greater than the March median value (19 µg/m^3); the March mean is greater than nearly 83% of all samples in any March. The skew in the data is due to the presence of a handful of extreme values and can create the flawed perception that those months experiencing these high wind events are somehow 'dirtier' than other months of the year. Figure 123 suggests that typical, day to day PM_{10} concentrations exposures for the months of June and September are highest among all months. The sample of March 31, 2014, clearly exceeds the typical data at this site.

3.6.2 Wind Speed Correlations

Wind speeds in southeast Colorado increased early morning of March 31, 2014 and stayed elevated through late evening, gusting to speeds in excess of 30 mph with sustained hourly averages in excess of 20 mph. The two charts in Figure 124 display wind speed (mph) as a function of date from meteorological sites within the affected area for a number of days before and after the event.

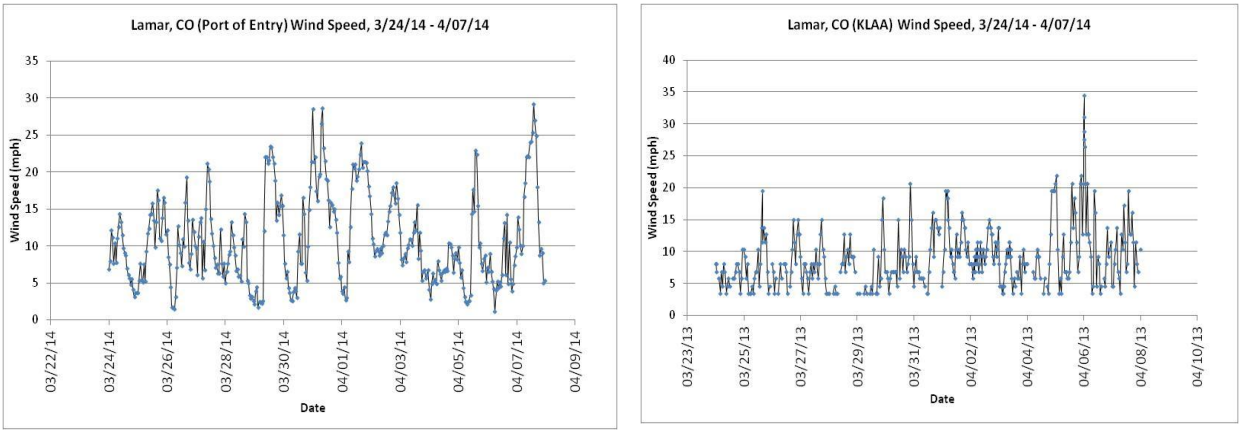


Figure 124: Wind Speed (mph), Lamar, 3/24/2014 – 4/07/2014

Figure 125 plots PM_{10} concentrations from the Lamar Municipal site for the period for seven days prior to and following the sample of March 31, 2014.

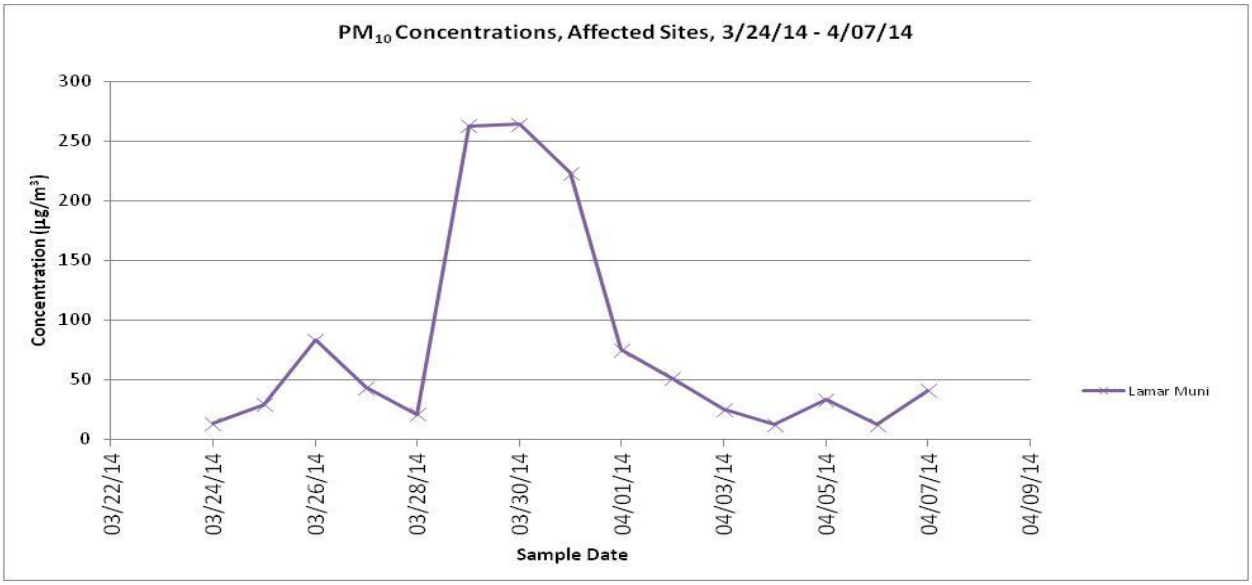


Figure 125: PM_{10} Concentrations, Lamar Municipal, 3/11/2014 – 3/25/2014

Figure 125 mimics the plots for wind speed, suggesting an association between the regional high winds and PM_{10} concentrations at the affected sites. Although the samples were affected to differing degrees by the event (possibly reflecting the variation in contribution from local sources) the elevated concentrations are clearly associated with the elevated wind speeds. The relationship between the two data sets would suggest that the regional high winds had an effect on PM_{10} samples in Lamar on March 31, 2014.

3.6.3 Percentiles

The monthly percentile plot in Figure 126 demonstrate a high degree of association between monthly median values and relatively high monthly percentile values, e.g. the Pearson's r value between the monthly 90^{th} percentile value at Lamar Municipal and the monthly median is 0.65. As the percentile value decreases (i.e. 85%, 75%, etc) the correlation between those values and the monthly median values increases sharply.

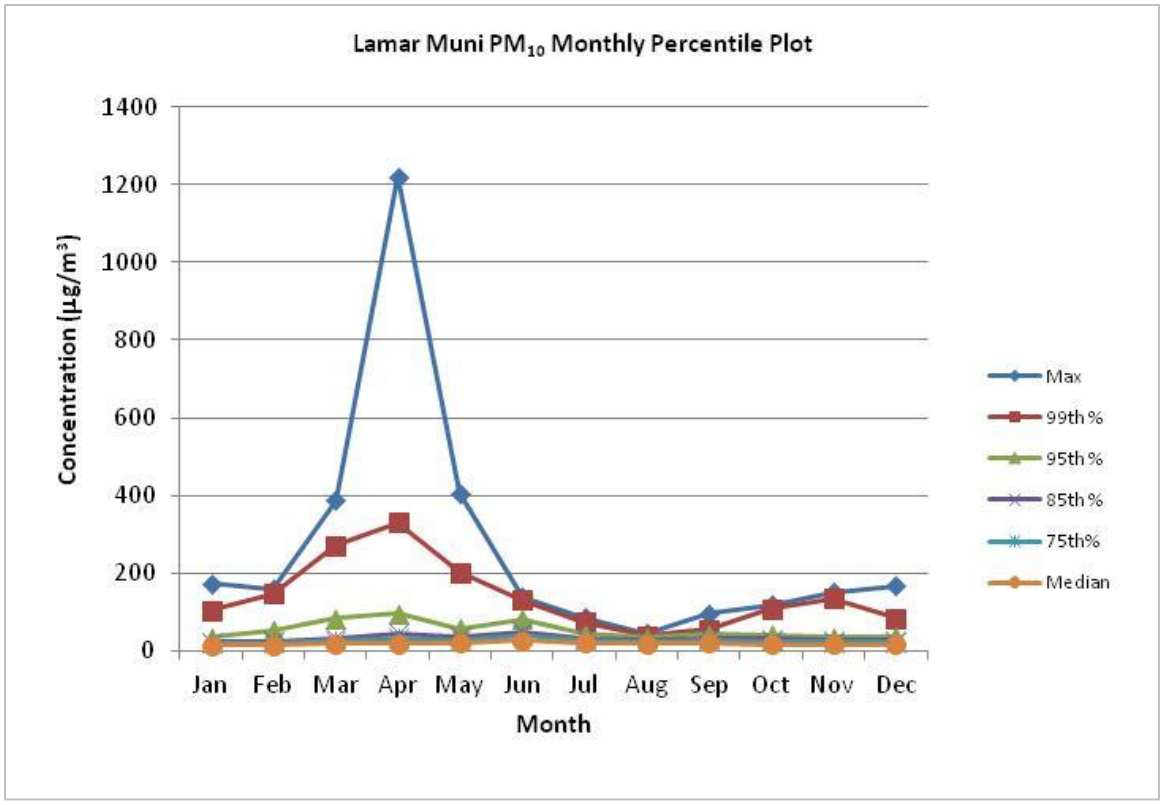


Figure 126: Monthly PM_{10} Percentile Plot

It is certainly the case that monthly median values are indicative of typical, day to day concentrations. Additionally, there is a range of samples that are a product of normal variation subject to typical, day to day local effects. This range may be restricted to percentile values that are well correlated with the median. For the data set of concern (Lamar Municipal) a conservative estimate of the percentile value that is reflective of typical, day to day variation is the 75th percentile value. Nearly all of the variation in the monthly 75th percentile values of this data set can be explained by the variation in monthly medians; for Lamar Municipal the correlation between the median and monthly 75th percentile values is r^2 = 0.9. A reasonable estimate of the contribution to the event from local sources for this data set may be the monthly 85th percentile values the correlation between the median and the monthly 85th percentile values is r^2 = 0.80. If these percentile values are taken as an estimate of event PM_{10} due to local variation then the portion of the sample concentration remaining from these monthly percentile values would be the sample contribution due to the event.

Table 38 identifies various percentile values that are representative of the maximum contribution due to local sources for Lamar Municipal from all March data (2009 – 2014). In Table 38 the range estimate in the 'Est. Conc. Above Typical' column is derived using the difference between the actual sample value and the 85th percentile as the minimum (reasonable) event contribution estimate and the difference between the actual sample value and the 75th percentile as the maximum (conservative) event contribution estimate. This column represents the range of estimated contribution to the March 31, 2014 sample at Lamar Municipal due to the high wind event.

Table 38: Estimated Maximum Event PM_{10} Contribution, March 31, 2014

Site	Event Day Concentration ($\mu g/m^3$)	March Median ($\mu g/m^3$)	March Average ($\mu g/m^3$)	March 75th % ($\mu g/m^3$)	March 85th % ($\mu g/m^3$)	Est. Conc. Above Typical ($\mu g/m^3$)
Lamar Municipal	223	19	32.7	28	33	**190 – 195**

Clearly, there would have been no exceedance but for the additional contribution to the PM_{10} sample provided by the event.

3.7 April 23, 2014 Monitoring Data and Statistics

On April 23, 2014, a powerful spring storm system moves across Southern Colorado. Strong and gusty northerly winds blowing over dry soil transported blowing dust into Lamar. The intense surface winds in the wake of the passing front affected PM_{10} samples at the site in Lamar, Colorado. During this event a sample in excess of 150 $\mu g/m^3$ was recorded at Lamar Municipal Building 08-099-0002 (Lamar Muni, 350 $\mu g/m^3$).

3.7.1 Historical Fluctuations of PM_{10} Concentrations in Lamar

This evaluation of PM_{10} monitoring data for sites affected by the April 23, 2014, event was made using valid samples from PM_{10} samplers in Lamar from 2009 through August of 2014; APCD has been monitoring PM_{10} concentrations in Lamar since 1985. The overall data summary for the affected site is presented in Table 39, with all data values being presented in $\mu g/m^3$:

Table 39: April 23, 2014, Event Data Summary

	Lamar Municipal
4/23/2014	**350**
Mean	25.5
Median	19
Mode	14
St. Dev	38.5
Var.	1487.9
Minimum	1
Maximum	1220
Percentile	99.5%
Count	1997

The PM_{10} sample on April 23, 2014, at Lamar Municipal of 350 $\mu g/m^3$ exceeds the 99^{th} percentile value for all evaluation criteria and is the 4^{th} largest sample of the dataset. The three samples greater than the event sample are associated with high wind events. There are 1,997 samples in this dataset. The sample of April 23, 2014 clearly exceeds the typical samples for this site.

Figure 127 and Figure 128 graphically characterize the Lamar Municipal PM_{10} data. The first, Figure 127, is a simple time series; every sample in this dataset (2009 – 2014) greater than 150 µg/m^3 is identified. Note the overwhelming number of samples occupying the lower end of the graph; an interested reader can count the number of samples greater than 100 µg/m^3. Of the 1,997 samples in this data set less than 1% are greater than 100 µg/m^3.

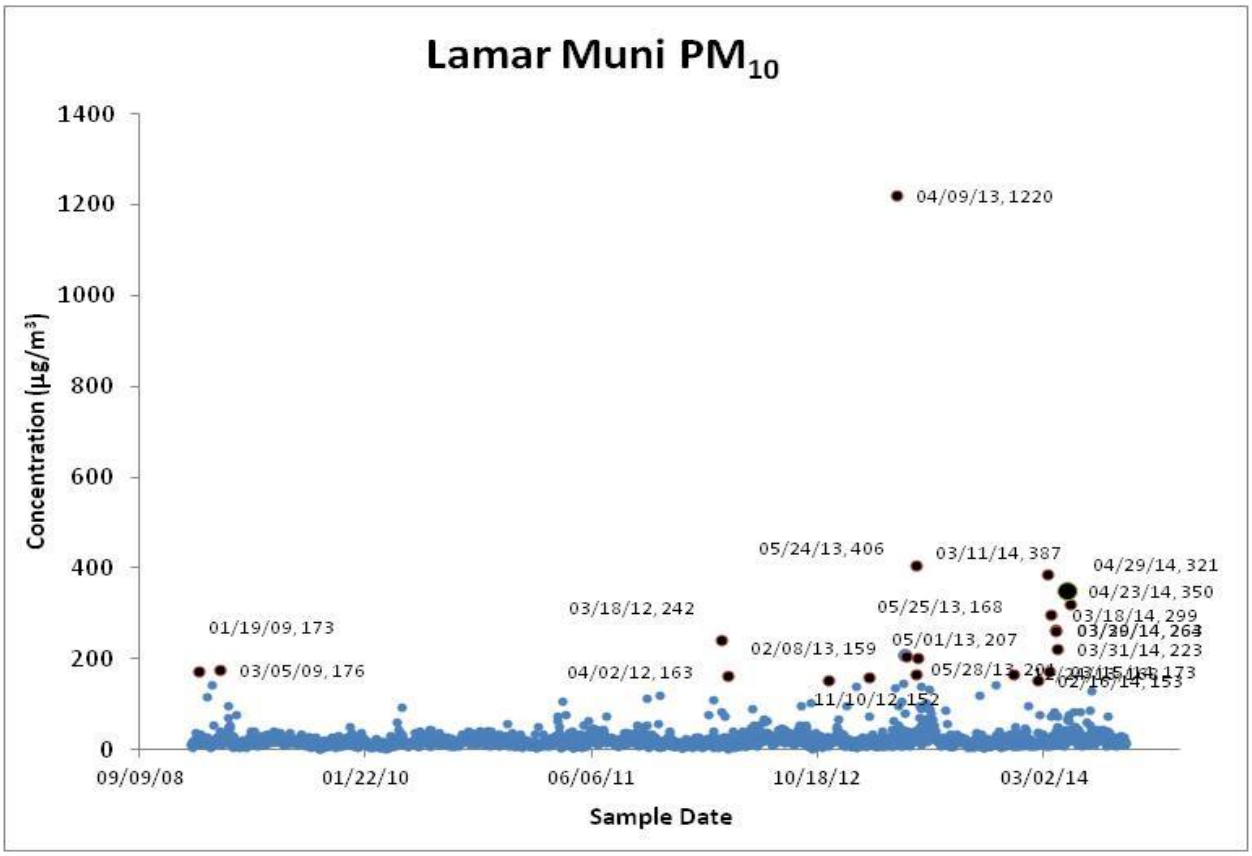


Figure 127: Lamar Municipal PM_{10} Time Series, 2009-2014

The monthly box-whisker plot in Figure 128 highlights the consistency of the majority of data from month to month. Note the greater variability (wider inner-quartile range) and greater range of the data through the winter and early spring months that's accompanied by typically greater monthly maxima. Recall, this time period experiences a greater number of days with meteorological conditions similar to those experienced on April 23, 2014. Although these high values affect the variability and central tendency (average) of the dataset they are not representative of what is typical at the site.

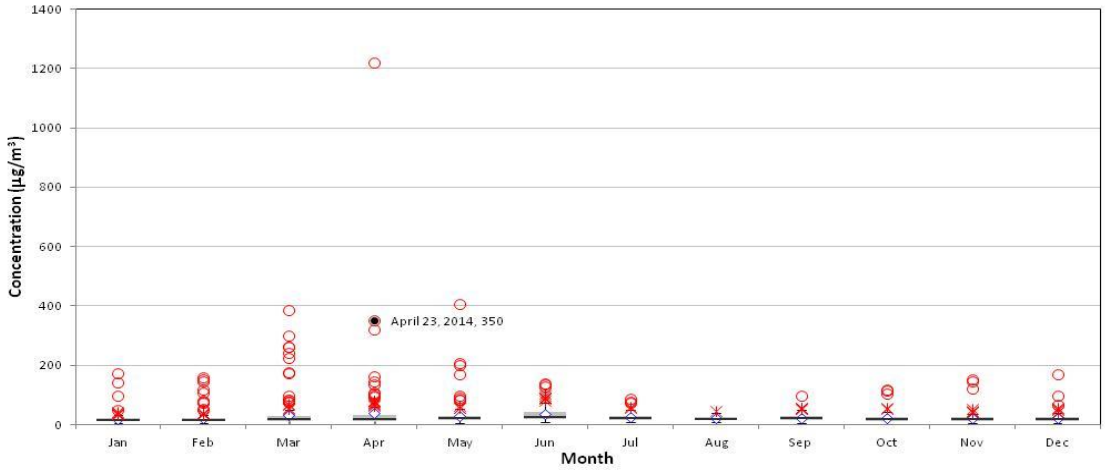


Figure 128: Lamar Municipal PM_{10} Box-Whisker Plot, 2009-2014

Note the degree to which the data in the months of fall through spring, beginning in October and extending through May, are skewed. The April mean (37.7 µg/m^3) is greater than the April median value (19 µg/m^3); the April mean is greater than nearly 95% of all samples in any April. The skew in the data is due to the presence of a handful of extreme values and can create the flawed perception that those months experiencing these high wind events are somehow 'dirtier' than other months of the year. Figure 128 suggests that typical, day to day PM_{10} concentrations exposures for the months of June and September are highest among all months. The sample of April 23, 2014, clearly exceeds the typical data at this site.

3.7.2 Wind Speed Correlations

Wind speeds in southeast Colorado increased early morning of April 23, 2014 and stayed elevated through late evening, gusting to speeds in excess of 30 mph with sustained hourly averages in excess of 20 mph. The two charts in Figure 129 display wind speed (mph) as a function of date from meteorological sites within the affected area for a number of days before and after the event.

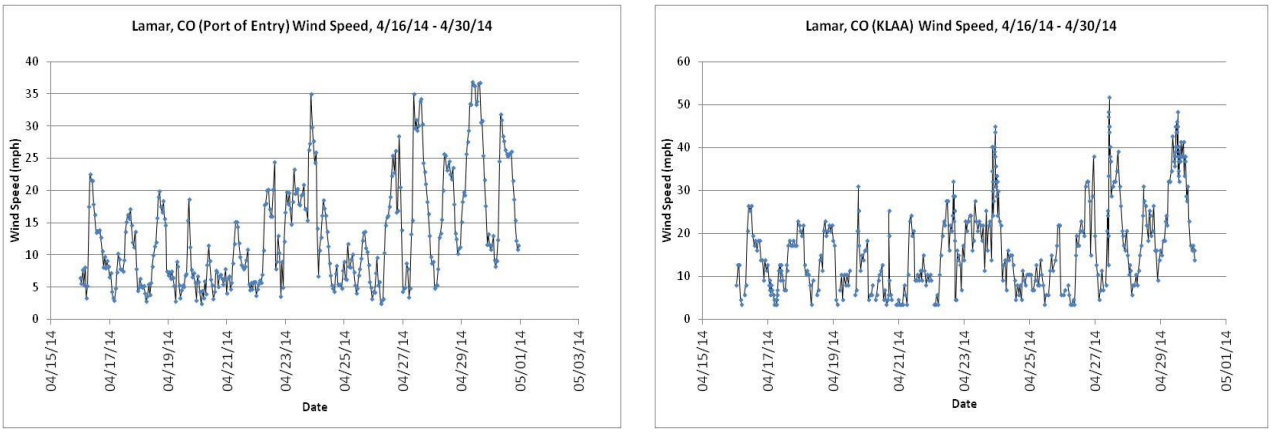


Figure 129: Wind Speed (mph), Lamar, 4/16/2014 – 4/30/2014

Figure 130 plots PM_{10} concentrations from the Lamar Municipal site for the period for seven days prior to and following the sample of April 23, 2014.

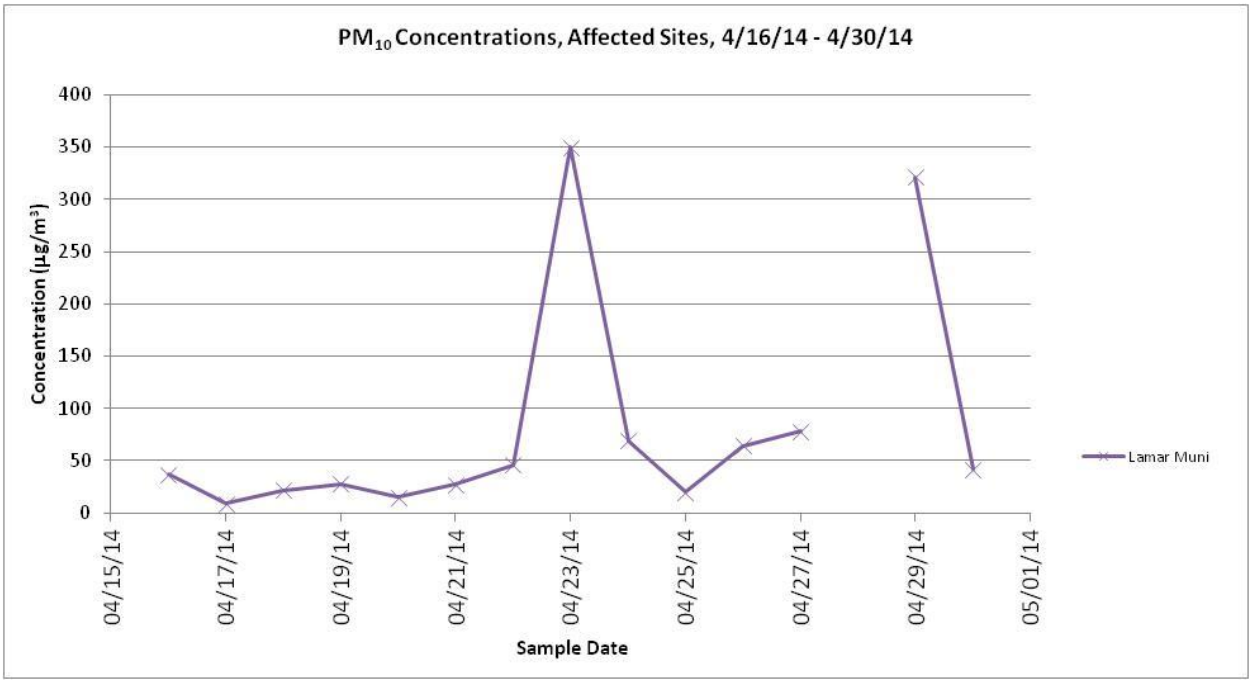


Figure 130: PM_{10} Concentrations, Lamar Municipal, 4/16/2014 – 4/30/2014

Figure 130 mimics the plots for wind speed, suggesting an association between the regional high winds and PM_{10} concentrations at the affected site. Although the event sample was affected to differing degrees by the event (possibly reflecting the variation in contribution from local sources) the elevated concentration is clearly associated with the elevated wind speeds. The relationship between the two data sets would suggest that the regional high winds had an effect on PM_{10} samples in Lamar on March 31, 2014.

3.7.3 Percentiles

The monthly percentile plot in Figure 131 demonstrate a high degree of association between monthly median values and relatively high monthly percentile values, e.g. the Pearson's r value between the monthly 90^{th} percentile value at Lamar Municipal and the monthly median is 0.65. As the percentile value decreases (i.e. 85%, 75%, etc) the correlation between those values and the monthly median values increases sharply.

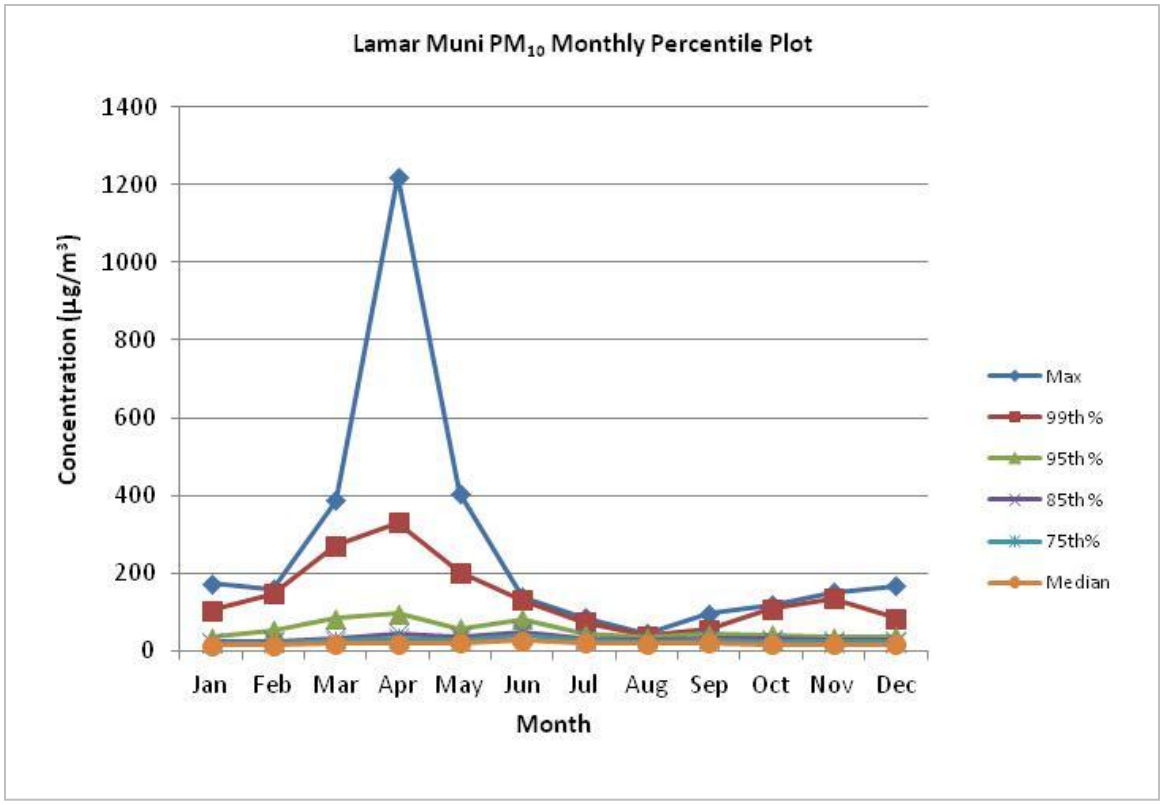


Figure 131: Monthly PM_{10} Percentile Plot

It is certainly the case that monthly median values are indicative of typical, day to day concentrations. Additionally, there is a range of samples that are a product of normal variation subject to typical, day to day local effects. This range may be restricted to percentile values that are well correlated with the median. For the data set of concern (Lamar Municipal) a conservative estimate of the percentile value that is reflective of typical, day to day variation is the 75th percentile value. Nearly all of the variation in the monthly 75th percentile values of this data set can be explained by the variation in monthly medians; for Lamar Municipal the correlation between the median and monthly 75th percentile values is r^2 = 0.9. A reasonable estimate of the contribution to the event from local sources for this data set may be the monthly 85th percentile values the correlation between the median and the monthly 85th percentile values is r^2 = 0.80. If these percentile values are taken as an estimate of event PM_{10} due to local variation then the portion of the sample concentration remaining from these monthly percentile values would be the sample contribution due to the event.

Table 40 identifies various percentile values that are representative of the maximum contribution due to local sources for the site from all April data (2009 – 2014). In Table 40 the range estimate in the 'Est. Conc. Above Typical' column is derived using the difference between the actual sample value and the 85th percentile as the minimum (reasonable) event contribution estimate and the difference between the actual sample value and the 75th percentile as the maximum (conservative) event contribution estimate. This column represents the range of estimated contribution to the April 23, 2014 sample at Lamar Municipal due to the high wind event.

Table 40: Estimated Maximum Event PM_{10} Contribution, April 23, 2014

Site	Event Day Concentration ($\mu g/m^3$)	April Median ($\mu g/m^3$)	April Average ($\mu g/m^3$)	April 75th % ($\mu g/m^3$)	April 85th % ($\mu g/m^3$)	Est. Conc. Above Typical ($\mu g/m^3$)
Lamar Municipal	**350**	19	37.7	32.8	45	**305 – 317**

Clearly, there would have been no exceedance but for the additional contribution to the PM_{10} sample provided by the event.

3.8 April 29, 2014 Monitoring Data and Statistics

On April 29, 2014, a powerful spring storm system moved caused intense surface winds across southeast Colorado. The strong winds moving over dry soil affected the PM_{10} sample at the site in Lamar, Colorado. During this event a sample in excess of 150 $\mu g/m^3$ was recorded at Lamar Municipal Building 08-099-0002 (Lamar Muni, 321 $\mu g/m^3$).

3.8.1 Historical Fluctuations of PM_{10} Concentrations in Lamar

This evaluation of PM_{10} monitoring data for sites affected by the April 29, 2014, event was made using valid samples from PM_{10} samplers in Lamar from 2009 through August of 2014; APCD has been monitoring PM_{10} concentrations in Lamar since 1985. The overall data summary for the affected site is presented in Table 41, with all data values being presented in $\mu g/m^3$:

Table 41: April 29, 2014, Event Data Summary

	Lamar Municipal
4/29/2014	**321**
Mean	25.5
Median	19
Mode	14
St. Dev	38.5
Var.	1487.9
Minimum	1
Maximum	1220
Percentile	99.5%
Count	1997

The PM_{10} sample on April 29, 2014, at Lamar Municipal of 321 $\mu g/m^3$ exceeds the 99th percentile value for all evaluation criteria and is the 5th largest sample of the dataset. The four samples greater than the event sample are associated with high wind events. There are 1,997 samples in this dataset. The sample of April 29, 2014 clearly exceeds the typical samples for this site.

Figure 132 and Figure 133 graphically characterize the Lamar Municipal PM_{10} data. The first, Figure 132, is a simple time series; every sample in this dataset (2009 – 2014) greater than 150 µg/m^3 is identified. Note the overwhelming number of samples occupying the lower end of the graph; an interested reader can count the number of samples greater than 100 µg/m^3. Of the 1,997 samples in this data set less than 1% are greater than 100 µg/m^3.

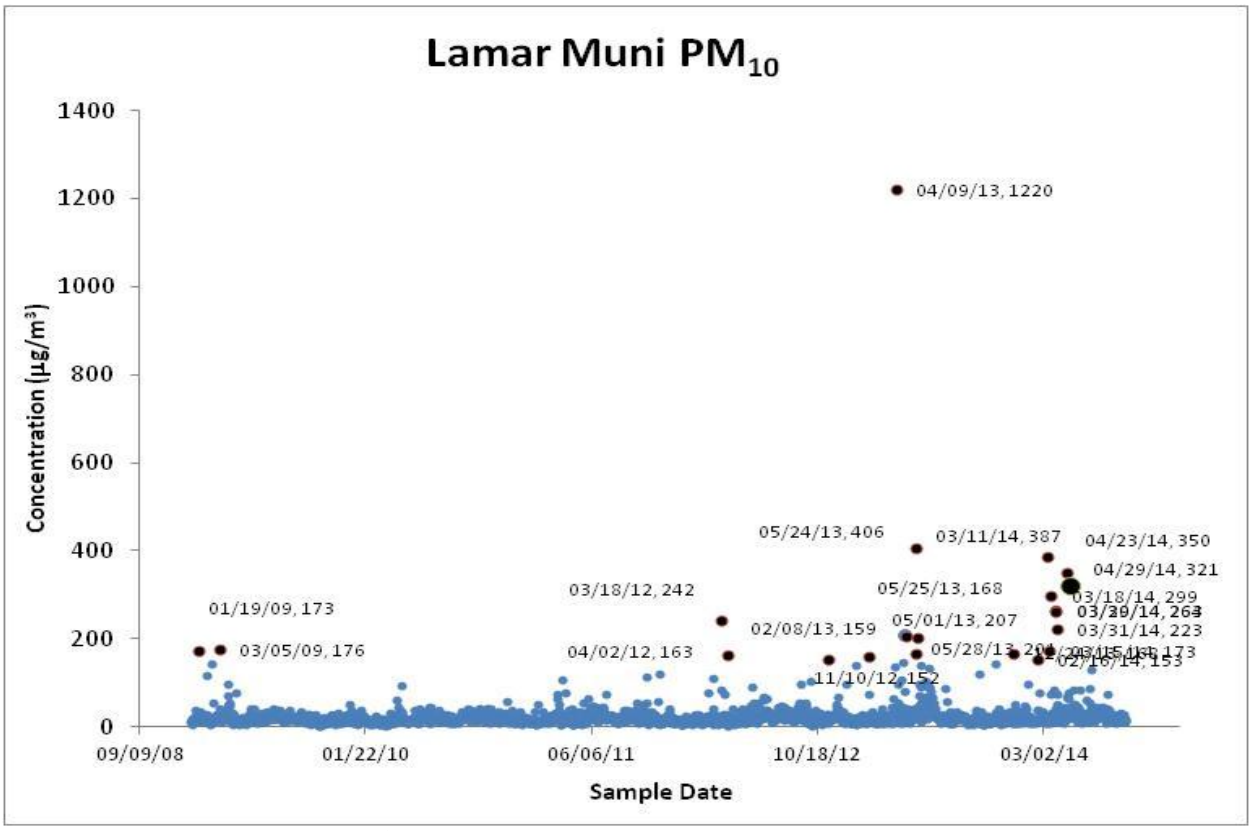


Figure 132: Lamar Municipal PM_{10} Time Series, 2009-2014

The monthly box-whisker plot in Figure 133 highlights the consistency of the majority of data from month to month. Note the greater variability (wider inner-quartile range) and greater range of the data through the winter and early spring months that's accompanied by typically greater monthly maxima. Recall, this time period experiences a greater number of days with meteorological conditions similar to those experienced on April 29, 2014. Although these high values affect the variability and central tendency (average) of the dataset they are not representative of what is typical at the site.

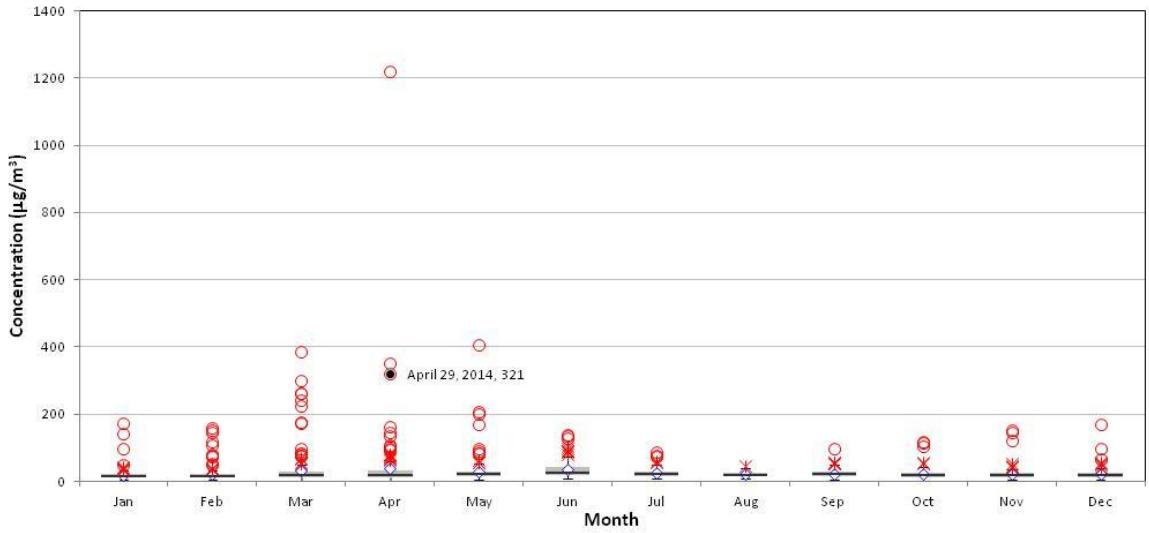


Figure 133: Lamar Municipal PM_{10} Box-Whisker Plot, 2009-2014

Note the degree to which the data in the months of fall through spring, beginning in October and extending through May, are skewed. The April mean (37.7 µg/m^3) is greater than the April median value (19 µg/m^3); the April mean is greater than nearly 95% of all samples in any April. The skew in the data is due to the presence of a handful of extreme values and can create the flawed perception that those months experiencing these high wind events are somehow 'dirtier' than other months of the year. Figure 133 suggests that typical, day to day PM_{10} concentrations exposures for the months of June and September are highest among all months. The sample of April 29, 2014, clearly exceeds the typical data at this site.

3.8.2 Wind Speed Correlations

Wind speeds in southeast Colorado increased mid morning of April 29, 2014 and stayed elevated through late afternoon, gusting to speeds in excess of 40 mph with sustained hourly averages in excess of 25 mph. The two charts in Figure 134 display wind speed (mph) as a function of date from meteorological sites within the affected area for a number of days before and after the event.

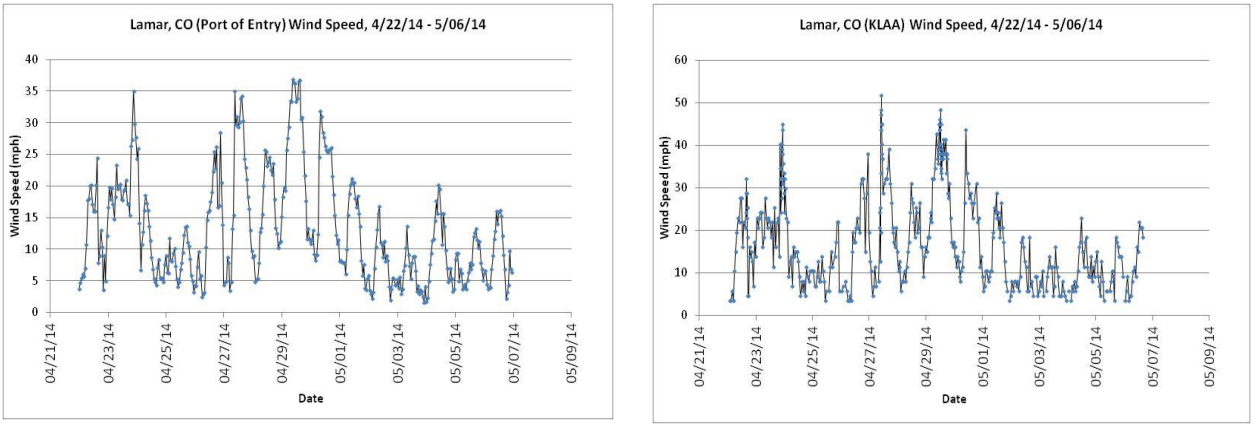


Figure 134: Wind Speed (mph), Lamar, 4/22/2014 – 5/06/2014

Figure 135 plots PM_{10} concentrations from the Lamar Municipal site for the period for seven days prior to and following the sample of April 29, 2014. Missing data are due to one faulty sampler running every four days.

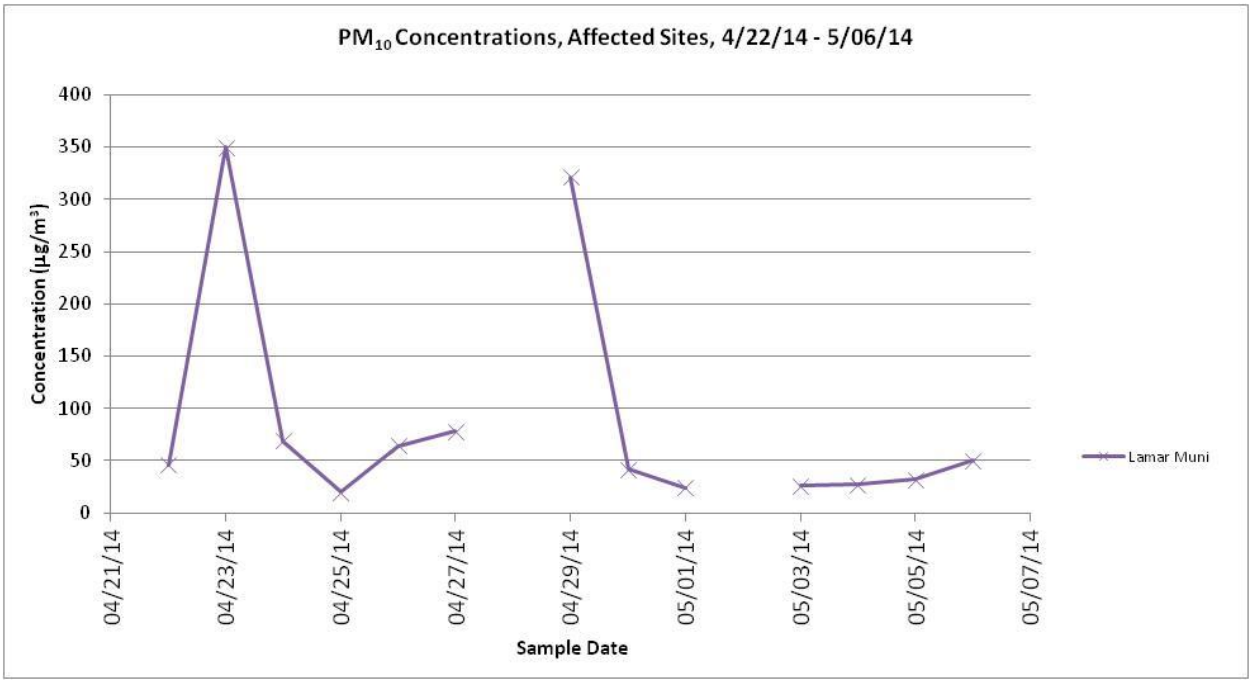


Figure 135: PM_{10} Concentrations, Lamar Municipal, 4/22/2014 – 5/06/2014

Figure 135 mimics the plots for wind speed, suggesting an association between the regional high winds and PM_{10} concentrations at the affected site. Although the event sample was affected to differing degrees by the event (possibly reflecting the variation in contribution from local sources) the elevated concentration is clearly associated with the elevated wind speeds. The relationship between the two data sets would suggest that the regional high winds had an effect on PM_{10} samples in Lamar on April 29, 2014.

3.8.3 Percentiles

The monthly percentile plot in Figure 136 demonstrate a high degree of association between monthly median values and relatively high monthly percentile values, e.g. the Pearson's r value between the monthly 90^{th} percentile value at Lamar Municipal and the monthly median is 0.65. As the percentile value decreases (i.e. 85%, 75%, etc) the correlation between those values and the monthly median values increases sharply.

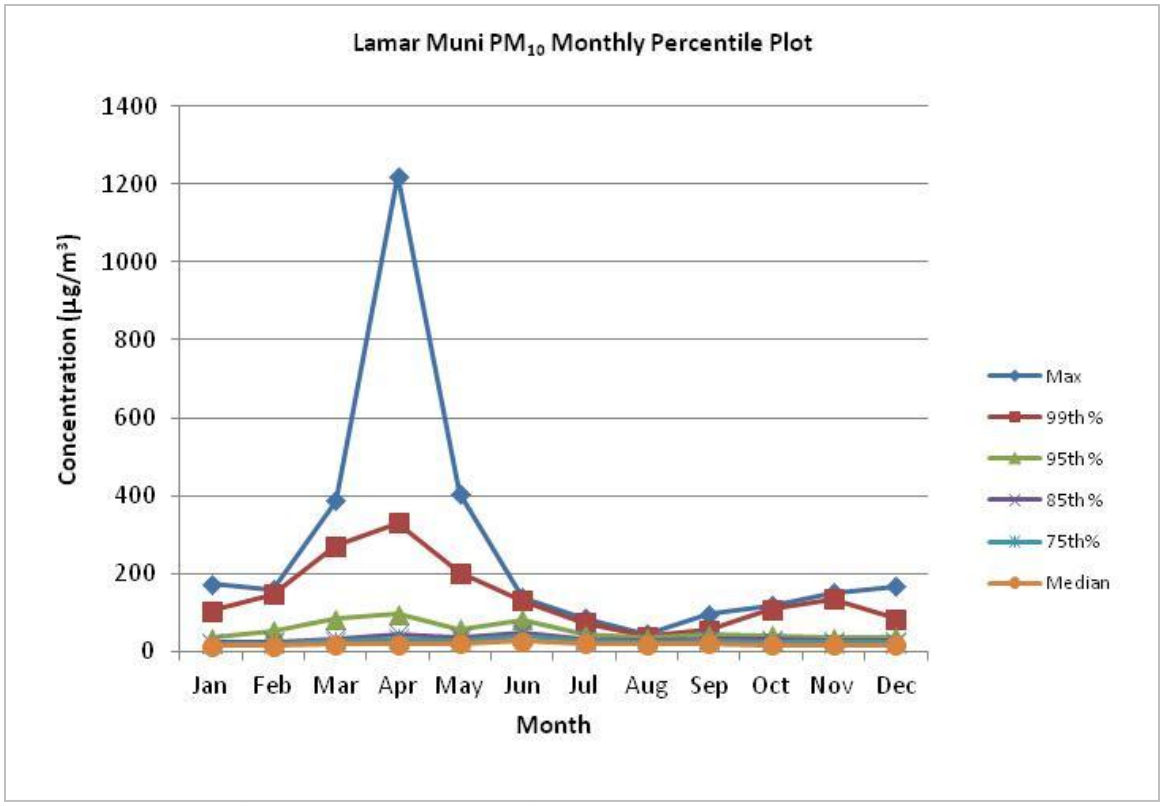


Figure 136: Monthly PM_{10} Percentile Plot

It is certainly the case that monthly median values are indicative of typical, day to day concentrations. Additionally, there is a range of samples that are a product of normal variation subject to typical, day to day local effects. This range may be restricted to percentile values that are well correlated with the median. For the data set of concern (Lamar Municipal) a conservative estimate of the percentile value that is reflective of typical, day to day variation is the 75th percentile value. Nearly all of the variation in the monthly 75th percentile values of this data set can be explained by the variation in monthly medians; for Lamar Municipal these the correlation between the median and monthly 75th percentile values is r^2 = 0.9. A reasonable estimate of the contribution to the event from local sources for this data set may be the monthly 85th percentile values the correlation between the median and the monthly 85th percentile values is r^2 = 0.80. If these percentile values are taken as an estimate of event PM_{10} due to local variation then the portion of the sample concentration remaining from these monthly percentile values would be the sample contribution due to the event.

Table 42 identifies various percentile values that are representative of the maximum contribution due to local sources for the site from all April data (2009 – 2014). In Table 42 the range estimate in the 'Est. Conc. Above Typical' column is derived using the difference between the actual sample value and the 85th percentile as the minimum (reasonable) event contribution estimate and the difference between the actual sample value and the 75th percentile as the maximum (conservative) event contribution estimate. This column represents the range of estimated contribution to the April 29, 2014 sample at Lamar Municipal due to the high wind event.

Table 42: Estimated Maximum Event PM_{10} Contribution, April 29, 2014

Site	Event Day Concentration ($\mu g/m^3$)	April Median ($\mu g/m^3$)	April Average ($\mu g/m^3$)	April 75th % ($\mu g/m^3$)	April 85th % ($\mu g/m^3$)	Est. Conc. Above Typical ($\mu g/m^3$)
Lamar Municipal	**321**	19	37.7	32.8	45	**276 – 288**

Clearly, there would have been no exceedance but for the additional contribution to the PM_{10} sample provided by the event.

3.9 November 10, 2014 Monitoring Data and Statistics

On November 10, 2014, intense surface winds in the wake of a passing cold front affected the PM_{10} sample at the site in Lamar, Colorado. The intense surface winds, predominantly out of a north to northeast direction, moved over dry soils producing significant blowing dust. During this event a sample in excess of 150 $\mu g/m^3$ was recorded at Lamar Municipal Building 08-099-0002 (Lamar Muni, 298 $\mu g/m^3$).

3.9.1 Historical Fluctuations of PM_{10} Concentrations in Lamar

This evaluation of PM_{10} monitoring data for sites affected by the November 10, 2014, event was made using valid samples from PM_{10} samplers in Lamar from 2009 through whatever data was available at the time of writing this document, mid November of 2014; APCD has been monitoring PM_{10} concentrations in Lamar since 1985. The overall data summary for the affected site is presented in Table 43, with all data values being presented in $\mu g/m^3$:

Table 43: November 10, 2014, Event Data Summary

	Lamar Municipal
11/10/2014	**298**
Mean	25.5
Median	19
Mode	14
St. Dev	38.4
Var.	1476.4
Minimum	1
Maximum	1220
Percentile	99.69%
Count	2074

The PM_{10} sample on November 10, 2014, at Lamar Municipal of 298 $\mu g/m^3$ exceeds the 99th percentile value for all evaluation criteria and is the 7th largest sample of the dataset. The six samples greater than the event sample are associated with high wind events. There are 2,074 samples in this dataset. The sample of November 10, 2014 clearly exceeds the typical samples for this site.

Figure 137 and Figure 138 graphically characterize the Lamar Municipal PM_{10} data. The first, Figure 137, is a simple time series; every sample in this dataset (2009 – 2014) greater than 150 µg/m^3 is identified. Note the overwhelming number of samples occupying the lower end of the graph; an interested reader can count the number of samples greater than 100 µg/m^3. Of the 2,074 samples in this data set less than 1% are greater than 100 µg/m^3.

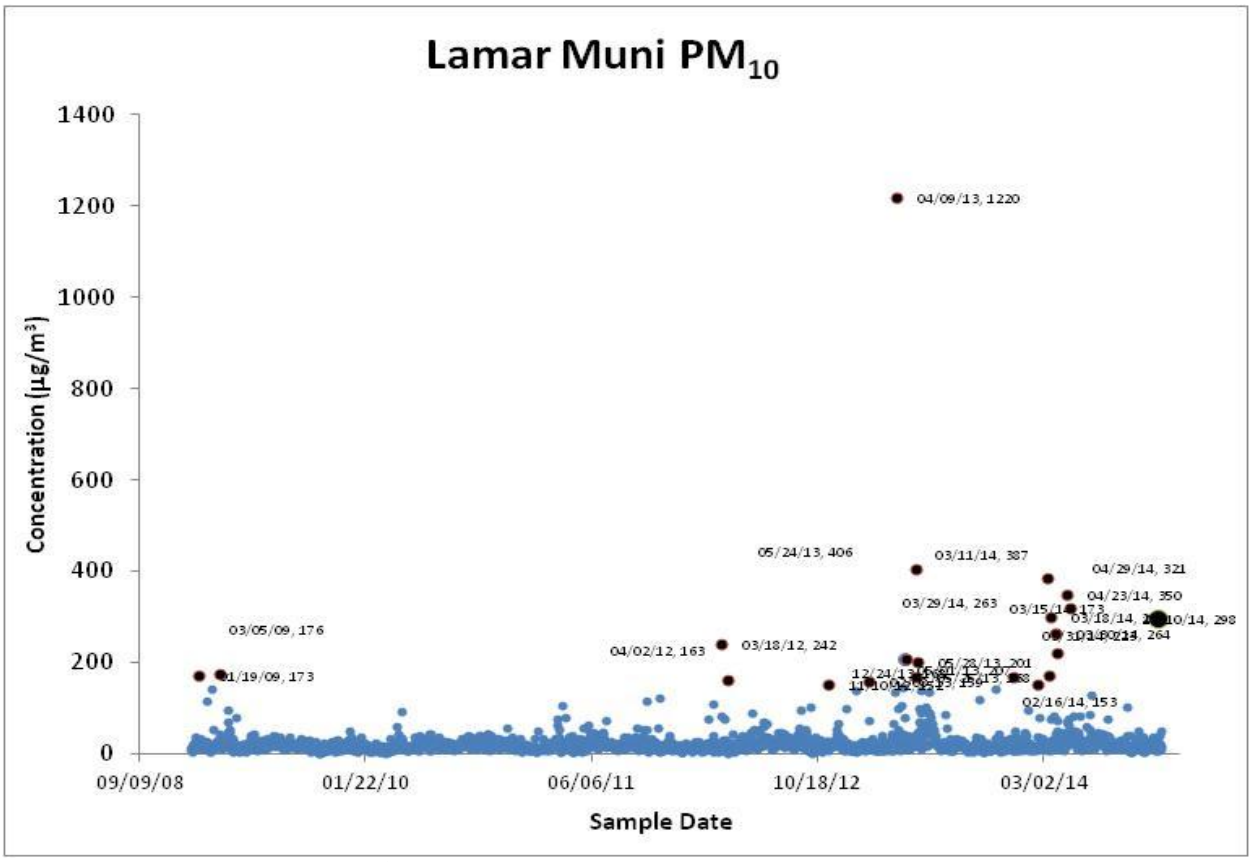


Figure 137: Lamar Municipal PM_{10} Time Series, 2009-2014

The monthly box-whisker plot in Figure 138 highlights the consistency of the majority of data from month to month. Note the greater variability (wider inner-quartile range) and greater range of the data through the winter and early spring months that's accompanied by typically greater monthly maxima. Recall, this time period experiences a greater number of days with meteorological conditions similar to those experienced on November 10, 2014. Although these high values affect the variability and central tendency (average) of the dataset they are not representative of what is typical at the site.

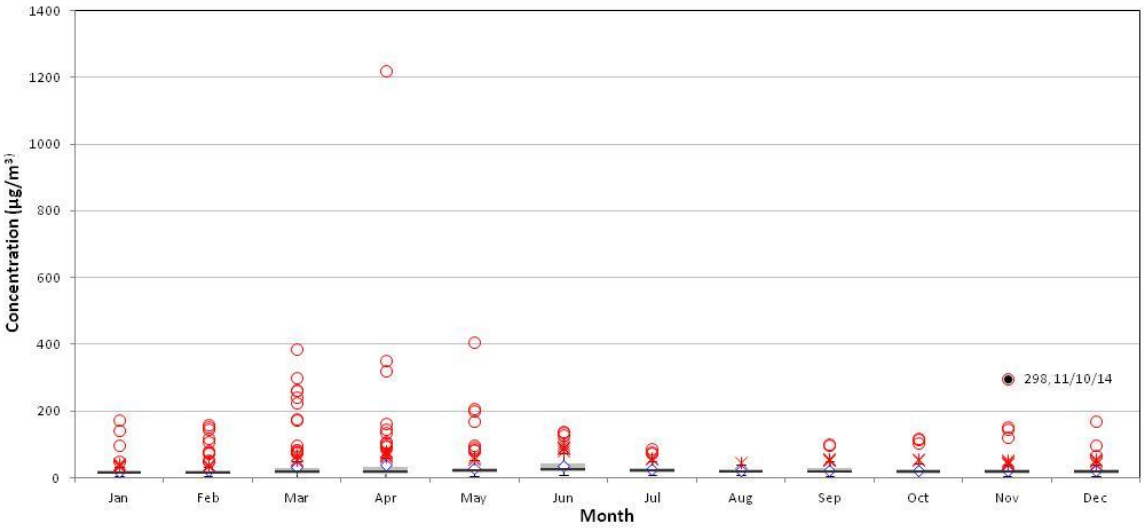


Figure 138: Lamar Municipal PM_{10} Box-Whisker Plot, 2009-2014

Note the degree to which the data in the months of fall through spring, beginning in October and extending through May, are skewed. The November mean (22.9 µg/m^3) is greater than the November median value (17 µg/m^3); the November mean is greater than nearly 71% of all samples in any November. The skew in the data is due to the presence of a handful of extreme values and can create the flawed perception that those months experiencing these high wind events are somehow 'dirtier' than other months of the year. Figure 138 suggests that typical, day to day PM_{10} concentrations exposures for the months of June and September are highest among all months. The sample of November 10, 2014, clearly exceeds the typical data at this site.

3.9.2 Wind Speed Correlations

Wind speeds in southeast Colorado increased early afternoon of November 10, 2014 and stayed elevated through mid evening, gusting to speeds in excess of 50 mph. The two charts in Figure 139 display wind speed (mph) as a function of date from meteorological sites within the affected area for a number of days before and after the event.

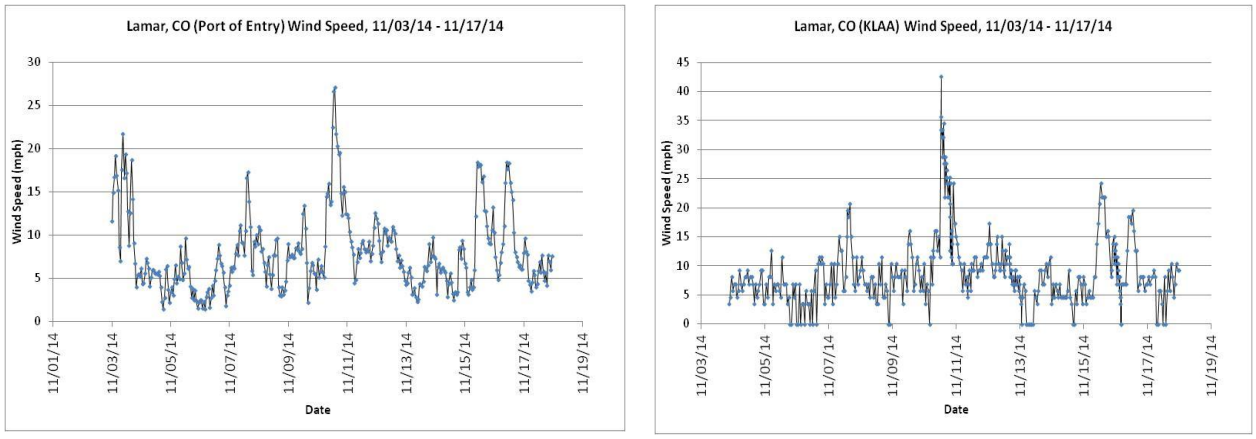


Figure 139: Wind Speed (mph), Lamar, 11/03/2014 – 11/17/2014

Figure 140 plots PM_{10} concentrations from the Lamar Municipal site for the period for seven days prior to and following the sample of November 10, 2014.

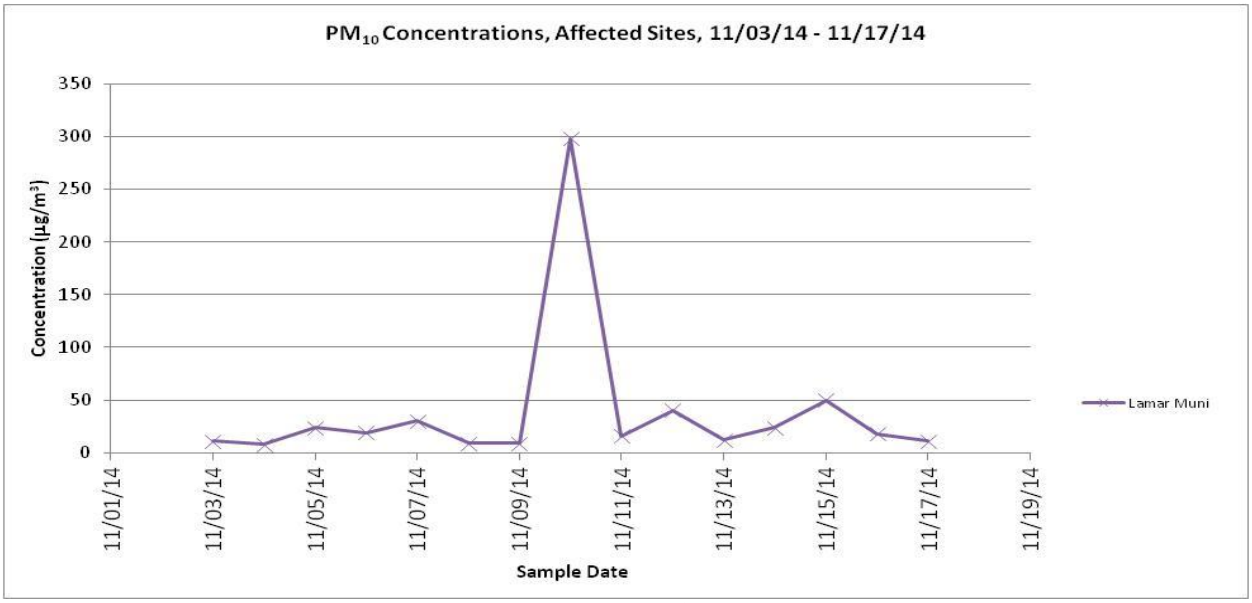


Figure 140: PM_{10} Concentrations, Lamar Municipal, 11/03/2014 – 11/17/2014

Figure 140 generally mimics the plots for wind speed, suggesting an association between the regional high winds and PM_{10} concentrations at the affected sites. Although the sample was affected to differing degrees by the event (possibly reflecting the variation in contribution from local sources) the elevated concentration is clearly associated with the elevated wind speeds. The relationship between the two data sets would suggest that the regional high winds had an effect on PM_{10} samples in Lamar on November 10, 2014.

3.9.3 Percentiles

The monthly percentile plot in Figure 141 demonstrate a high degree of association between monthly median values and relatively high monthly percentile values, e.g. the Pearson's r value between the monthly 90^{th} percentile value at Lamar Municipal and the monthly median is 0.65. As the percentile value decreases (i.e. 85%, 75%, etc) the correlation between those values and the monthly median values increases sharply.

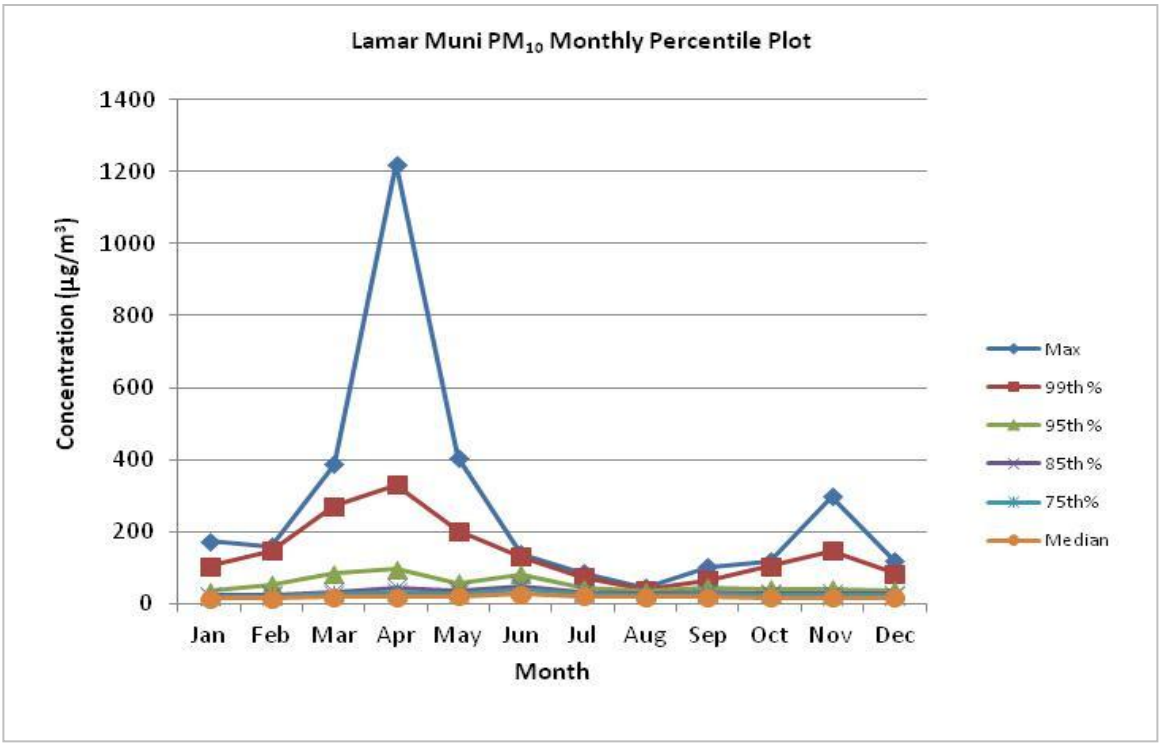


Figure 141: Monthly PM_{10} Percentile Plot

It is certainly the case that monthly median values are indicative of typical, day to day concentrations. Additionally, there is a range of samples that are a product of normal variation subject to typical, day to day local effects. This range may be restricted to percentile values that are well correlated with the median. For the data set of concern (Lamar Municipal) a conservative estimate of the percentile value that is reflective of typical, day to day variation is the 75th percentile value. Nearly all of the variation in the monthly 75th percentile values of this data set can be explained by the variation in monthly medians; for Lamar Municipal the correlation between the median and monthly 75th percentile values is r2 = 0.9. A reasonable estimate of the contribution to the event from local sources for this data set may be the monthly 85th percentile values the correlation between the median and the monthly 85th percentile values is r2 = 0.80. If these percentile values are taken as an estimate of event PM10 due to local variation then the portion of the sample concentration remaining from these monthly percentile values would be the sample contribution due to the event.

Table 44 identifies various percentile values that are representative of the maximum contribution due to local sources for Lamar Municipal from all November data (2009 – 2014). In

Table 44 the range estimate in the 'Est. Conc. Above Typical' column is derived using the difference between the actual sample value and the 85th percentile as the minimum (reasonable) event contribution estimate and the difference between the actual sample value

and the 75th percentile as the maximum (conservative) event contribution estimate. This column represents the range of estimated contribution to the November 10, 2014 sample at Lamar Municipal due to the high wind event.

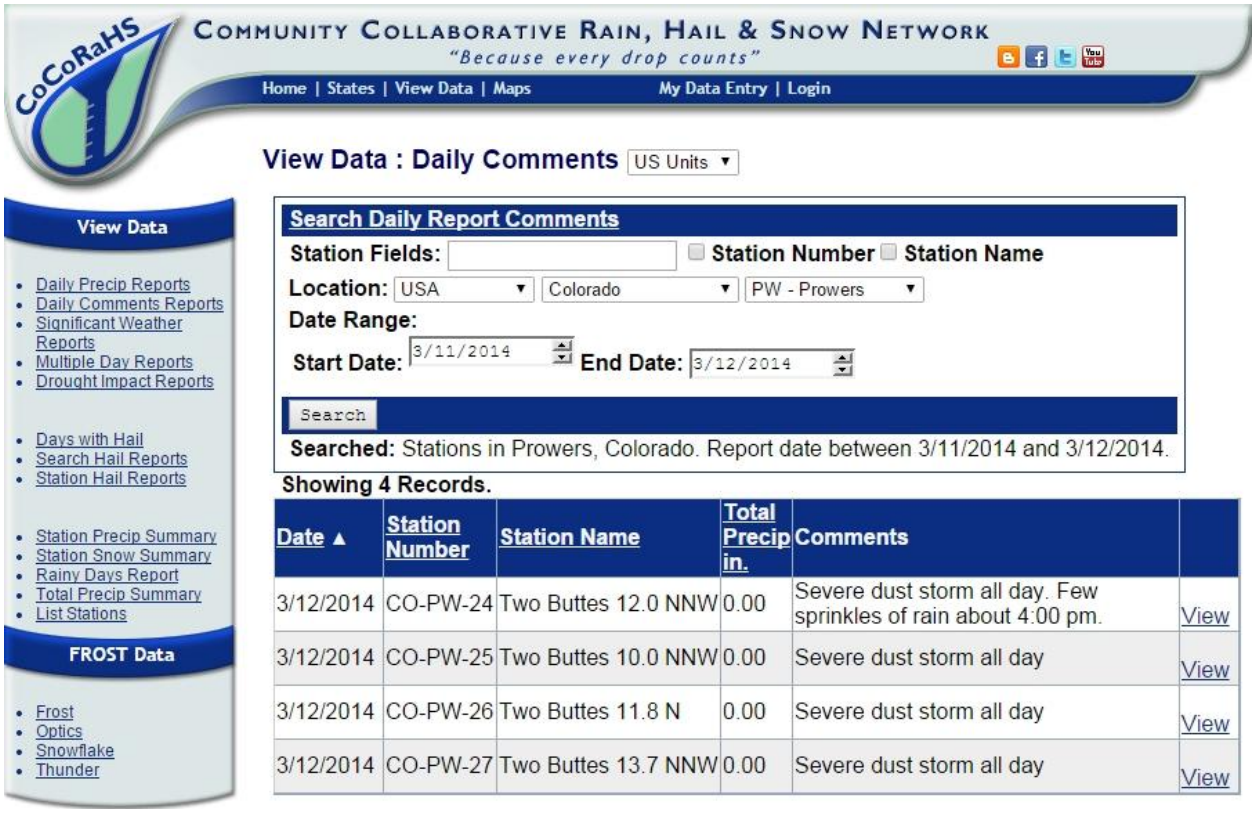
Table 44: Estimated Maximum Event PM_{10} Contribution, November 10, 2014

Site	Event Day Concentration ($\mu g/m^3$)	November Median ($\mu g/m^3$)	November Average ($\mu g/m^3$)	November 75th % ($\mu g/m^3$)	November 85th % ($\mu g/m^3$)	Est. Conc. Above Typical ($\mu g/m^3$)
Lamar Municipal	**298**	17	22.9	24	28.9	**269 - 274**

Clearly, there would have been no exceedance but for the additional contribution to the PM_{10} sample provided by the event.

4.0 News and Credible Evidence

4.1 March 11, 2014 Event



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- Daily Comments Reports
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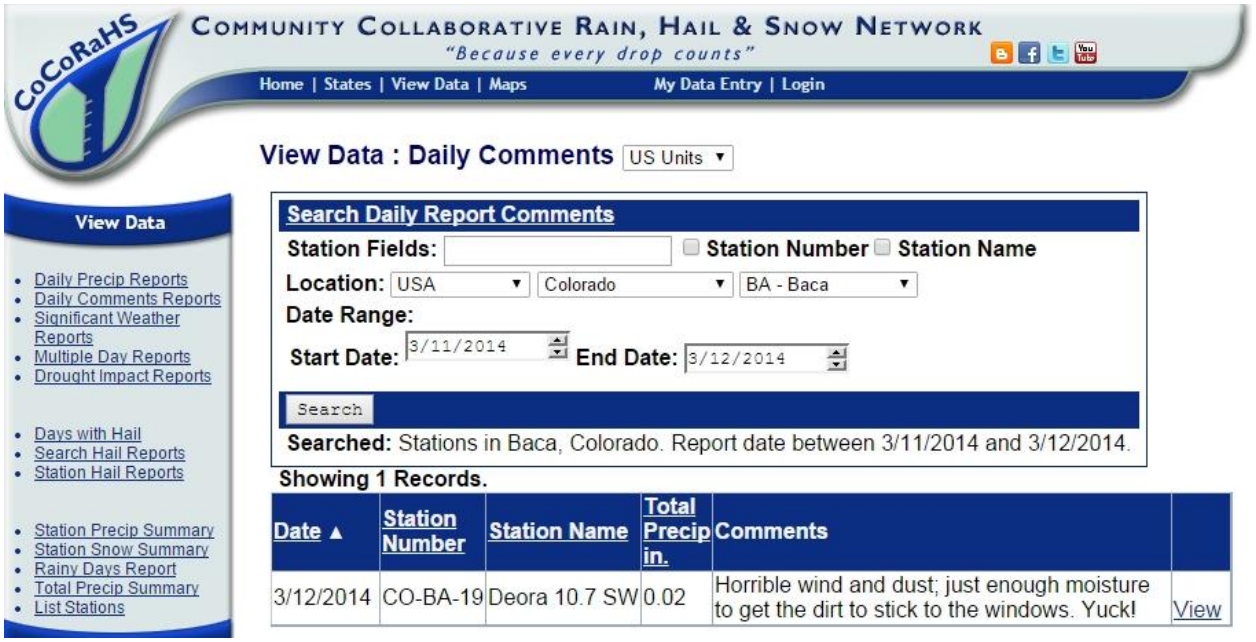
- Multiple Day Reports
- Drought Impact Reports
- Days with Hail
- Search Hail Reports
- Station Hail Reports
- Station Precip Summary
- Station Snow Summary
- Rainy Days Report
- Total Precip Summary
- List Stations

FROST Data
- Frost
- Optics
- Snowflake
- Thunder

Search Daily Report Comments
Station Fields: Station Number Station Name
Location: USA Colorado PW - Prowers
Date Range:
Start Date: 3/11/2014 End Date: 3/12/2014
Search
Searched: Stations in Prowers, Colorado. Report date between 3/11/2014 and 3/12/2014.

Showing 4 Records.

Date ▲	Station Number	Station Name	Total Precip in.	Comments	
3/12/2014	CO-PW-24	Two Buttes 12.0 NNW	0.00	Severe dust storm all day. Few sprinkles of rain about 4:00 pm.	View
3/12/2014	CO-PW-25	Two Buttes 10.0 NNW	0.00	Severe dust storm all day	View
3/12/2014	CO-PW-26	Two Buttes 11.8 N	0.00	Severe dust storm all day	View
3/12/2014	CO-PW-27	Two Buttes 13.7 NNW	0.00	Severe dust storm all day	View



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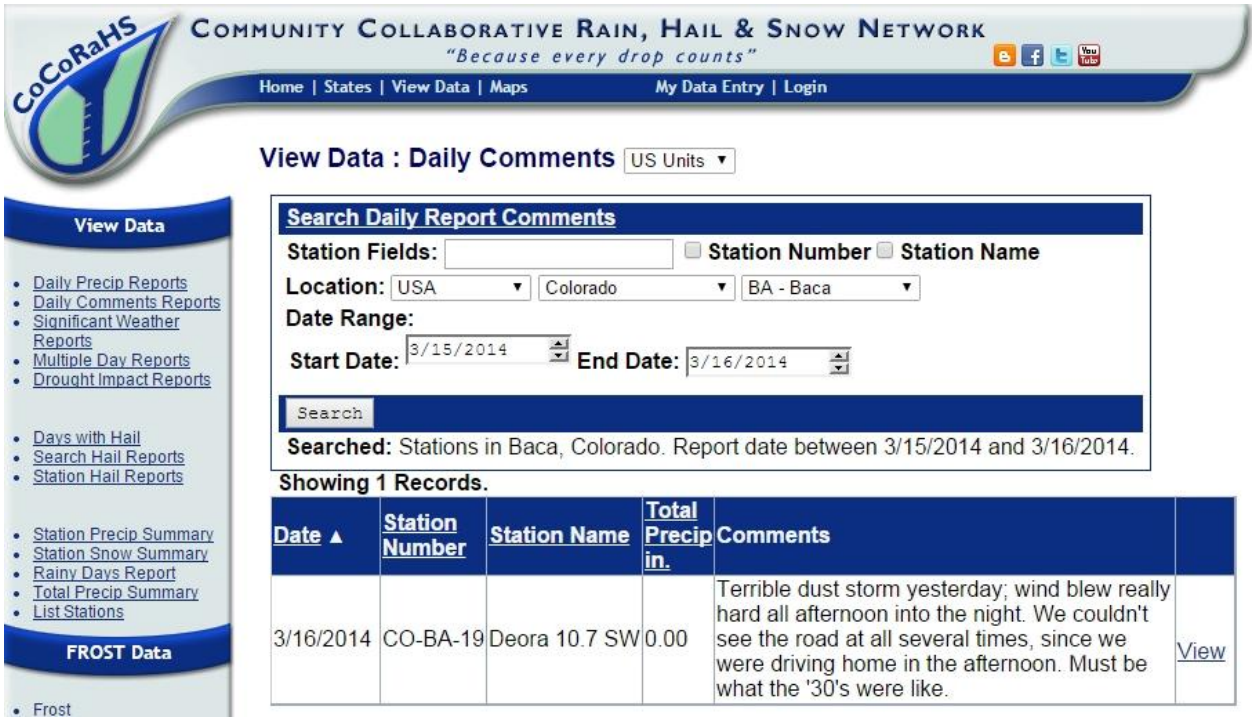
- Rainy Days Report
- Total Precip Summary
- List Stations

Search Daily Report Comments
Station Fields: Station Number Station Name
Location: USA Colorado BA - Baca
Date Range:
Start Date: 3/11/2014 End Date: 3/12/2014
Search
Searched: Stations in Baca, Colorado. Report date between 3/11/2014 and 3/12/2014.

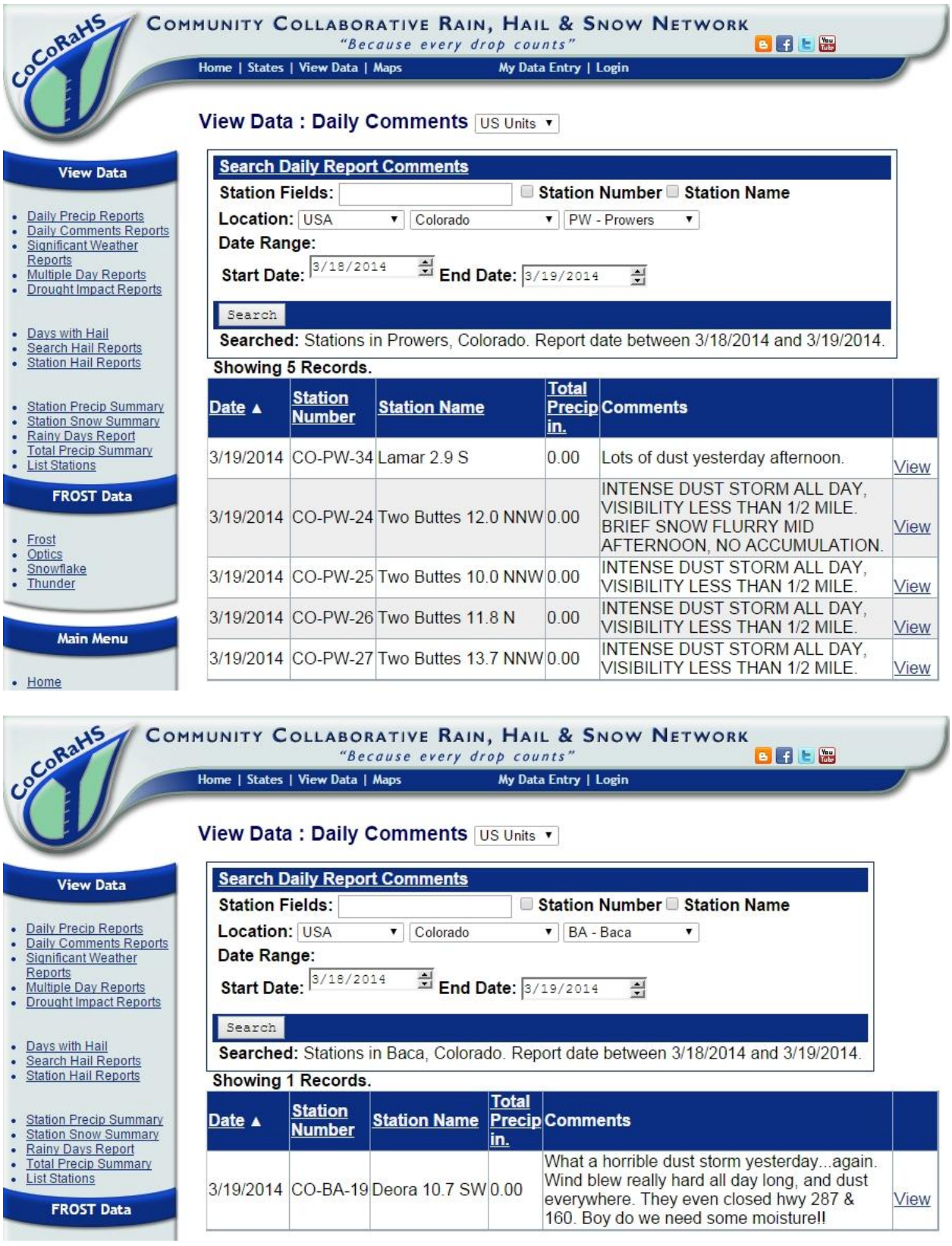
Showing 1 Records.

Date ▲	Station Number	Station Name	Total Precip in.	Comments	
3/12/2014	CO-BA-19	Deora 10.7 SW	0.02	Horrible wind and dust; just enough moisture to get the dirt to stick to the windows. Yuck!	View

4.2 March 15, 2014 Event



4.3 March 18, 2014 Event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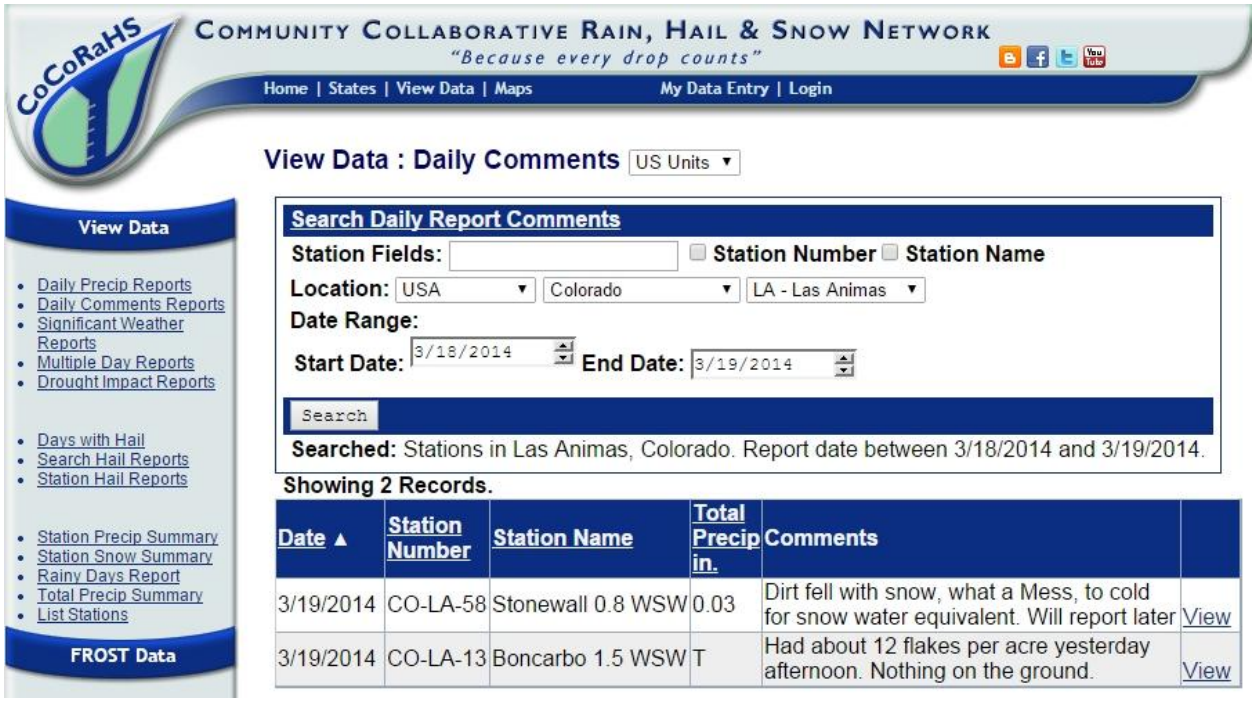
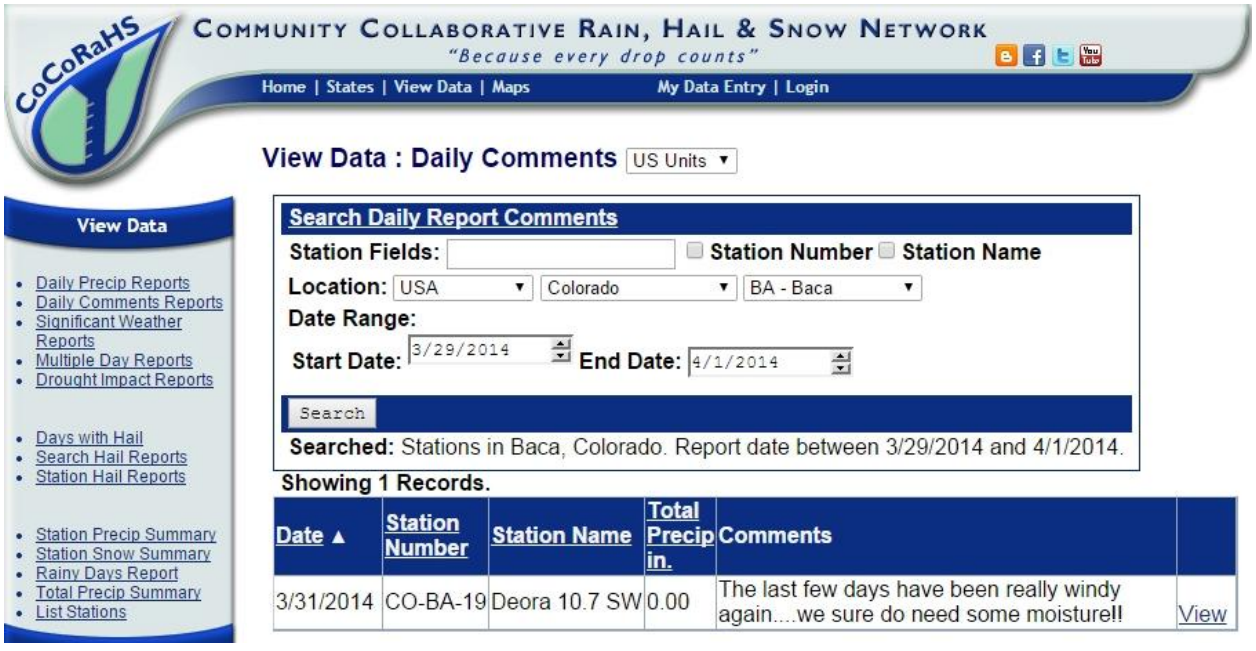
Multiple Day Reports
Drought Impact Reports
Days with Hail
Search Hail Reports
Station Hail Reports
Station Precip Summary
Station Snow Summary
Rainy Days Report
Total Precip Summary
List Stations
FROST Data
Frost
Optics
Snowflake
Thunder
Main Menu
Home
Search Daily Report Comments
Station Fields:
Station Number
Station Name
Location: USA Colorado PW - Prowers
Date Range:
Start Date: 3/18/2014
End Date: 3/19/2014
Search
Searched: Stations in Prowers, Colorado. Report date between 3/18/2014 and 3/19/2014.
Showing 5 Records.
Date ▲
Station Number
Station Name
Total Precip in.
Comments
3/19/2014 CO-PW-34 Lamar 2.9 S 0.00 Lots of dust yesterday afternoon. View
3/19/2014 CO-PW-24 Two Buttes 12.0 NNW 0.00 INTENSE DUST STORM ALL DAY, VISIBILITY LESS THAN 1/2 MILE. BRIEF SNOW FLURRY MID AFTERNOON, NO ACCUMULATION. View
3/19/2014 CO-PW-25 Two Buttes 10.0 NNW 0.00 INTENSE DUST STORM ALL DAY, VISIBILITY LESS THAN 1/2 MILE. View
3/19/2014 CO-PW-26 Two Buttes 11.8 N 0.00 INTENSE DUST STORM ALL DAY, VISIBILITY LESS THAN 1/2 MILE. View
3/19/2014 CO-PW-27 Two Buttes 13.7 NNW 0.00 INTENSE DUST STORM ALL DAY, VISIBILITY LESS THAN 1/2 MILE. View

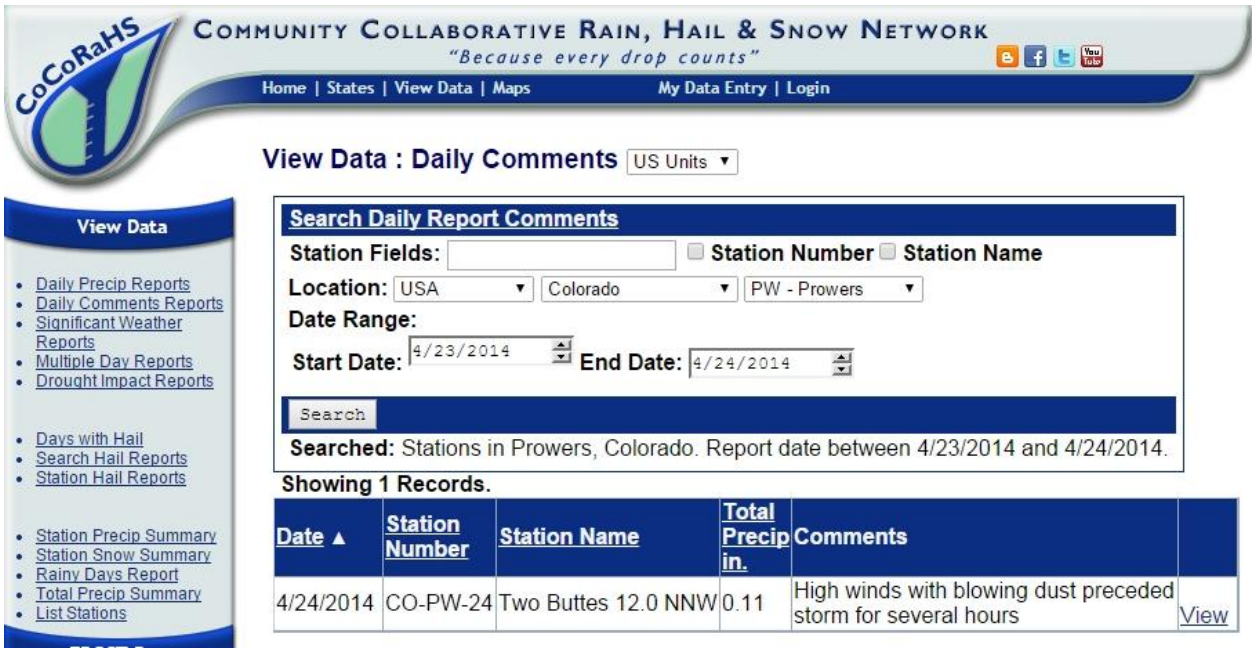
CoCoRaHS
COMMUNITY COLLABORATIVE RAIN, HAIL & SNOW NETWORK
"Because every drop counts"
Home | States | View Data | Maps
My Data Entry | Login
View Data : Daily Comments
US Units
View Data
Daily Precip Reports
Daily Comments Reports
Significant Weather Reports
Multiple Day Reports
Drought Impact Reports
Days with Hail
Search Hail Reports
Station Hail Reports
Station Precip Summary
Station Snow Summary
Rainy Days Report
Total Precip Summary
List Stations
FROST Data
Search Daily Report Comments
Station Fields:
Station Number
Station Name
Location: USA Colorado BA - Baca
Date Range:
Start Date: 3/18/2014
End Date: 3/19/2014
Search
Searched: Stations in Baca, Colorado. Report date between 3/18/2014 and 3/19/2014.
Showing 1 Records.
Date ▲
Station Number
Station Name
Total Precip in.
Comments
3/19/2014 CO-BA-19 Deora 10.7 SW 0.00 What a horrible dust storm yesterday...again. Wind blew really hard all day long, and dust everywhere. They even closed hwy 287 & 160. Boy do we need some moisture!! View



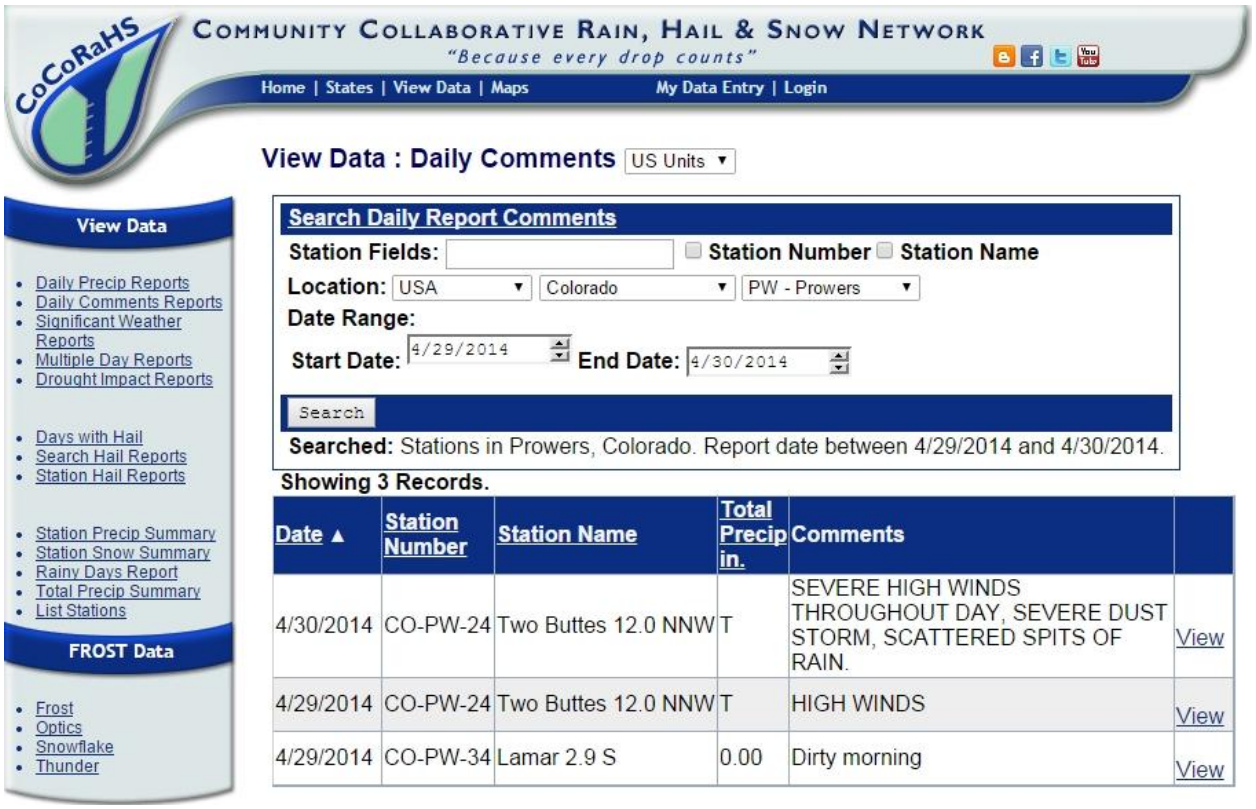
4.4 March 29-31, 2014 Events



4.5 April 23, 2014 Event



4.6 April 29, 2014 Event

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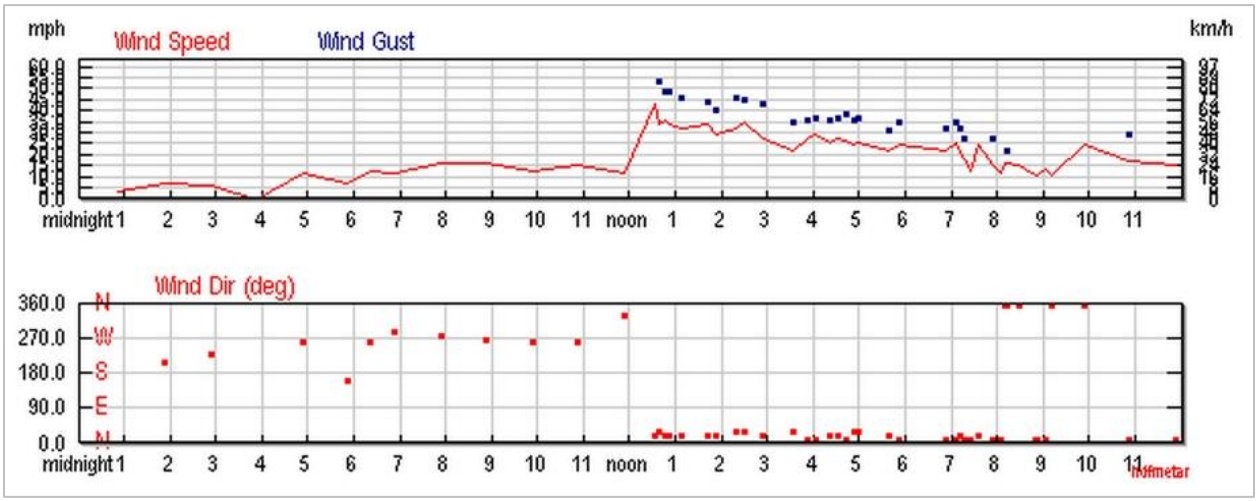
Home | States | View Data | Maps
My Data Entry | Login
View Data : Daily Comments
US Units
View Data
Daily Precip Reports
Daily Comments Reports
Significant Weather Reports
Multiple Day Reports
Drought Impact Reports
Days with Hail
Search Hail Reports
Station Hail Reports
Station Precip Summary
Station Snow Summary
Rainy Days Report
Total Precip Summary
List Stations
Search Daily Report Comments
Station Fields:
Station Number
Station Name
Location: USA Colorado BA - Baca
Date Range:
Start Date: 4/29/2014
End Date: 4/30/2014
Search
Searched: Stations in Baca, Colorado. Report date between 4/29/2014 and 4/30/2014.
Showing 1 Records.
Date ▲
Station Number
Station Name
Total Precip in.
Comments
4/30/2014
CO-BA-19
Deora 10.7 SW
0.00
Really horrible wind all day and way into the night. Yuck!
View
CoCoRaHS
COMMUNITY COLLABORATIVE RAIN, HAIL & SNOW NETWORK
"Because every drop counts"
Home | States | View Data | Maps
My Data Entry | Login
View Data : Daily Comments
US Units
View Data
Daily Precip Reports
Daily Comments Reports
Significant Weather Reports
Multiple Day Reports
Drought Impact Reports
Days with Hail
Search Hail Reports
Station Hail Reports
Station Precip Summary
Station Snow Summary
Rainy Days Report
Total Precip Summary
List Stations
FROST Data
Frost
Optics
Snowflake
Thunder
Search Daily Report Comments
Station Fields:
Station Number
Station Name
Location: USA Colorado LA - Las Animas
Date Range:
Start Date: 4/29/2014
End Date: 4/30/2014
Search
Searched: Stations in Las Animas, Colorado. Report date between 4/29/2014 and 4/30/2014.
Showing 4 Records.
Date ▲
Station Number
Station Name
Total Precip in.
Comments
4/30/2014
CO-LA-16
Kim 8.8 SSE
0.00
terrible wind
View
4/30/2014
CO-LA-48
Trinidad 1.9 ENE
0.07
Snow
View
4/30/2014
CO-LA-13
Boncarbo 1.5 WSW
T
Just a race of snow last night. 37F, winds 4-8 mph from the NE and mostly cloudy skies.
View
4/29/2014
CO-LA-48
Trinidad 1.9 ENE
0.01
Ice
View

4.7 November 10, 2014 Event



(Source: Weather Underground, Lamar 11/10/2014)

5.0 Not Reasonably Controllable or Preventable: Local Particulate Matter Control Measures

While it is likely that some dust was generated within the local communities by gusts from the regional dust storms that passed through the area, the amount of dust generated locally was easily overwhelmed by, and largely unnoticeable as compared to the dust transported in from surrounding areas. The following sections will describe in detail the regulations and programs in place designed to control PM_{10} in each affected community. These sections will demonstrate that the events were not reasonably controllable, as laid out in Section 50.1(j) of Title 40 CFR 50, within the context of reasonable local particulate matter control measures. As shown from the meteorological and monitoring analyses (Sections 2 and 3), the source regions for the associated dust that occurred during the 2013 events in Lamar originated outside of the monitored areas.

The APCD conducted thorough analyses and outreach with local governments to confirm that no unusual anthropogenic PM_{10}-producing activities occurred in these areas and that despite reasonable control measures in place, high wind conditions overwhelmed all reasonably available controls. The following subsections describe in detail Best Available Control Measures (BACM), other reasonable control measures, applicable federal, state, and local regulations, appropriate land use management, and an in-depth analysis of potential areas of local soil disturbance for each affected community during the 2013 events. This information shall confirm that no unusual anthropogenic actions occurred in the local areas of Lamar during this time.

5.1 Regulatory Measures - State

The APCDs regulations on PM_{10} emissions are summarized in Table 45.

Table 45: State Regulations Regulating Particulate Matter Emissions

Rule/Ordinance	Description
Colorado Department of Public Health and Environment Regulation 1- Emission Control For Particulate Matter, Smoke, Carbon Monoxide, And Sulfur Oxides	Applicable sections include but are not limited to: Everyone who manages a source or activity that is subject to controlling fugitive particulate emissions must employ such control measures and operating procedures through the use of all available practical methods which are technologically feasible and economically reasonable and which reduce, prevent and control emissions so as to facilitate the achievement of the maximum practical degree of air purity in every portion of the State. Section III.D.1.a) Anyone clearing or leveling of land greater than five acres in attainment areas or one acre in non-attainment areas from which fugitive particulate emissions will be emitted are required to use all available and practical methods which are technologically feasible and economically

	reasonable in order to minimize fugitive particulate emissions.(Section III.D.2.b) Control measures or operational procedures for fugitive particulate emissions to be employed may include planting vegetation cover, providing synthetic cover, watering, chemical stabilization, furrows, compacting, minimizing disturbed area in the winter, wind breaks and other methods or techniques approved by the APCD. (Section III.D.2.b) Any owner or operator responsible for the construction or maintenance of any existing or new unpaved roadway which has vehicle traffic exceeding 200 vehicles per day in the attainment/maintenance area and surrounding areas must stabilize the roadway in order to minimize fugitive dust emissions (Section III.D.2.a.(i))
Colorado Department of Public Health and Environment Regulation 3- Stationary Source Permitting and Air Pollutant Emission Notice Requirements	Construction Permit required if a land development project exceeds 25 acres and spans longer than 6 months in duration (Section II.D.1.j) All sources with uncontrolled actual PM_{10} emissions equal to or exceeding five (5) tons per year, must obtain a permit. The new source review provisions require all new and modified major stationary sources in non-attainment areas to apply emission control equipment that achieves the "lowest achievable emission rate" and to obtain emission offsets from other stationary sources of PM_{10}.
Colorado Department of Public Health and Environment Regulation 4- New Wood Stoves and the Use of Certain Woodburning Appliances During High Pollution Days	Regulates wood stoves, conventional fireplaces and woodburning on high pollution days. Prohibits the sale and installation a wood-burning stove in Colorado unless it has been tested, certified, and labeled for emission performance in accordance with criteria and procedures specified in the Federal Regulations and meets emission standards. (Section II) Section III regulates pellet stoves. Section IV regulates masonry heaters. Section VII limits the use of stoves on high pollution days.
Colorado Department of Public Health and Environment	Implements federal standards of performance for new stationary sources including ones that have

Regulation 6- Standards of Performance for New Stationary Sources	particulate matter emissions. (Section I)
Colorado Department of Public Health and Environment Regulation 9- Open Burning, Prescribed Fire, and Permitting	Prohibits open burning throughout the state unless a permit has been obtained from the appropriate air pollution control authority. In granting or denying any such permit, the authority will base its action on the potential contribution to air pollution in the area, climatic conditions on the day or days of such burning, and the authority's satisfaction that there is no practical alternate method for the disposal of the material to be burned. Among other permit conditions, the authority granting the permit may impose conditions on wind speed at the time of the burn to minimize smoke impacts on smoke-sensitive areas. (Section III)
Colorado Department of Public Health and Environment- Common Provisions Regulation	Applies to all emissions sources in Colorado When emissions generated from sources in Colorado cross the state boundary line, such emissions shall not cause the air quality standards of the receiving state to be exceeded, provided reciprocal action is taken by the receiving state. (Section II A)
Federal Motor Vehicle Emission Control Program	The federal motor vehicle emission control program has reduced PM_{10} emissions through a continuing process of requiring diesel engine manufacturers to produce new vehicles that meet tighter and tighter emission standards. As older, higher emitting diesel vehicles are replaced with newer vehicles; the PM_{10} emissions in areas will be reduced.

5.2 Lamar Regulatory Measures and Other Programs

Natural Events Action Plan (NEAP)

In response to exceedances of the PM_{10} NAAQS (two in 1995 and one in 1996), the APCD, in conjunction with the City of Lamar's Public Works Department, Parks and Recreation, and Prowers County Commissioners, the Natural Resources Conservation Services, the Burlington Northern Santa Fe Railroad, and other agencies developed a Natural Events Action Plan. That Plan was presented to EPA in 1998 and subsequently approved. Since 1998, it is this plan that has assisted the area in addressing blowing dust due to uncontrollable winds.

The most recently updated NEAP for High Wind Events in Lamar, Colorado was completed in 2012. The NEAP addresses public education programs, public notification and health advisory programs, and determines and implements Best Available Control Measures (BACM) for anthropogenic sources of windblown dust in the Lamar area. The City of Lamar, Prowers County, the APCD, and participating federal agencies worked diligently to identify contributing sources and to develop appropriate BACM as required by the Natural Events Policy.

Please refer to the 2012 Revised Natural Events Action Plan For High Wind Events, Lamar, Colorado at http://www.colorado.gov/airquality/tech_doc_repository.aspx?action=open&file=LamarNaturalEventsActionPlan2012.pdf for more detail if needed.

Control Measures from the December 2012 Maintenance Plan

Control of Emissions from Stationary Sources
Although there are few stationary sources located in the Lamar attainment/maintenance area, the State's comprehensive permit rules listed in Table 45 will limit emissions from any new source that may, in the future, locate in the area.

The EPA approval of the original PM_{10} Maintenance Plan, effective on 11/25/2005, reinstates the prevention of significant deterioration (PSD) permitting requirements in the Lamar Attainment/Maintenance area. The federal PSD requirements apply to new or modified major stationary sources which must utilize "best available control technology" (BACT).

Federal Motor Vehicle Emission Control Program (FMVECP)
The FMVECP has reduced PM_{10} emissions through a continuing process of requiring diesel engine manufacturers to produce new vehicles that meet tighter and tighter emission standards. As older, higher emitting diesel vehicles are replaced with newer vehicles through fleet turnover; tailpipe PM_{10} emissions in the Lamar area will be further reduced.

Voluntary and State-Only Measures
Additional activities in Lamar that result in the reduction of PM_{10} emissions include:

- The City of Lamar has historically cleaned their streets in town throughout the winter and spring using street sweepers. The frequency of this voluntary effort is determined by weather. In October 2013, the Public Works Director informed APCD that the streets are swept on a weekly basis unless there is snow on the streets.
- The City of Lamar and immediately surrounding areas require that new developments have paved streets. The City's Planning Commission has been working on making this an official city ordinance. In the past, it has been required despite the lack of official rule.

State Implementation Plan Measures
Any owner or operator responsible for the construction or maintenance of any existing or new unpaved roadway which has vehicle traffic exceeding 200 vehicles per day in the Lamar attainment/maintenance area and surrounding areas must stabilize the roadway in order to minimize fugitive dust emissions. These statewide requirements are defined in detail in the AQCC's Regulation No. 1 as listed in Table 45.

City of Lamar

The City of Lamar has been very proactive in addressing potential PM_{10} sources within the Lamar area including the application of grass turf at baseball fields, implementing and enhancing a street sweeping program, and chip-seal paving of many unpaved roads. The City of Lamar Public Works Department has implemented the following BACM controls within the area:

1. *Wind Break*
Beginning in the spring of 1997, a wind break of trees was planted north of the Power Plant monitoring site (080990001). The Russian Olive tree wind break is located approximately one half mile north of the Power Plant monitoring site and will block potential contributing blowing dust sources such as the Lamar Transfer Station and other unpaved equipment traffic areas to the north. The Russian Olive is a quick growing large shrub/small tree that thrives despite the semi-arid and windy climate of Lamar. In October 2013, the Public Works Director stated that most of the trees were still alive and in place. According to section 3.5.2.1 of EPA guidance entitled "*Fugitive Dust Background Document and Technical Information Document for Best Available Control Measures*", dated September 1992, one-row of trees is considered an effective windbreak.

In addition to the plantation of tree wind breaks, a drip irrigation system has been installed to promote sustained tree growth. In October 2013, the Public Works Director stated that the drip system was still operational but due to the drought the City has been on strict water restrictions.

2. *Landfill Controls*

The East Lamar Landfill is located approximately six (6) miles east of the city limits. The landfill has a CDPHE Permit (#09PR1379) which specifies that visible emissions shall not exceed twenty percent (20%) opacity during normal operation of the source and that fugitive PM_{10} cannot exceed 5.77 tons per year. The permit also contains a Particulate Emissions Control Plan that states that:

- No off-property transport of visible emissions shall apply to on-site haul roads.
- There shall be no off-property transport of visible emissions from haul trucks.
- All unpaved roads and other disturbed surface areas on site shall be watered as often as needed to control fugitive particulate emissions.
- Surface area disturbed shall be minimized.
- Exposed land areas to be undisturbed for more than six months shall be revegetated.

According to section 3.5.1 of the "Operations and Closure Plan for the East Lamar Landfill", the Director of the Public Works Department and/or the landfill operator is required to do the following litter control measures under high wind conditions:

- Soil cover is required to be placed on the working face of the landfill daily during periods of wind in excess of 30 mph; and,
- The landfill must be closed down when sustained winds reach 35 mph or greater.

An on-site wind gauge monitors wind speed at the landfill. Operators have radios in their equipment connecting them with the main office so that when the decision to close the landfill is made, it can take place immediately. According to the Director of Public Works, landfill operators have been directed to close the landfill at their discretion. Because trash debris (paper) begins to lift and blow into the debris fences at wind speeds of 25 to 30 mph, the operator usually closes the landfill prior to wind speeds reaching 30 mph. The City of Lamar has agreed to make the closure of the Lamar landfill mandatory when wind speeds reach 30 mph, which reduces windblown dust from the landfill as earth moving activities are

reduced or eliminated during periods of shut down. In October 2013, the Public Works Director stated that all of these practices are still enforced.

In addition, the placement of chain link fencing and various debris fences have been added to the previous litter entrapment cage. These additional fences better minimize the release of materials during high wind conditions. The Public Works Director stated that this is a dynamic process; as the debris moves, the fences are moved too.

3. *Vegetative Cover/Sod*

The Lamar Recreation Department installed 100,000 square feet of turf sod at a recreational open space called Escondido Park in the early 2000s. Escondido Park is located in northwest Lamar at 11th and Logan Streets. A sprinkler system has also been installed by the Parks and Recreation Department. The sod provides a vegetative cover for the open area. This dense turf cover provides an effective control against windblown soil from the open area of the park.

In addition, the Lamar Public Works Department stabilizes the entrance road leading to and from Escondido Park with chemical soil stabilizer and chip-seal to reduce dirt tracked out onto city streets and minimize additional releases of PM_{10}. This is done on an as needed basis.

4. *Additional Public Works Projects*

The Public Works Department implemented the following projects to further reduce emissions of PM_{10}:

- The purchase of a TYMCO regenerative air street sweeper (May 2001) which is much more effective in reducing dust during street sweeping activities. The use of this sweeper allows for improved cleaning of the streets (e.g., sweeps the gutter and street);
- The fencing of an area around the City Shop at 103 North Second Street in 2011 to reduce vehicle traffic that may be responsible for lifting dust off of the dirt area between the railroad tracks and the City Shop;
- The stabilization of a large dirt and mud hole in 2008 on the north side of the City Shop by installing a curb and gutter that allows for better drainage. This project is credited with keeping mud from being tracked out into the street and becoming airborne by vehicular traffic;
- The ongoing commitment to search for other stabilization projects that benefit the community and improve area air quality, and;
- The relocation of the Municipal Tree Dump in the early 2000s (formerly located in the northeastern corner of the city) to approximately six miles east of the city (now housed at the Municipal Landfill). This relocation eliminates a major source of smoke from agricultural burns that may have previously affected the community.

Regulatory Measures - City

Lamar has an ordinance that requires that all off-street parking lots shall have a dust-free surface to control PM_{10} emissions (City of Lamar Charter and Code, ARTICLE XVII, Sec. 16-17-60).

Burlington-Northern/Santa Fe Rail Line

The rail line running east-west of the Lamar Power Plant monitoring site was deemed to be an important PM_{10} source during conditions of high winds and low precipitation. Ground disturbance from vehicle traffic, which damages vegetation and breaks-up the hard soil surfaces, resulted in re-entrainment of dust from traffic, high winds or passing trains. This area is problematic in the two block area immediately west of the Power Plant monitoring site as shown in Figure 143 as Site F. Control of this open area requires a close working agreement between the Burlington-Northern/Santa Fe Railroad Company (BNSF) and the City of Lamar Public Works Department. The purpose of this BACM is to reduce the amount of particulate matter susceptible to wind erosion under high wind conditions and general re-entrainment of dust in the ambient air as a result of local train traffic passing in close proximity of the PM_{10} monitor.

In September 1997, the City chemically stabilized exposed lands north of the rail line between Fourth and Second Street where there was evidence of vehicle traffic. All other lands on either side of the rail road tracks between Main Street (Fifth) and Second Street and extending westward have either natural, undisturbed ground cover or it is used for commercial/recreation purposes that do not allow for significant re-entrainment (BNSF is responsible for maintaining 50 feet of property on either side of the main track). Most of these lands are leased by the City. After September 1997, the City negotiated the lease of these lands. Once acquired, a long term plan will be developed for these lands such as restricting vehicle access, permanently stabilizing lands with vegetation and gravel, increasing park and recreational use, and using the lands for city maintenance and storage activities. In October 2013, the Public Works Director stated that gravel was periodically added to minimize blowing dust.

According to the Manager of Environmental Operations for BNSF, the railroad company owns the main rail line and 200 feet on either side of the track. Much of this property has been sold or leased under private contracts. At this time BNSF is responsible only for the main rail line and for 50 feet of property on either side of the main track. All property sold or under contract is not the responsibility of BNSF. As a result, BNSF has stabilized the railroad corridor 50 feet on either side of the main rail line.

In May 1997, BNSF placed chips (gravel) 50 feet on either side of the main track from Main Street to Second Street (three blocks) to control fugitive dust emissions from this section of the track. Graveling exposed surfaces not exposed to regular vehicle traffic is considered a permanent mitigation measure. Details of this arrangement can be found in the documentation under the 1998 SIP Maintenance Plan submittal.

Prowers County

Prowers County Land Use Plan:

Beginning in 1997, Prowers County with the assistance of local officials, environmental health officers and the general public began preparing a county land use plan. The Prowers County Land Use Plan is designed to have wide-reaching authority over the myriad of land use issues involving building (construction sites), siting, health, fire, environmental codes, and other social concerns associated with the City of Lamar and Prowers County. The county land use

plan, entitled "*Guidelines and Regulations for Areas and Activities of State Interest – County of Prowers – State of Colorado*", was adopted on April 19, 2004 and amended on August 17, 2006. The plan incorporates provisions to minimize airborne dust including re-vegetation of disturbance areas associated with land development. The Prowers County Land Use Master Plan can be found on the County's website at: http://www.prowerscounty.net.

Regulations and ordinances of the Land Use Plan specific to reducing blowing dust and its impacts include:

- Additional regulations on development of fragile lands and vegetation to protect topsoil;
- Development of performance standards and best management practices to prevent soil erosion;
- Development of best management practices to reduce blowing sands and movement of area sand dunes across the county;
- Development of new special use permits to address the siting of animal feedlots and feed yards;
- Development of special use permits for other future stationary sources. The special use permits will also likely include the requirement for comprehensive fugitive dust control plans for both construction and operation of facilities;
- Consideration and review of enforcement capabilities through the area zoning ordinances, and;
- Planned public review and comment processes following the legal update of the draft County Land Use Plan.

Windblown Dust from Disturbed Soils

The City of Lamar is located in Prowers County in southeastern Colorado. Situated along the Arkansas River and near the Kansas border, Lamar serves as the largest city and the agricultural center for southeast Colorado. The area surrounding Lamar consists of gently rolling to nearly level uplands where the dominant slopes are less than 3 percent. The climate is generally mild and semiarid. Annual precipitation is about 15 inches. Summers are long and have hot days and cool nights. In winter and spring, windstorms are common, especially in drier years. It is due to these high velocity dust storms and drought conditions that Lamar experiences most of the PM_{10} problems for the area. Figure 142 through Figure 176 illustrate potential areas of local soil disturbance that have been evaluated by the APCD for the Lamar Municipal PM_{10} monitor (080990002).

5.3 Potential Areas of Local Soil Disturbance North of Lamar

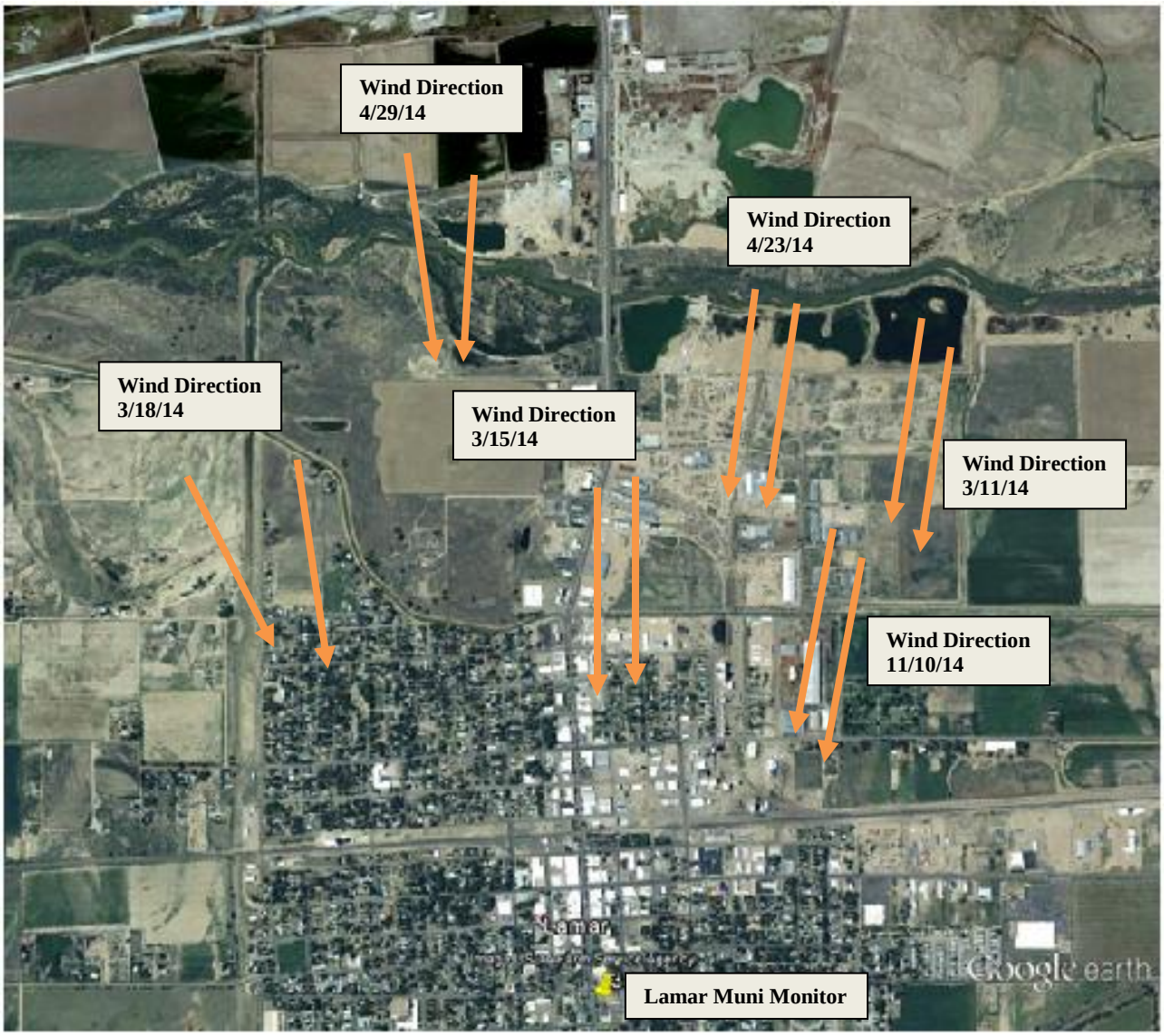


Figure 142: North of Lamar Municipal PM_{10} monitor and wind direction. (Google Earth Image August 2012)

Figure 143: Relative positions of Lamar Municipal PM_{10} Monitor and potential disturbed soil (~1 mile distance). (Google Earth Image August 2012)

Site A in Figure 143 is west of the Lamar PM_{10} monitor at 200 N 4th St. This site is owned by "Heath & Son & Turpin Trucking", a company that repairs large trucks and shared with "HVH Transportation Inc", a freight service trucking company. This site consists of well maintained gravel. The APCD considers maintained gravel and limited access to be the appropriate available and practical method for a small site of this size in this area of Colorado that has been designated a drought area for years, is in an economic recession, and is owned by multiple small businesses to be technologically feasible and economically reasonable in order to minimize fugitive particulate emissions for this site.

Site B in Figure 143 is west of the Lamar PM_{10} monitor. The site is shared by a few businesses. All businesses have restricted access by fences surrounding the property. "Cowboy Corral Storage" at 102 North 4th Street is one of the businesses on the lot. It has a very small gravel parking lot and is no longer in business according to the previous owner in October 2013. The storage company has a small gravel parking lot with access being restricted by a security fence as shown in Figure 144. The lot is also shared with the "Prowers Area Transit" county

bus garage. The bus garage is very small, only four bays. The garage has a concrete slab that runs to the asphalt road to avoid the busses driving on the gravel in order to mitigate fugitive dust. The gravel lot is watered on an as needed basis. The other business is an old feed supply company with grain storage as shown in Figure 145. The feed supply company is out of business and the grain elevators are not being utilized. The APCD considers maintained gravel and limited access to be the appropriate available and practical method for a small site of this size in this area of Colorado that has been designated a drought area for years, is in an economic recession, and is owned by multiple small businesses to be technologically feasible and economically reasonable in order to minimize fugitive particulate emissions for this site.

Figure 144: Site B - Cowboy Corral Storage (Google Image 2012)

Figure 145: Site B - Feed Storage Company (Google Image 2012)

Site C in Figure 143 is west of the Lamar PM_{10} monitor at about 201 N 2nd Street. The gravel parking lot on site is owned by "Heath & Son & Turpin Trucking" and is shown in Figure 146. The lot is used to store trucks when not in use. This site consists of well maintained gravel. The APCD considers maintained gravel and limited access to be the appropriate available and practical method for a small site of this size in this area of Colorado that has been designated a drought area for years, and is in an economic recession to be technologically feasible and economically reasonable in order to minimize fugitive particulate emissions for this site.

Figure 146: Site C - Heath & Son & Turpin Trucking Storage Lot (Google Image 2012)

Site D in Figure 143 is west of the Lamar PM_{10} monitor at about 103 North 2nd Street. It is the "Lamar Water Department". Also on site D is the "Lamar-Prowers County Volunteer Fire Department" at 300 E Poplar Street. Both sites have restricted access with security fences. The City of Lamar maintains their gravel lots by grating and watering them on an as needed basis. The APCD considers maintained gravel, limited access, grating, and watering to be the appropriate available and practical method for a small site of this size in this area of Colorado that has been designated a drought area for years and is in an economic recession to be technologically feasible and economically reasonable in order to minimize fugitive particulate emissions for this site.

Site E in Figure 143 is the power plant that the Lamar PM_{10} monitor is located within at 100 North 2nd Street. "Lamar Light and Power" historically operated a natural gas-fired boiler that produced steam for a 25 MW turbine/generator set. This boiler was constructed prior to 1972 and was grandfathered from construction permitting requirements. In the early 2000s, factors such as increasing costs of natural gas made the plant uneconomical to run. As a result, Lamar Light and Power purchased power and ran the natural gas-fired boiler very infrequently or not at all. In February 2006, APCD issued a permit for Lamar Light and Power to replace the existing natural gas-fired boiler with a coal-fired circulating fluidized bed (CFB) boiler rated at approximately 42 MW. The conversion prompted legal challenges from Lamar residents partnered with WildEarth Guardians, a New Mexico-based environmental group. Lamar Light and Power settled and agreed to shut down the coal-fired power plant. The power plant was shut down on November 11, 2011. The settlement also calls for the plant to stay offline until at least 2022, when the current agreement to supply electricity to Lamar and other communities expires.

“Lamar Light and Power” has an air quality permit (CDPHE # 05PR0027). The permit includes the following point and fugitive dust control measures:

- Limestone and ash handling, processing, and storage are controlled by high efficiency baghouses
- Water wash-down-systems are used for flushing down any accumulated dust on walkways, platforms, and other surfaces to prevent re-entrainment of the dust into the atmosphere.
- On-site haul roads are paved, and these surfaces are inspected at least once each day in which hauling activities occur, and cleaned as needed. Various cleaning methods are used depending on the extent of dust accumulations. These activities emit less than 1 ton per year of PM_{10} and are APEN Exempt.
- All transport vehicles containing substances that potentially generate fugitive particulate matter emissions (such as trucks containing limestone, inert material, or ash) are fully enclosed, or covered with a mechanical closing lid or a tight tarp-like cover at all times while on the facility grounds except during loading / unloading operations.
- Emissions from emergency coal stockpile are effectively controlled with a water dust suppression system.

Access to the power plant is restricted by security fences. The APCD considers the enforceable conditions of the permit, including identified Best Available Control Technology (BACT) for limestone and ash handling, paving, wash-down systems, and enclosures, to be technologically feasible and economically reasonable for a facility of this size in order to minimize fugitive particulate emissions for this site. The winds speeds during the 2014 events did exceed the blowing dust thresholds of 30 mph or greater and gusts of 40 mph or greater at which the APCD expects stable surfaces (i.e., controlled anthropogenic and undisturbed natural surfaces) to be overwhelmed.

Site F in Figure 143 is the Burlington Northern Santa Fe railroad that runs past the Lamar PM_{10} monitor to the south. On either side of the rail road tracks is gravel as shown in Figure 147. In May 1997, Burlington Northern Santa Fe placed chips (gravel) 50 feet on either side of the main track from Main Street to Second Street (three blocks) to control fugitive dust emissions from this section of the track. Graveling exposed surfaces not exposed to regular vehicle traffic is considered a permanent mitigation measure. Also, all the train tracks are raised up on 3 inch diameter rock and tracks. Areas that are not used by the railroad are allowed to be naturally vegetated with Xeriscape. With regard to AQCC Regulation 1 requirements (Section III.D), the APCD considers gravel and ‘Xeriscape’ vegetation to be the appropriate available and practical method that is technologically feasible and economically reasonable in order to minimize fugitive particulate emissions for this type of source.

Figure 147: Site F - Railroad tracks with gravel on each side (Google Image 2012)

Site G in Figure 143 is Colorado Mills LLC a facility that produces sunflower oil and processes the leftover solids combined with grains and additives into feed that used locally for cattle and hogs. APDC issued the initial permit 95PR622 for this facility in 1996 to Cargill, Inc. A final approval permit and two transfers of ownership have since been issued in 1997, 1999 and 2000 respectively and the facility is now owned and operated by Colorado Mills, LLC. The permit includes the following point and fugitive dust control measures:

- Visible emissions shall not exceed 20% opacity during normal operations and 30% opacity at all other times.
- Permit limits on Particulate Matter.
- Requirement to follow the developed Operation and Maintenance plan.

This Facility was inspected by the APCD on 2/14/2012 and no visible emissions were observed. Records review revealed that Colorado Mills has been in compliance with their permitted emission limits. An Operating and Maintenance Plan was submitted to the APCD for this facility on November 21, 1996 and approved by the APCD on December 24, 1996. The General Manager of the facility stated during the inspection that Colorado Mills conducts monthly inspections and maintenance on process and control equipment at the facility and no evidence was observed during the inspection to suggest that process and control equipment at the facility are not operated and maintained in a manner consistent with good air pollution control practices for minimizing emissions. Additionally, particulate emissions from oil extraction activities, grinding of grains, extruding and materials conveyance are controlled by several cyclones. The APCD considers the enforceable conditions of the permit, to be technologically feasible and economically reasonable for a facility of this size in order to minimize fugitive particulate emissions for this site.

Site H in Figure 143 is southwest of the Lamar PM_{10} monitor. It is located at about 356 South 4th Street. Part of the property is owned by Century Link. Century Link has a storage lot for

fleet vehicles that is well maintained gravel. Access to the storage lot is restricted by a fence as shown in Figure 148. A large part of site P is a free public gravel parking lot for the Prowers County Jail and the Prowers County Municipal Court as shown in Figure 149. The lot is maintained by the County. The parking lot is chip sealed and covered in crushed gravel. Site P, as shown in Figure 148, has reasonable dust control measures in place with regard to AQCC Regulation 1 requirements (Section III.D.1(a)). The APCD considers maintained gravel and limited access to be the appropriate available and practical method for a small site of this size in this area of Colorado that has been designated a drought area for years, is in an economic recession, and is owned by multiple businesses to be technologically feasible and economically reasonable in order to minimize fugitive particulate emissions for this site.

Figure 148: Site H - Century Link Fleet Storage Lot (Google Image 2012)

Figure 149: Site H - Parking lot for the Prowers County Jail and the Prowers County Municipal Court (Google Image 2012)

Site I in Figure 143 is located to the north of the Lamar PM_{10} monitor on the northeast corner of Washington St and 4th St. Site I is at 310 E Washington Street. The site used to be "Big R Warehouse" but is currently owned by Prowers County and is rented out to the Colorado State Patrol for office space. The lot is covered in gravel for dust suppression, drainage, and erosion control. Within the lot, vehicle speeds are restricted to 5 mph. Access to the lot is restricted by a chain link fence. The lot is watered on an as needed basis. Site I, as shown in Figure 150, has reasonable dust control measures in place with regard to AQCC Regulation 1 requirements (Section III.D.1(a)). The APCD considers restricted vehicle speeds in combination with maintained gravel and restricted access to be the appropriate available and practical

methods that are technologically feasible and economically reasonable in order to minimize fugitive particulate emissions for this site.

Figure 150: Site I - 310 E. Washington St., Lamar (Google Image 2012)

Site J in Figure 143 is located to the north of the Lamar PM_{10} monitor. Site J is "Ranco", a heavy duty construction trailer manufacturing company located at 700 Crystal St. All of the property owned by Ranco is covered in pavement, gravel, or natural vegetation. The company informed CDPHE that there are no unnatural, disturbed, areas of dirt on the property that could contribute to the issue of blowing dust. The APCD considers pavement, maintained gravel, natural vegetation, and restricted access to be the appropriate available and practical methods that are technologically feasible and economically reasonable in order to minimize fugitive particulate emissions for this site.

Site K in Figure 143 is Valley Glass, located at 201 east Washington Street. Valley Glass does commercial and residential glass work including storefronts, windows, siding and railings. The property has restricted access and a well maintained gravel parking area (Figure 151). The APCD considers pavement, maintained gravel, natural vegetation, and restricted access to be the appropriate available and practical methods that are technologically feasible and economically reasonable in order to minimize fugitive particulate emissions for this site.

Figure 151: Site K - Valley Glass, 201 E. Washington St., Lamar (Google Image 2012)

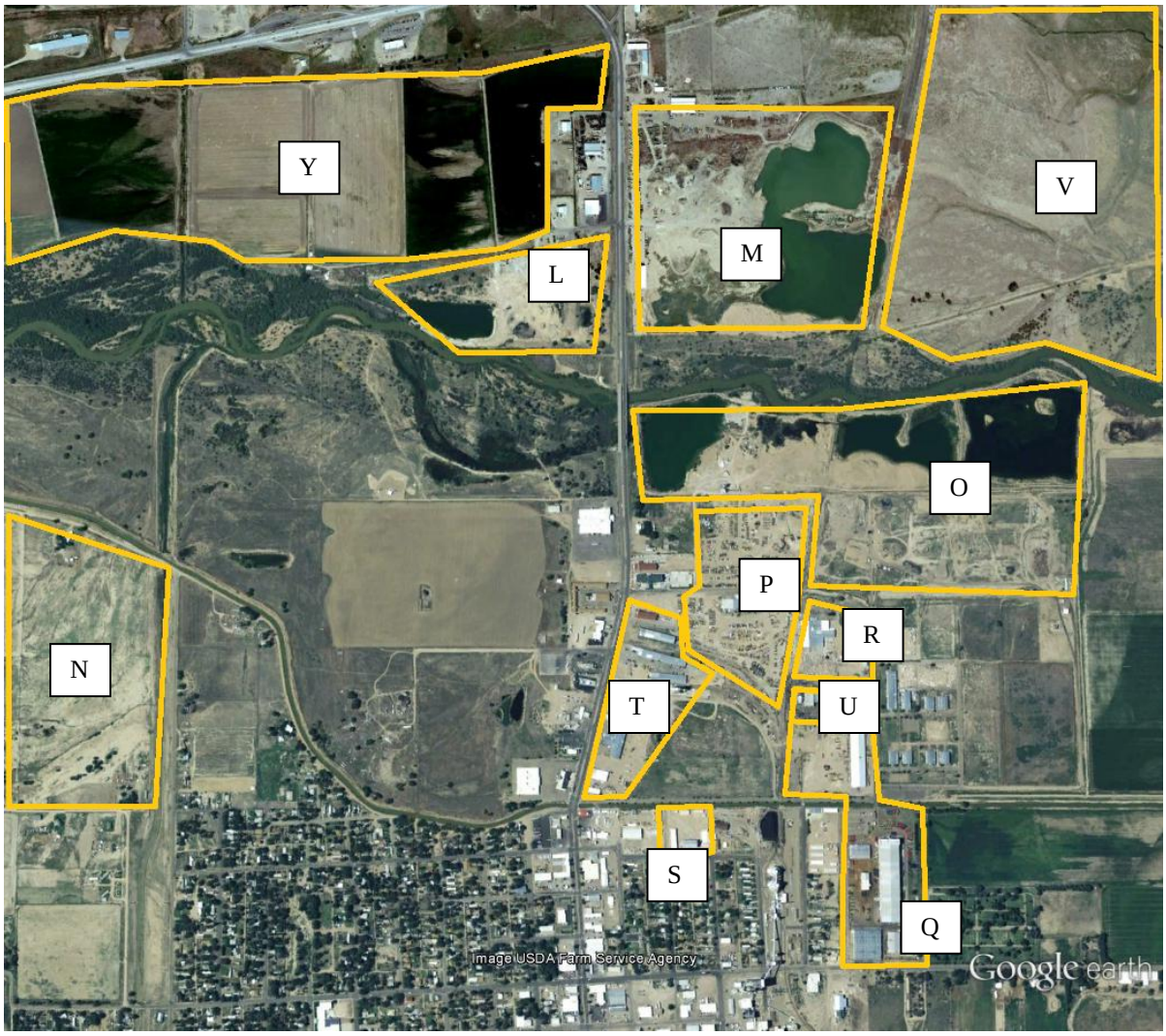


Figure 152: Relative positions of Lamar Municipal PM_{10} Monitor and potential disturbed soil (~2 mile distance). (Google Earth August 2012)

Site L in Figure 152 is located to the northwest of the Lamar Muni PM_{10} monitor. Site L is "All-Rite Paving and Redi-Mix Inc" at 200 Speculator Ave. This is a concrete batch plant with a permit from CDPHE (#12PR1396). However, this facility is considered APEN exempt and emits less than 1 ton per year of PM_{10}. This facility has a PM baghouse collection efficiency of 99%. Water spray and magnesium chloride is used on storage piles and all unpaved roads as needed. The unpaved roads at site L are covered with gravel and the vehicle speed is restricted to 10 mph at all times. The transfer of aggregate to storage bins and trucks is entirely conducted in enclosed areas. All aggregate is washed prior to storage in order to reduce dust emissions. The APCD considers the enforceable conditions of the permit, including identified continuous controls such as gravel roads with miles per hour restrictions and enclosures, to be technologically feasible and economically reasonable for a facility of this size in order to minimize fugitive particulate emissions for this site. The winds speeds during the 2014 events did exceed the blowing dust thresholds of 30 mph or greater and gusts of 40 mph or greater at which the APCD expects stable surfaces (i.e., controlled anthropogenic and undisturbed natural surfaces) to be overwhelmed.

Site M in Figure 152 is mined by "Carder Inc" and is located to the northwest of the Lamar PM_{10} monitor. Carder Inc mines for sand and gravel primarily for road construction. This site has a permit from CDPHE (#99PR0180F) and emits approximately 15 tons per year of PM_{10}. This is a wet mining operation so it produces minimal fugitive dust. The dust control measures that are part of the permit include watering the disturbed area as needed, re-vegetation within one year of disturbance, compacting of piles, mining moist materials, vehicles cannot exceed 10 mph on site at all times, and temporary roads are covered with gravel and watered as needed. The APCD considers the enforceable conditions of the permit, including identified continuous controls such as gravel roads with miles per hour restrictions, compaction, re-vegetation, watering, and extraction limitation, to be technologically feasible and economically reasonable for a facility of this size in order to minimize fugitive particulate emissions for this site. The winds speeds during the 2014 events did exceed the blowing dust thresholds of 30 mph or greater and gusts of 40 mph or greater at which the APCD expects stable surfaces (i.e., controlled anthropogenic and undisturbed natural surfaces) to be overwhelmed.

Site N in Figure 152 is restricted access property located just south of the Lamar Canal Road and west of N. 13th Street. The land is naturally vegetated and undisturbed as shown in Figure 153.

Figure 153: Site N (Google Image 2014)

Site O in Figure 152 is located to the north of the Lamar PM_{10} monitor. Site O is mined by "All-Rite Paving and Redi-Mix Inc" at 1 Valco Road. This is a concrete batch plant with a permit from CDPHE, (#85PR108). However, this facility is considered APEN exempt and emits less than 1 ton per year of PM_{10} This facility has a PM baghouse collection efficiency of 99%. Visible emissions from this source shall not exceed 20% opacity. Water sprays and magnesium chloride are used on storage piles and all unpaved roads as needed. The unpaved roads at site O are covered with gravel and the vehicle speed is restricted to 10 mph at all times. The

transfer of aggregate to storage bins and trucks is entirely conducted in enclosed areas. All aggregate is washed prior to storage in order to reduce dust emissions. Access to the site is restricted by a fence. The APCD considers the enforceable conditions of the permit, including identified continuous controls such as gravel roads with miles per hour restrictions and enclosures to be technologically feasible and economically reasonable for a facility of this size in order to minimize fugitive particulate emissions for this site. The winds speeds during the 2014 events did exceed the blowing dust thresholds of 30 mph or greater and gusts of 40 mph or greater at which the APCD expects stable surfaces (i.e., controlled anthropogenic and undisturbed natural surfaces) to be overwhelmed. Additionally, the City of Lamar took over the concrete plant in the spring of 2013 and is in the process of reseeding it and turning the site into a park for fishing and wildlife with motorized vehicles being prohibited. The City of Lamar and the Division of Wildlife are partners in this effort.

Site P in Figure 152 is "Ranchers Supply Co., Inc." at 400 Crystal Street. The company started in 1961 and their products include used trucks, construction equipment, military vehicles, new and used trailers and other government surplus items. The property is used for inventory storage. To control fugitive dust emissions, onsite vehicle speeds are restricted to 10 mph. The owner states that 90% of the lot is covered in well maintained gravel. The site is watered down on an as needed basis to mitigate dust to protect assets and for pollution prevention. Also, all of the large equipment also acts as a wind block. Access to the site is restricted by a security fence. Site P, as shown in Figure 154, has reasonable dust control measures in place with regard to AQCC Regulation 1 requirements (Section III.D.1(a)). The APCD considers restricted vehicle speeds in combination with maintained gravel to be the appropriate available and practical method that is technologically feasible and economically reasonable in order to minimize fugitive particulate emissions for this storage site.

Figure 154: Site P - Ranchers Supply Co., Inc. (Google Image 2012)

Site Q in Figure 152 is located to the north of the Lamar PM_{10} monitor. Site Q is "Ranco", a heavy duty construction trailer manufacturing company located at 700 Crystal Street. All of the property owned by Ranco is pavement, gravel, or natural vegetation. The company informed APCD that there are no unnatural, disturbed, areas of dirt on the property that could contribute to the issue of blowing dust. The APCD considers pavement, maintained gravel, natural vegetation, and restricted access to be the appropriate available and practical methods that are technologically feasible and economically reasonable in order to minimize fugitive particulate emissions for this site.

Site R in Figure 152 is located to the north of the Lamar PM_{10} monitor. Site R is "C.F. Maier Composites Inc" at 500 East Crystal Street. This 57,000 square foot facility has been operating since 1990 and specializes in highly difficult fiber reinforced composites and OEM component

application. C.F. Maier offers product design, development, prototype and full production of reinforced composite parts for high stress or high impact uses. The company has a paved parking lot. The rest of the lot is covered in natural vegetation. There is a short (200 ft.) well maintained gravel road that leads up to the loading dock that gets used on average one a day. Site R, as shown in Figure 152, has reasonable dust control measures in place with regard to AQCC Regulation 1 requirements (Section III.D.1(a)). The APCD considers restricted maintained gravel and natural vegetation to be the appropriate available and practical methods that are technologically feasible and economically reasonable in order to minimize fugitive particulate emissions for this site.

Site S in Figure 152 is located to the north of the Lamar PM_{10} monitor on the northeast corner of Washington Street and 4th Street. Site S is at 201 E. Washington Street. The site used to be "Big R Warehouse" but is currently owned by Prowers County and is rented out to the Colorado State Patrol for office space. The lot is covered in gravel for dust suppression, drainage, and erosion control. Within the lot, vehicle speeds are restricted to 5 mph. Access to the lot is restricted by a chain link fence. The lot is watered on an as needed basis. Site S, as shown in Figure 152, has reasonable dust control measures in place with regard to AQCC Regulation 1 requirements (Section III.D.1(a)). The APCD considers restricted vehicle speeds in combination with maintained gravel and restricted access to be the appropriate available and practical methods that are technologically feasible and economically reasonable in order to minimize fugitive particulate emissions for this site.

Site T in Figure 152 is Lamar Feed and Grain – White Stone Farms located at 110 Anderson Street. This animal feed mill was purchased by Wells Fargo Bank in October 2009 and combined with 207 Anderson Street, which Wells Fargo Bank foreclosed on in July of 2008. Wells Fargo reported that the mill had not operated for several years and would not be operated under the ownership of Wells Fargo Bank. In September 2011, the property was purchased by Lamar Feed and Grain, LLC and recommenced operations. The facility consists of a grain receiving pit, a grain shipping truck loadout station, grain storage, a grain cleaning scalper, and grain handling and milling systems. In November 2000, APCD issued the initial permit for this source (00PR0431) and at the time of this event, Lamar Feed and Grain, LLC was operating under the Final Approval permit issued on 7/21/2006. The permit includes the following point and fugitive dust control measures:

- Total PM, PM10 and PM2.5 annual emissions limitations.
- Visible emissions cannot exceed 20%.
- All equipment must be maintained and operated in a manner consistent with good air pollution control practices for minimizing emissions.
- The feed mill must be equipped with a mineral oil spray system for the control of PM emissions.

The APCD considers the enforceable conditions of the permit, to be technologically feasible and economically reasonable for a facility of this size in order to minimize fugitive particulate emissions for this site. The winds speeds during the 2014 events did exceed the blowing dust thresholds of 30 mph or greater and gusts of 40 mph or greater at which the APCD expects stable surfaces (i.e., controlled anthropogenic and undisturbed natural surfaces) to be overwhelmed.

Site U in Figure 152 is Dragon ESP, located at 700 East Crystal Street. This equipment manufacturing facility commenced operation in 1993 and was combined with the Ranco

Trailers facility in 2011. The APCD issued a joint permit for these facilities (08PR0603) on 12/21/2011 which consist of paint booths and abrasive blasting units. The permit includes the following point and fugitive dust control measures:

- Permitted annual TSP, PM_{10} and $PM_{2.5}$ emission limits
- High Volume Low Pressure paint spray guns or other APCD-approved surface coating method must be used to meet PM emission limits
- Paint spray booths shall be equipped with exhaust filters or paint arresters to control PM emissions and shall be maintained per manufacturer's recommendations
- Blasting operations shall be done in a complete enclosure with baghouse filters to control PM emissions and blasting shall be done with doors closed. The baghouse shall be maintained per manufacturer's recommendation.
- Visible emissions shall not exceed 20% during normal operations
- Source must follow the APCD approved O&M plan

The facility was last inspected on 11/9/2011 and was found to be in compliance with all the permitted conditions. The APCD considers the enforceable conditions of the permit, to be technologically feasible and economically reasonable for a facility of this size in order to minimize fugitive particulate emissions for this site.

Site V in Figure 152 is restricted access property that lies south of State Highway 196 and north of the Arkansas River, East of Highway 287. The land is naturally vegetated and undisturbed as shown in Figure 155. Figure 155 demonstrates that this site has minimally (if any) disturbed soil as of this writing. The APCD considers pavement, maintained gravel, natural vegetation, and restricted access to be the appropriate available and practical methods that are technologically feasible and economically reasonable in order to minimize fugitive particulate emissions for this site.

Figure 155: Site V (Google Image 2012)

Site Y in Figure 152 are rotating crop fields located south and west of U.S. Highway 287/U.S. Highway 50. As shown in Figure 156 and Figure 157, the crops in these fields are rotated from year to year, allowing fields to lay fallow between plantings.

Figure 156: Site Y - Rotating crop fields, 6/2005. (Google Earth Image 2005)

Figure 157: Site Y - Rotating crop fields, 8/2011. (Google Earth Image 2011)

Figure 158: Site W - Robins Redi-Mix Concrete Batch Plant, 7355 State Highway 196 Lamar (Google Earth 2012)

Site W in Figure 158 is the Robins Redi-Mix Concrete Batch Plant located at 7355 State Highway 196, approximately 4.5 miles north of the Lamar Municipal PM_{10} site. This batch plant opened in the spring of 2010 and consists of a dry truck mix plant that utilizes a cement and a dry ash silo each of which are operated with pneumatic conveyors and bag houses for the control of emissions. According to Robins Redi-Mix, the bag houses control 98% of the emissions. In April 2010, APCD issued a permit exempt letter for this source (10PR1310.XP). The permit includes the following point and fugitive dust control measures:

- Uncontrolled total PM cannot exceed 10 tpy and uncontrolled PM_{10} cannot exceed 5 tpy.
- Visible emissions cannot exceed 20%.

In addition to these permitted requirements, the source reported in their application that they moisten materials throughout their processes and prior to transferring on an as needed basis and have placed gravel on the road to minimize emissions. The APCD considers the enforceable conditions of the permit, including identified Best Available Control Technology (BACT) for limestone and ash handling, paving, wash-down systems, and enclosures, to be technologically feasible and economically reasonable for a facility of this size in order to minimize fugitive particulate emissions for this site. The winds speeds during the 2014 events did exceed the blowing dust thresholds of 30 mph or greater and gusts of 40 mph or greater at which the APCD expects stable surfaces (i.e., controlled anthropogenic and undisturbed natural surfaces) to be overwhelmed.

5.4 Potential Areas of Local Soil Disturbance South of Lamar

Figure 159: South of Lamar Municipal Building PM_{10} Monitor and Wind Direction. (Google Image 2014)

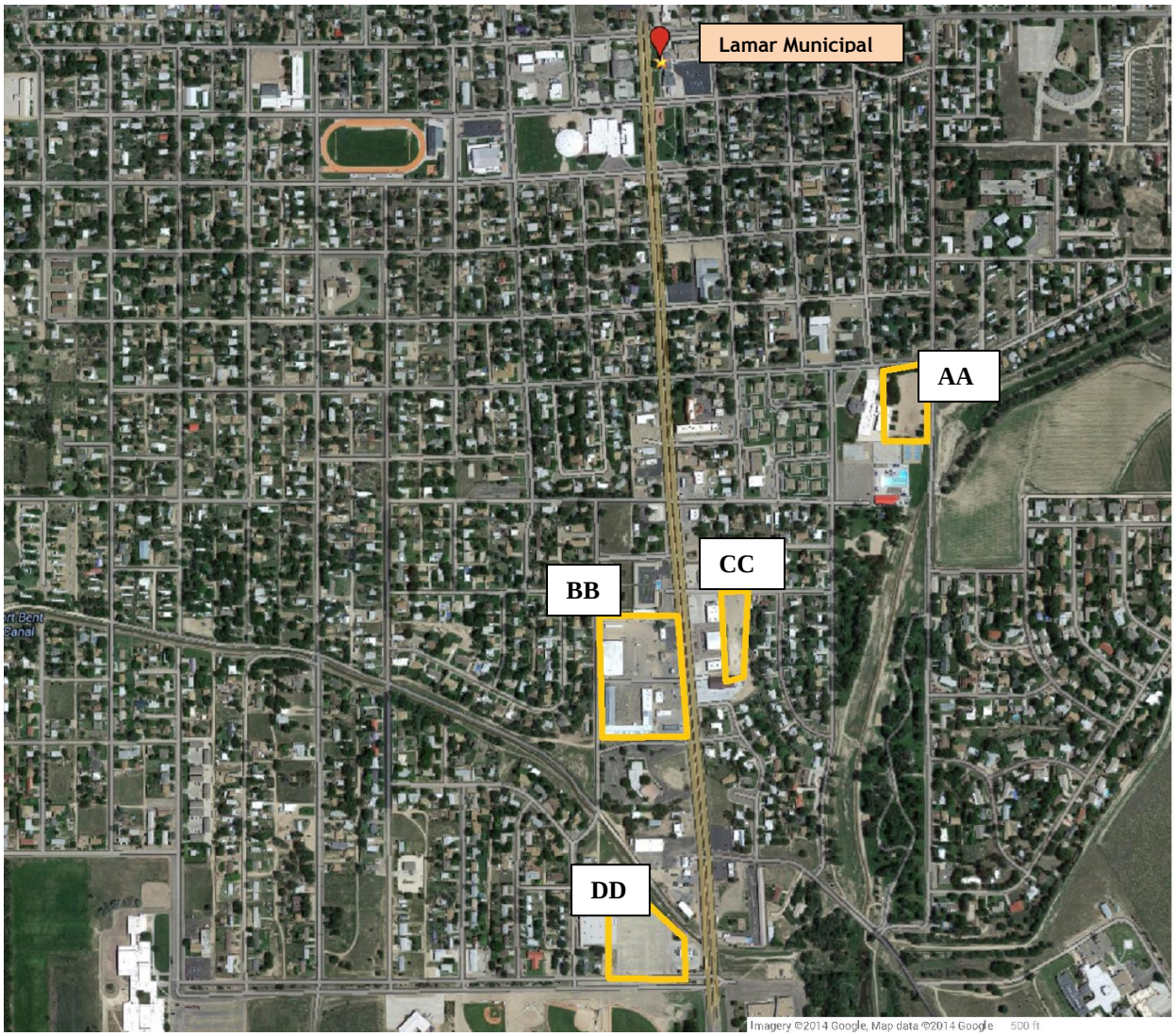


Figure 160: South of Lamar Municipal PM_{10} Monitor (~1mile distance) (Google Image 2014)

Site AA in Figure 160 is south of the Lamar PM_{10} monitor at 1105 Parkview Ave. The site is Parkview Elementary School and includes a gravel playground as shown in Figure 161. This site consists of a well maintained gravel yard that is surrounded by a fence to restrict access. Trees have also been planted around the parameter of the school yard, further reducing the potential for dust (Figure 161). The APCD considers maintained gravel and limited access to be the appropriate available and practical method for a small site of this size in this area of Colorado that has been designated a drought area for years and is in an economic recession to be technologically feasible and economically reasonable in order to minimize fugitive particulate emissions for this site.

Figure 161: Site AA - Parkview Elementary School (Google Image 2012)

Site BB in Figure 160 is a large parking area for several businesses along South Main Street on both sides of Lee Ave. Most of the area is paved as shown in Figure 162. There is a small area of land in the middle of the parking area that is unpaved but this area is covered in weeds (see arrow in Figure 162).

Figure 162: Site BB (Google Image 2012)

Site CC in Figure 160 is an undeveloped area behind several businesses east of Main Street and south of Forrest Street. The land is cordoned off from traffic through a barricade as shown in Figure 163 which restricts access to the area and the land behind the barricade is vegetated with weeds and grasses.

Figure 163: Site CC (Google Image 2012)

Site DD in Figure 160 is south of the Lamar PM_{10} monitor, it is located at approximately 106 Savage Ave. This parking lot has been paved over and is not a source of PM_{10}.

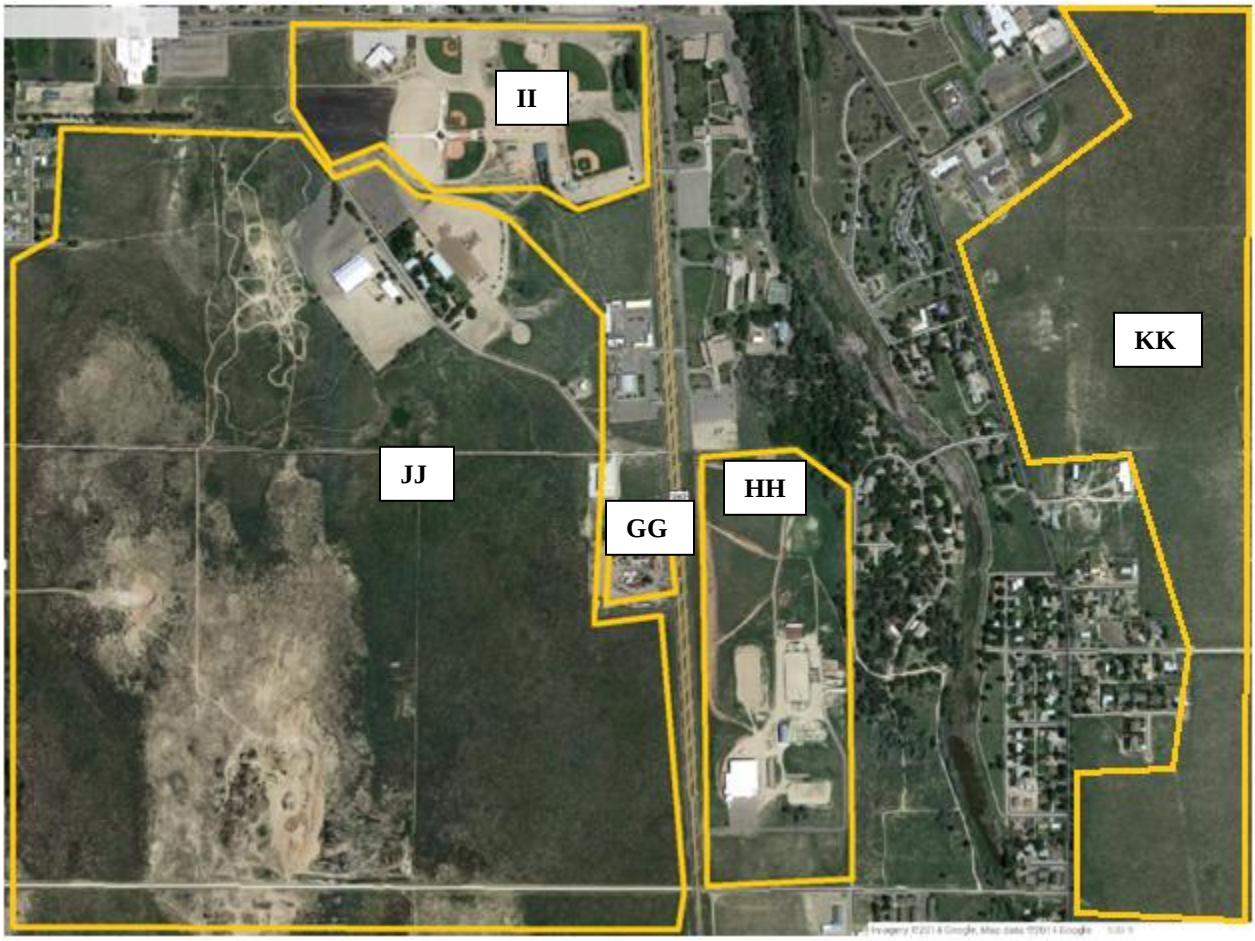


Figure 164: South of Lamar Municipal PM_{10} Monitor (~2mile distance) (Google Image 2014)

Site GG in Figure 164 is Country Acres RV Park located at 29151 US Highway 287. The park has well maintained gravel and Country Acres personnel reported that they have also purchased and put down recycled blacktop to help with dust suppression. The APCD considers maintained gravel and limited access to be the appropriate available and practical method for a small site of this size in this area of Colorado that has been designated a drought area for years and is in an economic recession to be technologically feasible and economically reasonable in order to minimize fugitive particulate emissions for this site.

Site HH in Figure 164 is Lamar Community College's Equine Complex located south of the main campus on US Highway 287. The facility is well maintained and fenced to restrict access.

Site II in Figure 164 is the Lamar Ball Complex at approximately 100 Savage Street, which has limited access through fencing. These fields are used by the Lamar Community College but owned and maintained by the city of Lamar. City personnel reported that they have brought rotamilling and pea gravel in to help with dust control. Rotamilling is ground up asphalt that has been spread across parts of the parking areas and much of the open areas around the fields consist of pea gravel. The city also drags the parking areas and applies water as needed for dust. The APCD considers pavement, maintained gravel, natural vegetation, and restricted access to be the appropriate available and practical methods that are technologically feasible and economically reasonable in order to minimize fugitive particulate emissions for this site. The fields are turf and regularly watered as shown in Figure 165. This complex is well maintained by the City and implements reasonable dust control measures on a regular basis.

Figure 165: Site II - Lamar Ball Complex (Google Image 2012)

Site JJ in Figure 164 is the Prowers County Fairgrounds located at 2206 Saddle Club Drive. The land is maintained by the county and is grated annually and watered frequently during most of the year. County personnel reported that the facility is frequently used from April to September and watered as needed during these times. The APCD considers pavement, maintained gravel, natural vegetation, and restricted access to be the appropriate available and practical methods that are technologically feasible and economically reasonable in order to minimize fugitive particulate emissions for this site.

Site KK in Figure 164 is restricted access property located just south of the Fort Bent Canal and east of Memorial Drive. The land is naturally vegetated and undisturbed as shown in Figure 166.

Figure 166: Site KK (Google Image 2012)

Figure 167: Site LL - Prowers County - Walker Pit North (Google Image 2014)

Site LL in Figure 167 is the Prowers County - Walker Pit North, located approximately 6 miles southeast of the Lamar PM_{10} monitor, south of County Road CC and County Road 10. This site is a sand a gravel production facility for which APCD issued a permit exemption letter for on 7/6/2010 (09PR0038F.XP). The permit exemption letter includes the following point and fugitive dust control measures:

- Comply with the developed dust control plan.
- Comply with production rate limit.

This facility was inspected by the Colorado Division of Reclamation, Mining and Safety Minerals Program on 3/29/2014 and was found to be in compliance. The inspector commented that previous disturbed areas will be reclaimed to rangeland and that "native grasses, forbs and cottonwood trees have volunteered throughout the site". Photos from of the site (Figure 168) indicate that the area is fenced and marked with a "No Trespassing" sign to restrict access and much of the land has been reclaimed by natural vegetation. The APCD considers the enforceable conditions of the permit, to be technologically feasible and economically reasonable for a facility of this size in order to minimize fugitive particulate emissions for this site.

Figure 168: Site LL (Images from Colorado Division of Reclamation, Mining and Safety Minerals Program Inspection Report on March 29, 2014)

5.5 Potential Areas of Local Soil Disturbance West of Lamar

Figure 169: West of Lamar Municipal Building PM_{10} monitor and wind direction. (Google Earth Image 2014)

Figure 170: West of the Lamar Municipal PM_{10} Monitor (Google Earth Image August 2013)

Site MM in Figure 170 is west of the Lamar PM_{10} monitor at W Parmenter St. and S 9th Street. The site is Washington Elementary School and includes a gravel playground as shown in Figure 171. This site consists of well maintained gravel that is surrounded by a fence to restrict access. The APCD considers maintained gravel and limited access to be the appropriate available and practical method for a small site of this size in this area of Colorado that has been designated a drought area for years and is in an economic recession to be technologically feasible and economically reasonable in order to minimize fugitive particulate emissions for this site.

Figure 171: Site MM - Washington Elementary School (Google Image 2012)

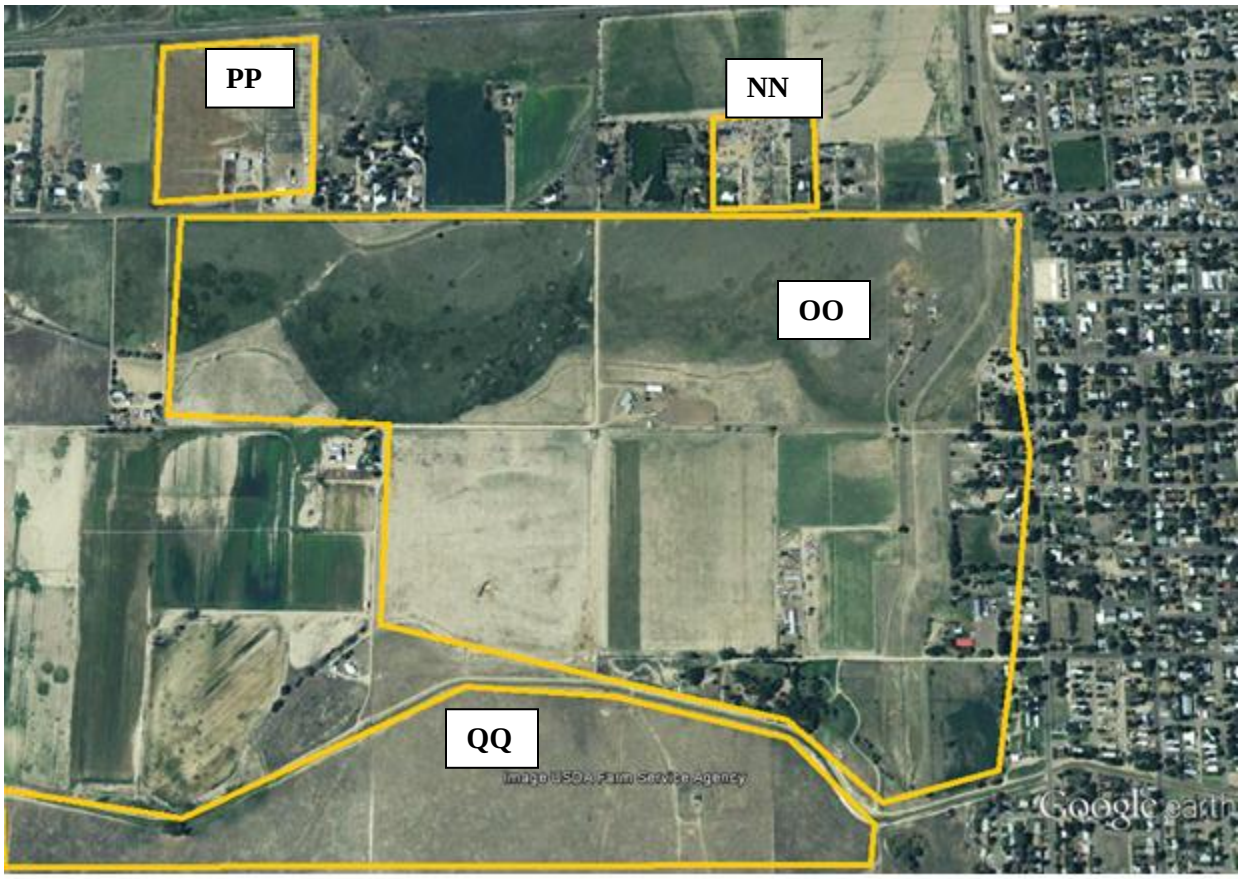


Figure 172: Further West of the Lamar Municipal PM_{10} Monitor (Google Earth Image 2012)

Site NN in Figure 172 is a metal recycling, welding, and custom fabrication business located at about 6673 County Road HH. "Out West Equipment Co., Inc." and "Lamar Scrap and Salvage" own the land. This small three acre lot is mostly gravel. The owner does water the site on an as needed basis to protect assets and mitigate fugitive dust. Site NN has reasonable dust control measures in place with regard to AQCC Regulation 1 requirements (Section III.D.1(a)). The APCD considers restricted maintained gravel and watering to be the appropriate available and practical methods that are technologically feasible and economically reasonable in order to minimize fugitive particulate emissions for this site.

Site OO in Figure 172 is naturally vegetated, undisturbed land as shown in Figure 173. There are a few residential homes on the land but it is mostly natural. With regard to AQCC Regulation 1 requirements (Section III.D), the APCD considers undisturbed, natural vegetation to be the appropriate available and practical method that is technologically feasible and economically reasonable in order to minimize fugitive particulate emissions for this type of source.

Figure 173: Site OO - Undisturbed land (Google Image August 2012)

Site PP in Figure 172 is restricted access property located just north of County Road HH and slightly east of County Road 6.2. The land is naturally vegetated and undisturbed as shown in Figure 174. With regard to AQCC Regulation 1 requirements (Section III.D), the APCD considers undisturbed, natural vegetation to be the appropriate available and practical method that is technologically feasible and economically reasonable in order to minimize fugitive particulate emissions for this type of source.

Figure 174: Site PP - Restricted access, naturally vegetated land (Google Image August 2012)

Site QQ in Figure 172 is restricted access property located just south of County Road 6.5 and Fort Bent Canal. The land is naturally vegetated and undisturbed as shown in Figure 175. With regard to AQCC Regulation 1 requirements (Section III.D), the APCD considers undisturbed, natural vegetation to be the appropriate available and practical method that is technologically feasible and economically reasonable in order to minimize fugitive particulate emissions for this type of source.

Figure 175: Site QQ - Restricted access, naturally vegetated land (Google Image August 2012)

Figure 176: Site RR - Carder Inc., 32625 County Rd 3.75 (Google Earth 2012)

Site RR in Figure 176 is "Carder Inc." at 32625 County Rd 3.75, approximately 5 miles west of Lamar. Carder Inc. mines this site, known as the Hard Scrabble Pit, for sand and gravel primarily for road construction. This site has a permit from CDPHE (#99PR0179F) and emits about 8 tons per year of PM_{10}. This is a wet mining operation so it produces minimal fugitive dust. The dust control measures that are part of the permit include watering the disturbed area as needed, re-vegetation within one year of disturbance, compacting of piles, mining moist materials, vehicles cannot exceed 10 mph on site at all times, and temporary roads are covered with gravel and watered as needed. The APCD considers the enforceable conditions of the permit, including identified continuous controls such as gravel roads with miles per hour restrictions, compaction, re-vegetation, watering, and extraction limitation, to be technologically feasible and economically reasonable for a facility of this size in order to minimize fugitive particulate emissions for this site. The winds speeds during the 2014 events, did exceed the blowing dust thresholds of 30 mph or greater and gusts of 40 mph or greater at which the APCD expects stable surfaces (i.e., controlled anthropogenic and undisturbed natural surfaces) to be overwhelmed.

The APCD conducted thorough assessments to determine if the potential soil disturbances shown in Figure 142 through Figure 176 were present during the 2014 exceedances in Lamar. During the course of these assessments, the APCD discovered that these sites were either reasonably controlled or considered to be natural sources during the 2014 high wind events. Therefore, these sites were not significant contributors to fugitive dust in the Lamar area during the 2014 high wind events.

Colorado State University CO-OP Extension Office

While the following initiatives are not meant to be enforceable, the CSU Co-Op Extension Office has many efforts underway that further reduce blowing dust and its impacts. These include:

- Crop residue efforts that encourage no- or low-till practices. These have been deemed appropriate and useful in reducing blowing dust.
- Ongoing outreach efforts to educate area agricultural producers on soil management programs. These include one-on-one visitations and annual meetings with various corn and wheat programs to discuss crop management.
- Drought workshops to protect topsoil throughout the county.

USDA: Natural Resources Conservation Service (NRCS)

1. *Conservation Reserve Program*

Prowers County is a predominately agricultural area that is made up of 1,048,576 acres of land area – 1,021,915 acres (or 97.5%) of which is land in farms.[2] For comparison, Baca County to the south is 91.9% land in farms, Bent County to the west is 75.0% land in farms, and Kiowa County to the north is 98.4% land in farms. It should be noted that cropland percentage in Bent County is lower than other Southeast Colorado counties at 11%. Figure 177 illustrates the counties of Southeast Colorado. Of the farm land acreage in Prowers County, cropland accounts for approximately half of the total (480,487 acres) and is approximately 46% of the total land in the county. Water, and often the lack of it, coupled with the frequent high

[2] 2012 Census of Agriculture. Volume 1, Chapter 2: County Level Data. U.S. Dept. Of Agriculture, National Agricultural Statistics Service.

winds experienced during late fall and early spring commonly destroy crops, encourage pests, and damage soil surfaces lending them susceptible to wind erosion, especially in recent drought years. Prowers County was classified as being in severe drought in November 2010 and remained so until July 2012 when the county was reclassified as being in an exceptional drought. Prowers County returned to being in a severe drought in October 2014 and remains in this classification. The majority of Prowers County cropland acreage is farmed using dryland practices (versus irrigated) and consists of soils classified as highly-erodible-land (HEL) by the Department of Agriculture.

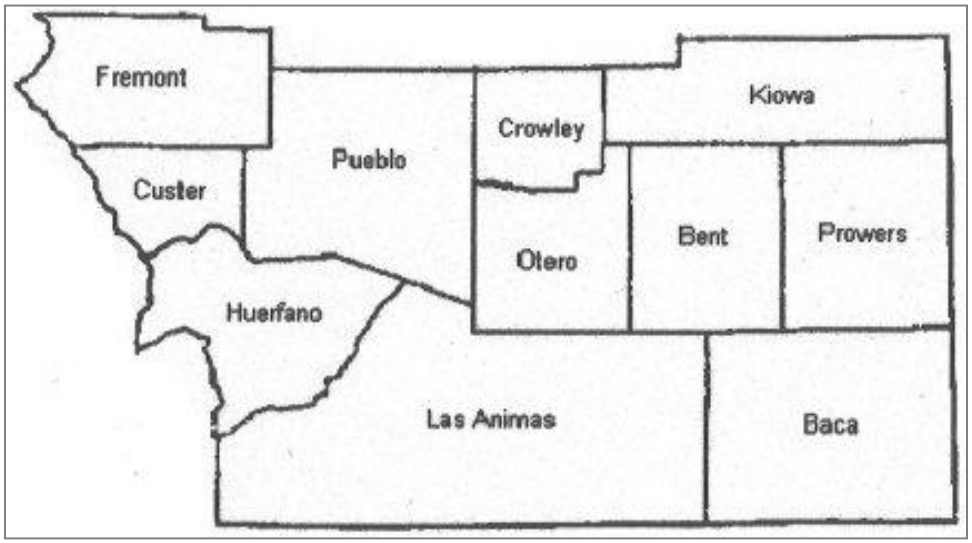


Figure 177: Southeast Colorado Counties

Recognizing the problems associated with erodible land and other environmental-sensitive cropland, the U.S. Department of Agriculture (USDA) included conservation provisions in the Farm Bill. This legislation created the Conservation Reserve Program (CRP) to address these concerns through conservation practices aimed at reducing soil erosion and improving water quality and wildlife habitat.

The CRP encourages farmers to enter into contracts with USDA to place erodible cropland and other environmentally-sensitive land into long-term conservation practices for 10-15 years. In exchange, landowners receive annual rental payments for the land and cost-share assistance for establishing those practices.

The CRP has been highly successful in Prowers County by placing approximately 155,611 acres of Prowers County cropland, or 32% of total cropland, under contract. Most of this land has been planted with a perennial grass cover to protect the soil and retain its moisture.

While the following initiatives are not meant to be enforceable, many efforts are underway that further reduce blowing dust and its impacts. These include:

- The CRP has moved to include all available area lands into area contracts. Success of the CRP initiatives is measured through ongoing monitoring of the contracts to ensure ample grass coverage to minimize blowing dust.

- CRP sends out information several times per year through radio and the area newspaper to further reach farmers interested in topsoil protection.
- In response to the significant Colorado drought (2011-2013) the NRCS and FSA are working with multiple parties in extensive annual planning efforts to limit blowing dust and its impacts. These planning efforts change year to year depending on the severity of the drought.

2. *Limestone-Graveyard Creeks Watershed Project*

A watershed improvement project is currently underway in the Limestone-Graveyard Creeks Watershed. This project covers approximately 60,000 acres of land north of the Arkansas River between Hasty (Bent County) and Lamar. An estimated 44,500 acres of the watershed area are classified as priority land due to the highly erodible nature of the soil. Over 2,000 acres of agricultural cropland northwest of Lamar are included in this watershed project. As of 2013, NRCS informed the APCD that this project is approximately 99% complete.

Working with the NRCS, each farmer will create their own conservation plan with costs for improvements split equally between farmers and the federal government. The 15-year project will help reduce soil erosion and improve water quality and efficiency through conservation tillage practices and/or other conservation efforts. In short, the Limestone-Graveyard Creeks Watershed Project will help to reduce soil erosion and lower the impacts of blowing soils during future high wind events.

More recently (since the 1998 NEAP submittal), the Watershed project has been evaluated and is seen as an ongoing successful program as most eligible acres are signed up.

3. *New Initiatives*

While the following initiatives are not meant to be enforceable, the Natural Resources Conservation Service has many efforts underway that further reduce blowing dust and its impacts. These include:

- A comprehensive rangeland management program;
- Tree planting program;
- Drip irrigation purchase program, and;
- A multi-party drought response planning effort coordinated through the State of Colorado Governor's office.
- In 2013, NRCS also tried a proactive approach to drought management by offering producers incentives to mitigate erosion hazard areas before they became an erosion problem.

These are but a few of the efforts at the local, county, and regional level underway to reduce emissions of PM_{10} and limit impacts.

6.0 Summary and Conclusions

APCD is requesting concurrence on exclusion of the PM_{10} values from the Lamar Municipal Building site (08-099-0002) on March 11, 2014, March 15, 2014, March 18, 2014, March 29, 2014, March 30, 2014, March 31, 2014, April 23, 2014, April 29, 2014 and November 10, 2014.

Elevated 24-hour PM_{10} concentrations were recorded in parts of Colorado on March 11, 2014, March 15, 2014, March 18, 2014, March 29, 2014, March 30, 2014, March 31, 2014, April 23, 2014, April 29, 2014, and November 10, 2014. All of the noted twenty-four-hour PM_{10} concentrations were above the 90^{th} percentile concentrations for their locations (see Section 3). These events exceeded the 99^{th} percentile values for these monitors. The statistical and meteorological data clearly shows that but for the high wind blowing dust events, Lamar would not have exceeded the 24-hour NAAQS on March 11, 2014, March 15, 2014, March 18, 2014, March 29, 2014, March 30, 2014, March 31, 2014, April 23, 2014, April 29, 2014, and November 10, 2014. Since at least 2005, there has not been an exceedance that was not associated with high winds carrying PM_{10} dust from distant sources in these areas. This is evidence that the events were associated with a measured concentration in excess of normal historical fluctuations including background.

The PM_{10} exceedances in Lamar would not have occurred if not for the following: (a) dry soil conditions over source regions with 30-day precipitation totals below the threshold identified as a precondition for blowing dust; and (b) meteorological conditions that caused strong surface winds over the area of concern.

Surface weather observations provide strong evidence that dust storms took place on March 11, 2014, March 15, 2014, March 18, 2014, March 29, 2014, March 30, 2014, March 31, 2014, April 23, 2014, April 29, 2014, and November 10, 2014. The meteorological conditions during these events in 2014 caused regional surface winds over 30 mph with gusts exceeding 40 mph. These speeds are above the thresholds for blowing dust identified in EPA draft guidance and in detailed analyses completed by the State of Colorado (see Blowing Dust Climatologies available at http://www.colorado.gov/airquality/tech_doc_repository.aspx#misc2). These PM_{10} exceedances were due to exceptional events associated with regional windstorm-caused emissions from erodible soil sources over a large source outside of the monitored areas. These sources are not reasonably controllable during significant windstorms under abnormally dry or moderate drought conditions.

Both wind speeds and soil moisture in surrounding areas were conducive to the generation of significant blowing dust. Multiple sources of data for the events in question and analyses of past dust storms in this area prove that these were natural events and, more specifically, significant natural dust storms originating outside the monitored areas. "But for" the large regional dust storms on March 11, 2014, March 15, 2014, March 18, 2014, March 29, 2014, March 30, 2014, March 31, 2014, April 23, 2014, April 29, 2014, and November 10, 2014, these exceedances would not have occurred.

7.0 References

7.1 March 11, 2014 References

United States Environmental Protection Agency, June 2012. *Draft Guidance on the Preparation of Demonstrations in Support of Requests to Exclude Ambient Air Quality Data Affected by High Winds under the Exceptional Events Rule.*

7.2 March 15, 2014 References

United States Environmental Protection Agency, June 2012. *Draft Guidance on the Preparation of Demonstrations in Support of Requests to Exclude Ambient Air Quality Data Affected by High Winds under the Exceptional Events Rule.*

7.3 March 18, 2014 References

United States Environmental Protection Agency, June 2012. *Draft Guidance on the Preparation of Demonstrations in Support of Requests to Exclude Ambient Air Quality Data Affected by High Winds under the Exceptional Events Rule.*

7.4 March 29, 2014 References

United States Environmental Protection Agency, June 2012. *Draft Guidance on the Preparation of Demonstrations in Support of Requests to Exclude Ambient Air Quality Data Affected by High Winds under the Exceptional Events Rule.*

7.5 March 30, 2014 References

United States Environmental Protection Agency, June 2012. *Draft Guidance on the Preparation of Demonstrations in Support of Requests to Exclude Ambient Air Quality Data Affected by High Winds under the Exceptional Events Rule.*

7.6 March 31, 2014 References

United States Environmental Protection Agency, June 2012. *Draft Guidance on the Preparation of Demonstrations in Support of Requests to Exclude Ambient Air Quality Data Affected by High Winds under the Exceptional Events Rule.*

7.7 April 23, 2014 References

United States Environmental Protection Agency, June 2012. *Draft Guidance on the Preparation of Demonstrations in Support of Requests to Exclude Ambient Air Quality Data Affected by High Winds under the Exceptional Events Rule.*

7.8 April 29, 2014 References

United States Environmental Protection Agency, June 2012. *Draft Guidance on the Preparation of Demonstrations in Support of Requests to Exclude Ambient Air Quality Data Affected by High Winds under the Exceptional Events Rule*.

7.9 November 10, 2014 References

United States Environmental Protection Agency, June 2012. *Draft Guidance on the Preparation of Demonstrations in Support of Requests to Exclude Ambient Air Quality Data Affected by High Winds under the Exceptional Events Rule*.