Chemical and Meteorological Analysis Applied to the San Joaquin Valley Air Pollution Control District's 2003 PM_{10} State Implementation Plan

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Overview

The goal of the chemical and meteorological analyses was to understand the causes of particulate matter concentrations that exceeded the National Ambient Air Quality Standards (NAAQS) in the San Joaquin Valley. Utilizing daily $PM_{2.5}$ and PM_{10} concentrations, chemical composition, and meteorological data, each PM_{10} episode was identified. An episode is defined as the complete period, from the beginning through the end, where PM_{10} concentrations increased to a peak that exceeded the Federal PM_{10} Standard of 150 $\mu g/m^3$ and then decreased dramatically as atmospheric dispersion conditions improved. Most of the episodes were separated by vigorous trough passages, which brought strong vertical mixing, moderate to high boundary layer mixing heights, precipitation, and wind speed and directional sheer with in the San Joaquin Valley boundary layer.

During each episode, cooler air at the surface and warm air above the mixing layer trapped pollutants under a strong temperature inversion. Horizontal movement of air was minimal and disorganized reducing dispersion and transport of pollutants. These conditions caused particulates to increase throughout the San Joaquin Valley. Under the poor mixing conditions, coarse and fine particulates accumulated leading to high particulate concentrations.

For the 2003 PM_{10} State Implementation Plan (SIP), **Table 1** summarizes the episode (event period), exceedance date, site location, PM_{10} concentration, and episode length of the PM_{10} exceedances, that occurred across the San Joaquin Valley from 1998 to 2001. PM_{10} exceedances were captured using routine and California Regional PM_{10} and $PM_{2.5}$ Air Quality Study (CRPAQS) mass data. Routine PM_{10} monitors operated on a one-in-six days sampling schedule. The CRPAQS PM_{10} monitors also operated on the same one-in-six days schedule, but were offset by three days from the routine network schedule. The CRPAQS mass data exceedances are not considered for compliance with the NAAQS, but are used in the December 1999 and January 2001 discussions to provide context for the episodes. Meteorological conditions and local emission activity led to similarities and differences between the episodes.

Table 1: HISTORICAL EPISODE CHART							
			Episode				Episode
Event Period	**Site Location**	**PM10**	**Length**	**Event Period**	**Site Location**	**PM10**	**Length**
Exceedance Date				***Exceedance Date***			
Dec. 20-Jan.16	Bakersfield-Golden	159	28	Dec.16-Jan.12	Clovis-Villa	155	26
12/31/1998	Visalia-Church	160		***1/1/2001***	Fresno-First	193	
Dec. 20-Jan.16	Oildale-Manor	156	28		Fresno-Drummond	186	
1/12/1999					Bakersfield-Cal.	186	
Oct.7-Oct. 28	Fresno-Drummond	162	21		Bakersfield-Gold	205	
10/21/1999	Corcoran-Patterson	174			Oildale-Manor	158	
	Turlock-Minaret	157		Dec.16-Jan.12	*Fresno-Drummond*	159	26
Nov. 8-Nov.17	Bakersfield-Golden	183	9	***1/4/2001***	Bakersfield-Cal.	190	
11/14/1999					*Bakersfield-Gold*	208	
Dec.10-Dec.31	Corcoran-Patterson	174	21		*Oildale-Manor*	195	
12/17/1999				Dec.16-Jan.12	Bakersfield-Cal.	159	26
Dec.10-Dec.31	*Fresno-Drummond*	168	21	***1/7/2001***	Bakersfield-Golden	174	
12/23/1999	*Hanford-S Irwin*	156			Corcoran-Patterson	165	
					Hanford-Irwin	185	
					Modesto-14th	158	
				Oct. 31-Nov. 10	Hanford-Irwin	155	11
				11/9/2001			

A majority of the episodes were characterized by a prolonged period (two to three weeks) of limited mixing and light wind flow. The November 14, 1999 and November 9, 2001 were an exception, when strong stability and local emissions drove the PM_{10} monitoring sites over the standard in less than a week and a half. Winter exceedances (December and January) were characterized by an increase in fine particles to a level that dominated filter samples. Fall exceedances (October and November) were dominated by coarse particles. To a lesser extent in the fall and a greater extent in the winter, cool damp mornings and restricted vertical air movement contributed to the formation of nitrates and sulfates. Total carbon concentrations from combustion sources remained proportionally the same during the fall and winter exceedances.

Due to stagnant weather conditions, the elevated PM_{10} measurement that resulted in an exceedance of the NAAQS were caused primarily by local emission sources, rather than background or long-range transport of material in most of the episodes. However, during the CRPAQS 2001 episode given the length of the episode and the large contributions from secondary components, there was an underlying regional component to this episode as it progressed. Local carbon and geologic contributions added to this regional component and influenced site to site concentration variations. As the CRPAQS episode continued, PM and precursors became more homogeneous across the region. This resulted in $PM_{2.5}$ concentrations at rural sites lagging those of urban sites, and rural concentrations continued to build throughout the episode

The October 1999 particulate episode was unique and did not follow the general meteorological and chemical pattern observed in other episodes. Concentrations during this event were dominated by geological particles (PM_{10}), with significant contributions from fine particulates of ammonium nitrate and sulfate and total carbon. The abundance of fine particulates in the samples may have been due to abnormalities in atmospheric chemistry reactions. Due to several wildfires to the north and a major tire fire at Westley earlier in October, particulate loading aloft may have decreased solar radiation intensity measurements across the Valley Floor. With reduced solar radiation, the atmospheric chemistry reactions may have changed from the ozone forming regime of mid-October to the secondary particulate regime of late November. As a result, the

geological particulates dominated the samples, but the fines exerted a large influence. Limited afternoon heating and stagnant weather conditions, resulted in local sources driving PM_{10} concentrations to exceed the Federal Standards.

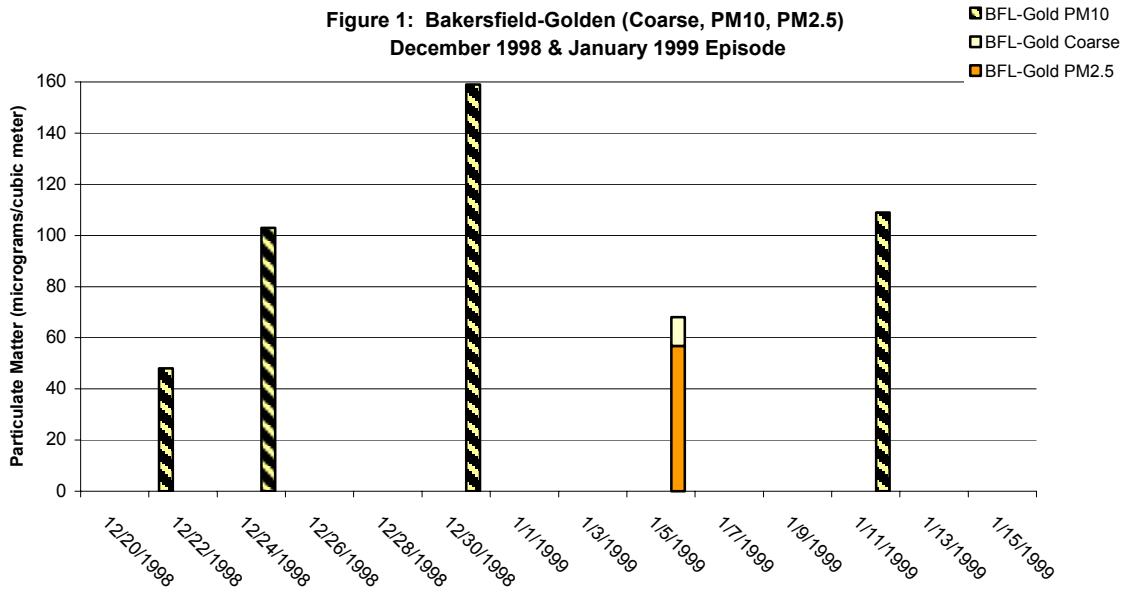
With these similarities and differences among the episodes, each PM_{10} episode is discussed in detail in the following sections. PM_{10} and $PM_{2.5}$ concentrations, chemical composition, and meteorological data around the exceedance dates are evaluated and analyzed to identify the characteristics and uniqueness of the exceedances at the FRM and CRPAQS PM_{10} monitoring sites.

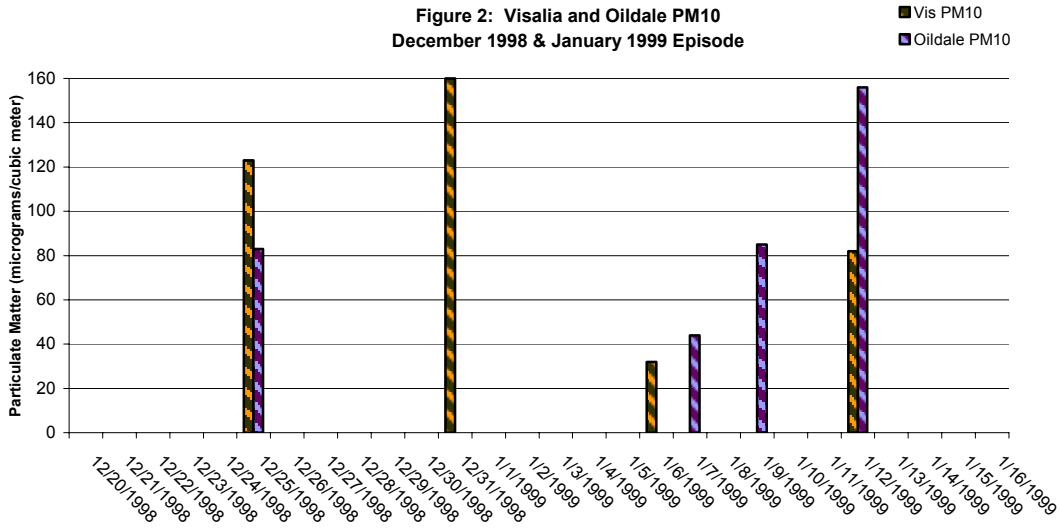
Tuesday, January 12, 1999 Episode

The January 1999 particulate episode was characterized by a prolonged period (four weeks) of strong stability and light wind flow, which resulted in poor atmospheric dispersion conditions across the San Joaquin Valley. Coarse and fine particulates accumulated during the period, leading to two separate exceedance days on Thursday, December 31, 1998 and Tuesday, January 12, 1999. A weak upper level disturbance moved over the region on December 31, 1998, dividing the episode into two separate periods. Concentrations were dominated by the fine particulates ($PM_{2.5}$) of ammonia nitrate and sulfate and were most prevalent in the central and southern San Joaquin Valley. The first period was marked by strong stability and light wind flow, which led to exceedances at Bakersfield-Golden with a PM_{10} concentration of 159 $\mu g/m^3$ and Visalia-Church with a PM_{10} concentration of 160 $\mu g/m^3$ on December 31, 1998 (**Figure 1 & 2**). PM_{10} concentrations at other central and southern Valley locations were much lower, below 115 $\mu g/m^3$, with the exception of nearby Bakersfield-California, which measured a PM_{10} concentration of 148 $\mu g/m^3$. However, the December 1998 exceedances are included in the discussion to provide context to the episode. After the weak trough passage on December 31, 1998 both primary and secondary pollutants accumulated once again leading to an exceedance of the 24-hour standard at Oildale-Manor, with a PM_{10} concentration of 156 $\mu g/m^3$ on January 12, 1999 (**Figure 2**). The next highest PM_{10} concentration measured was at Bakersfield-Golden with 109 $\mu g/m^3$. PM_{10} concentrations at other central and southern Valley locations were below 90 $\mu g/m^3$. During both periods, strong high pressure at the surface and aloft resulted in limited afternoon mixing and light offshore wind flow. Cool damp mornings and strong stability contributed to the formation of nitrates and sulfates during the episode. Chemical composition and meteorological data around December 31, 1998 and January 12, 1999, were evaluated and analyzed to identify the characteristics and uniqueness of the exceedances at Bakersfield-Golden, Visalia-Church, and Oildale-Manor.

The December 31, 1998 exceedances are not considered for compliance with the current Particulate Matter State Implementation Plan (SIP) because the exceedances fall outside of the three year required window. Although PM_{10} sampling is not conducted daily, information from changes in the meteorological conditions suggest that the highest PM_{10} concentration was not captured on the sampled day (December 31, 1998). Daily meteorological conditions suggested that the highest PM_{10} concentrations may have occurred on December 29th, when stability was the strongest. With the lack of chemical data for Bakersfield-Golden, similarities in trends from other sites were analyzed in order to conclude which chemical components were responsible for the exceedance. The analysis shows that the exceedance was driven by high concentrations of ammonium nitrate and sulfate that comprised 74% of the PM_{10} mass at nearby Bakersfield-California. At Visalia, the nitrate and sulfate chemical component of the PM_{10} sample was slightly higher compared to Bakersfield-California. These have accounted for the slight differences in the PM_{10} mass between the two sites. The other major chemical components of the sample were 21% total carbon and 13% geological of the PM_{10} mass. The size fraction data across the Valley indicated that most of the

PM_{10} was in the $PM_{2.5}$ fraction, with an average $PM_{2.5}/PM_{10}$ mass ratio of greater than 0.8.





This was further supported by the high $PM_{2.5}$ concentrations that reached 122 $\mu g/m^3$ at nearby Bakersfield-California accounting for 81 percent of the PM_{10} mass and at Visalia of 139 $\mu g/m^3$ accounting for 83 percent of the PM_{10} mass.

The concentration of coarse material may have been higher at the Bakersfield-Golden as is indicated by nearby Bakersfield-California and Visalia having the highest geological component of 13 $\mu g/m^3$ compared to other Valley locations. Urban geological may have influenced the sample at Bakersfield-Golden and Visalia. Light afternoon mixing and wind flow may have allowed some transported contribution from agricultural burning in Merced, Stanislaus, and San Joaquin Counties on December 31st. However a no burn day across the rest of the Valley, indicates that stagnant

conditions favored a larger influence from local emissions. Burn variances and noncompliant agricultural burns may have contributed to a small portion of the samples. Overnight minimum temperatures in the mid to upper 30's suggest that residential wood burning may have been a significant source of PM_{10}. The potential of increased residential wood burning on New Year's Eve, may have led to increased concentrations of total carbon in the samples. Analysis of PM_{10} and $PM_{2.5}$ concentrations showed that meteorological conditions led to the pollution buildup. Ammonium nitrate and sulfates, carbon, and geological material increased prior to the exceedances on December 31, 1998 and then later on January 12, 1999.

Meteorologically, dispersion worsened and particulate formation conditions strengthened from December 20th to the 29th. However, on December 31st, the exceedance day, dispersion conditions began to improve under decreasing stability. After the passage of a cold front on December 20th, which brought 0.10 inches of rainfall to Bakersfield, moisture was available for atmospheric chemistry reactions. Humidity measurements of 85 – 100 % in the morning across the Valley Floor showed a moist atmosphere with light fog and haze being reported. These cool damp mornings and strong stability favored the formation of nitrates and sulfates. Synoptically, the eastern Pacific high remained strong through December 29th and gradually weakened through December 31st. The high rebuilt over the region on January 1st, keeping a lid over the San Joaquin Valley trapping pollutants within the Valley boundary layer through January 16, 1999.

With a strong lid in place and maximum high temperatures on December 31, 1998 in the mid to upper 50's, the afternoon hours were marked by limited mixing, resulting in increasing particulate conditions. Mixing heights at Fresno remained below 500 feet under a strong inversion for 14 hours on December 31, 1998 breaking out by 10:00 AM and reforming shortly after 7:00 P.M. During the afternoon hours, there were higher mixing depths (maximum mixing depth of 4,500 feet), but the bulk of the day had limited to marginal mixing. Maximum temperatures for the December 1998 episode were slightly above normal, further illustrating the intensity of the high pressure system that was controlling the region's weather. Satellite imagery depicted extensive moisture (high and mid-level cloudiness) across the region on the 31st, resulting in slightly lower levels of solar radiation intensity. Along with the lower solar radiation intensities due to the low sun angle and limited daylight hours, the atmospheric chemistry reactions may have favored the secondary particulate forming regime.

Chemical composition and meteorological data showed with limited mixing depths and light and disorganized wind flow, these conditions resulted in minimal transport and dispersion of pollutants. Both primary and secondary pollutants from local emissions around Bakersfield-Golden and Visalia accumulated resulting in the exceedance of the 24-hour PM_{10} standard on December 31, 1998.

Meteorological stability between December 31, 1998 and January 10, 1999 remained strong leading to moderate to elevated particulate conditions continuing across the San Joaquin Valley. Weak disturbances were moving through northern California prior to

the exceedance day, inhibiting widespread exceedance levels. The strong ridge that dominated the region's weather finally began to breakdown on January 10, 1999, with decreasing stability. However, both primary and secondary pollutants from local emissions around Oildale-Manor accumulated resulting in an exceedance of the 24-hour PM_{10} standard on January 12, 1999 (**Figure 2**); with nearby Bakersfield Golden recording a peak PM_{10} concentration on the exceedance day of 109 $\mu g/m^3$. Additionally, later on January 14, 1999 $PM_{2.5}$ monitoring at nearby Bakersfield California showed peak concentrations of 109 $\mu g/m^3$. Concentrations were dominated by the fine particulates ($PM_{2.5}$) of ammonia nitrate and sulfate and were most prevalent in the central and southern San Joaquin Valley. During the period, strong high pressure at the surface and aloft resulted in limited afternoon mixing and light offshore flow. Moisture from recent rainfall was available and strong morning stability contributed to the formation of nitrates and sulfates during the episode. These meteorological conditions led to elevated particulate concentrations. Chemical composition and meteorological data around January 12, 1999, was evaluated and analyzed to identify the characteristics and uniqueness of the exceedance at Oildale-Manor.

Although PM_{10} sampling is not conducted daily, information from more frequent $PM_{2.5}$ sampling combined with an assessment of changes in the meteorological conditions suggest that the highest PM_{10} concentration was not captured on the sampled day. Analysis of daily meteorological conditions suggested that the highest PM_{10} concentrations may have occurred on January 10th, when stability was the strongest. Chemical data from Oildale-Manor showed that the exceedance was driven by high concentrations of ammonium nitrate and sulfate comprising about 57 % of the PM_{10} mass. The size fraction data across the Valley indicated that most of the PM_{10} was in the $PM_{2.5}$ fraction, with an average $PM_{2.5}/PM_{10}$ mass ratio of greater than 0.8. This was further supported by the high $PM_{2.5}$ concentrations that reached 84 $\mu g/m^3$ at nearby Bakersfield-California.

The concentration of coarse material was minimal on the exceedance day, indicating that the majority of the sample was comprised of fine particulates. Agricultural burning may not have contributed as a potential source of PM on the exceedance day, because January 8 through January 12, 1999 were declared No Burn Day's District-wide. However, burn variances and noncompliant agricultural burns may have contributed to a small portion of the samples. Overnight minimum temperatures in the upper 20's to low 30's suggested that residential wood burning may have been a significant source of PM_{10}. Residential wood burning may have been a potential source of carbon. Concentrations of total carbon were measured at three sites in the Valley and ranged from 12 $\mu g/m^3$ at Modesto-14th Street to 27 $\mu g/m^3$at Fresno-1st. PM_{10} and $PM_{2.5}$ concentrations showed that meteorological conditions led to the exceedance at Oildale-Manor. Local sources of ammonia nitrate and sulfate coupled with moderately strong atmospheric stability resulted in the high PM_{10} recorded at the exceedance site.

Meteorologically, dispersion conditions began to improve slightly a few days prior to the January 12, 1999 exceedance. After the passage of a weak cold front on December 20th, which brought 0.10 inches of rainfall to Bakersfield, some moisture was available

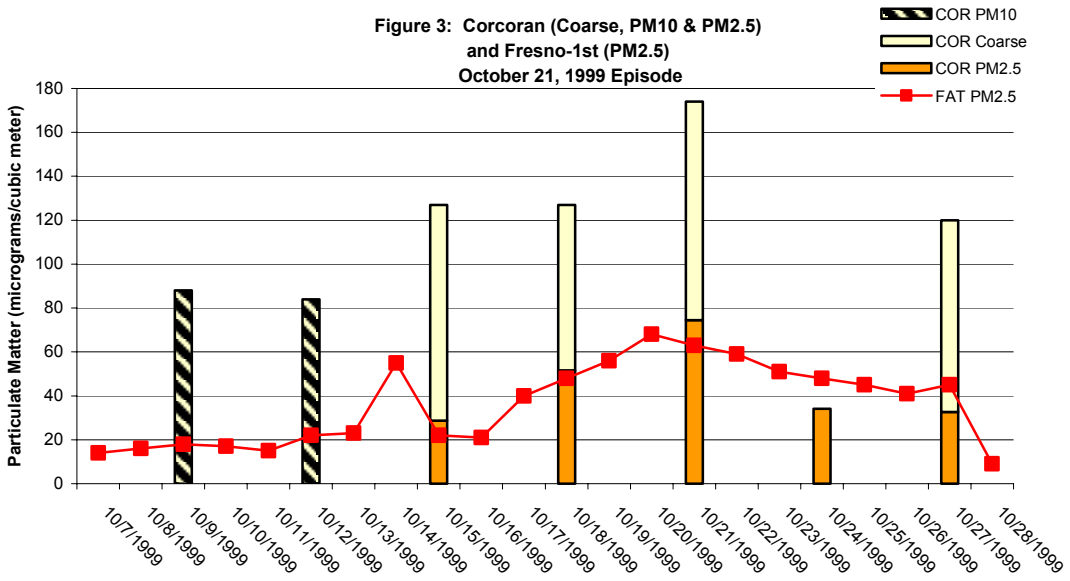
for atmospheric chemistry reactions. Humidity measurements of 85-95% in the morning across the Valley Floor showed a moist atmosphere, with light to dense fog and haze being reported. These cool damp mornings and strong stability favored the formation of nitrates and sulfates. Synoptically, the eastern Pacific high began to break down on the 10th, but stability remained strong across the region until the exceedance day. The high kept a strong lid in place over the Valley, trapping pollutants within the San Joaquin Valley boundary layer.

With a strong lid in place and maximum high temperatures in the low to mid 50's, the afternoon hours were marked by limited mixing, resulting in elevated particulate conditions. Mixing heights at Fresno remained below 500 feet for 21 hours on January 12th, breaking out by 3 P.M. and reforming shortly after 5:00 P.M. During the afternoon hours, there were higher mixing depths (maximum mixing depth of 1,000 feet), but the bulk of the day had limited mixing. Light to dense fog was reported at the Valley surface during the morning hours of January 12th, resulting in lower solar radiation intensities. Along with lower solar radiation intensities due to the low sun angle and decreasing daylight hours, the atmospheric chemistry reactions may have favored the secondary particulate forming regime.

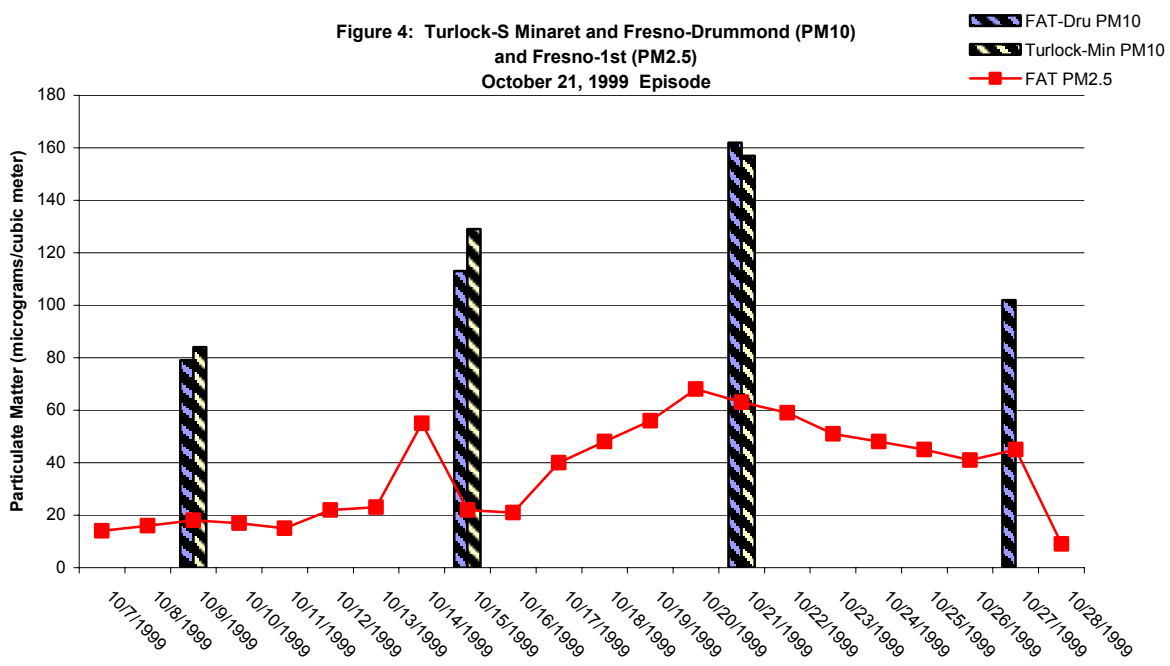
Chemical composition and meteorological data showed limited mixing depths and light and disorganized wind flow resulted in minimal transport and dispersion of pollutants. A major cause of the increase in PM10 at Oildale prior to January 12 appears to be from nitrates, which was more than double that concentration measured at Bakersfield California. This would suggest that something very localized or unique was occurring around Oildale that went beyond what was happening in other parts of the Valley. Both primary and secondary pollutants from local emissions around Oildale-Manor accumulated resulting in the exceedance of the 24-hour PM_{10} standard on January 12, 1999.

Thursday, October 21, 1999 Episode

The October 21, 1999 particulate episode was characterized by a prolonged period (three weeks) of strong stability and light wind flow, which resulted in poor atmospheric dispersion conditions across the San Joaquin Valley. Coarse and fine particulates accumulated during the period, leading to an exceedance of the 24-hour PM_{10} standard at three monitoring sites on October 21, 1999. Concentrations were dominated by geological particulates (PM_{10}), with significant contributions from fine particulates of ammonium nitrate and sulfate and total carbon and were most prevalent in the northern and central portions of the Valley and slightly lower in the southern portion (Kern County). The highest PM_{10} concentration of 174 $\mu g/m^3$ was measured at Corcoran-Patterson **(Figure 3)**. The second and third highest PM_{10} concentration of 162 and 157 $\mu g/m^3$ were measured at Fresno-Drummond and Turlock, respectively **(Figure 4)**. During the period, strong high pressure at the surface and aloft resulted in limited afternoon mixing and light offshore wind flow. Cool damp mornings and warm dry afternoons contributed to the geologic contribution, as well as nitrate and sulfate formation during the episode. A combination of these particulate species and poor dispersion conditions elevated particulate concentrations. Chemical composition and meteorological data around October 21, 1999, was evaluated and analyzed to identify the characteristics and uniqueness of the exceedances at Corcoran-Patterson, Fresno-Drummond, and Turlock- S Minaret.



Although PM_{10} sampling is not conducted daily, information from more frequent $PM_{2.5}$ sampling combined with an assessment of changes in the meteorological conditions suggest that the highest PM_{10} concentration was not captured on the sampled day. Daily $PM_{2.5}$ sampling and meteorological conditions suggested that the highest PM_{10} concentrations may have occurred on October 20th, when Fresno 1st measured a peak $PM_{2.5}$ concentration of 68 $\mu g/m^3$. Chemical composition data indicated that geological material was the single largest component of the PM_{10} during this episode.



While geological dominated the PM_{10} mass, increases in other components (carbon, and ammonium nitrate and sulfate) were what drove the increase in concentration to over the PM_{10} Standard. It appears that the exceedance was driven by high concentrations of geologic comprising about 50 to 60 % of the PM_{10} mass. The other components of the samples were composed of 15 to 25 % ammonium nitrate and sulfate and 10 to 20 % total carbon of the PM_{10} mass. The size fraction data across the Valley indicated that most of the PM_{10} was in the PM_{10} fraction, with an average $PM_{2.5}/PM_{10}$ mass ratio greater than 0.35. This was further supported by the high coarse concentrations that reached 100 $\mu g/m^3$ at Corcoran-Patterson, accounting for 57 percent of the PM10 mass **(Figure 3)**.

The concentration of coarse material may have been elevated due to the lack of precipitation since June 2, 1999 contributing to the high geologic fraction. Dry conditions and low soil moisture content, resulted in higher dust emission activity from agricultural land preparing and harvesting and urban geological activities. Agricultural burning probably did not contribute to PM on the exceedance day, because October 17 through October 21, 1999 were declared No Burn Days District-wide. However, burn variances and noncompliant agricultural burns may have contributed to a small portion of the samples. Overnight temperatures in the mid 50's suggested that residential wood burning was not likely a potential source of PM_{10}. PM_{10} and $PM_{2.5}$ concentrations showed that meteorological conditions led to the pollution buildup.

Meteorologically, dispersion worsened and particulate formation conditions strengthened from October 7th to the 20th. However, on October 21st, the day of the exceedance, dispersion conditions began to slightly improve under weakening stability. The lack of precipitation since June 2nd, 1999 may have contributed to the geologic fraction. Dry conditions and low soil moisture content, resulted in higher dust emission

activity. Humidity measurements of 60-80% in the morning across the Valley Floor showed a dry to moist atmosphere, with no fog present. The cool damp mornings and strong stability favored some formation of nitrate and sulfate particulates. The eastern Pacific high built over the San Joaquin Valley on October 7th and dominated the region's weather through the 20th. The high began to slowly break down on the 21st, but remained strong, trapping pollutants within the San Joaquin Valley boundary layer.

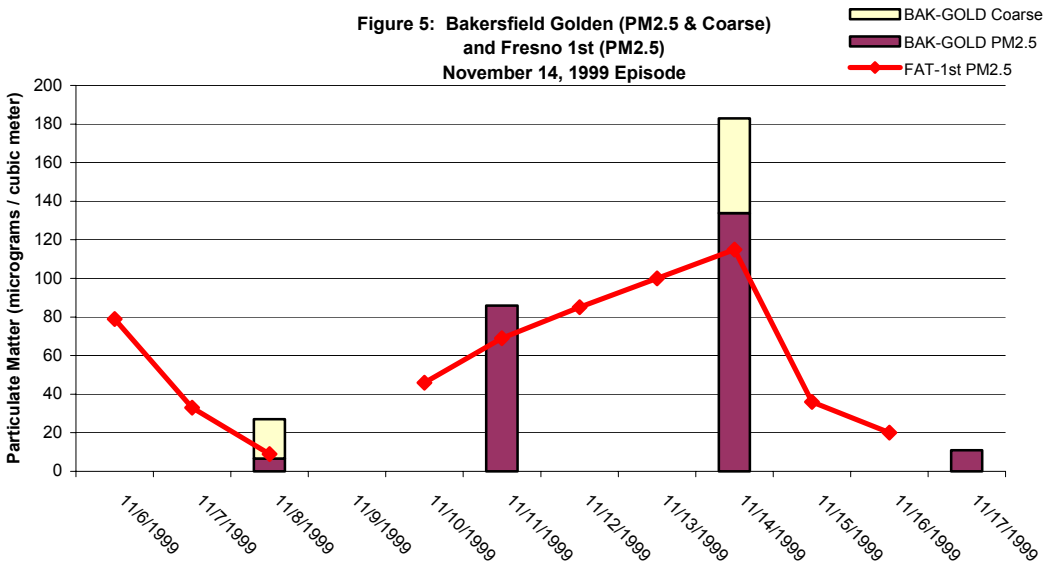
With a strong lid in place aloft and maximum high temperatures in the mid-80's, the afternoon hours were marked by limited mixing, resulting in elevated particulate conditions. Mixing heights at Fresno remained below 500 feet under a strong inversion for 16 hours on the 21st, breaking out by 12:00 P.M. and reforming by 5:00 P.M. During the afternoon hours, there were higher mixing depths (maximum mixing depth near 5,000 feet), but the bulk of the day had limited mixing. Maximum and minimum temperatures for the October 1999 were above normal, further illustrating the intensity of the high pressure system that was controlling the region's weather. Partly cloudy skies and hazy conditions reported at the Valley surface on October 21st resulted in lower levels of solar radiation intensities. Along with several wildfires to the north and along the California Coast and a major tire fire at Westley earlier in the month, particulate loading aloft may have further decreased solar radiation intensity measurements across the Valley Floor. The reduction of solar radiation intensity may have led to lower mixing depths and increased atmospheric chemistry reactions forming particulates. Ambient air samples around the Westley tire fire site on the 21st confirmed minimal hydrocarbon and carbon monoxide concentrations, showing little if any impact around the tire fire. However, visual observations of the tire fire plume behavior indicated transport and mixing well down-wind of the site, which may have fumigated and impacted other parts of the San Joaquin Valley.

With reduced solar radiation, the atmospheric chemistry reactions may have changed from the ozone-forming regime of mid-October to the secondary particulate regime that occurs during late November. The eight-hour average ozone measurements on October 20th showed one exceedance of the Federal standard at Clovis of 87 ppb. The following day a significant change in the photochemical reactions occurred in the atmosphere, with the eight-hour average ozone measurements dropping to well below the standard at Clovis to 73 ppb. Atmospheric stability remained rather strong and persistent on the 21st, however, solar radiation measurements Valley-wide showed reduced intensities. The change in the ozone measurements across the San Joaquin Valley may be illustrative of the atmospheric chemistry reactions shifting from an ozone to a particulate-forming regime. The change in the atmospheric chemistry reactions may have led to an increase in nitrate and sulfate in the PM samples that were measured on October 21st compared to the 15th. Increasing accumulations of carbon can be contributed to the deteriorating dispersion conditions experienced during the days preceding October 21st. It does not appear that any one source of carbon was a dominant contributor. Under the strong lid, wind flow was light and disorganized, leading to minimal transport and dispersion. As a result, local emissions may have contributed to the exceedances experienced on the 21st.

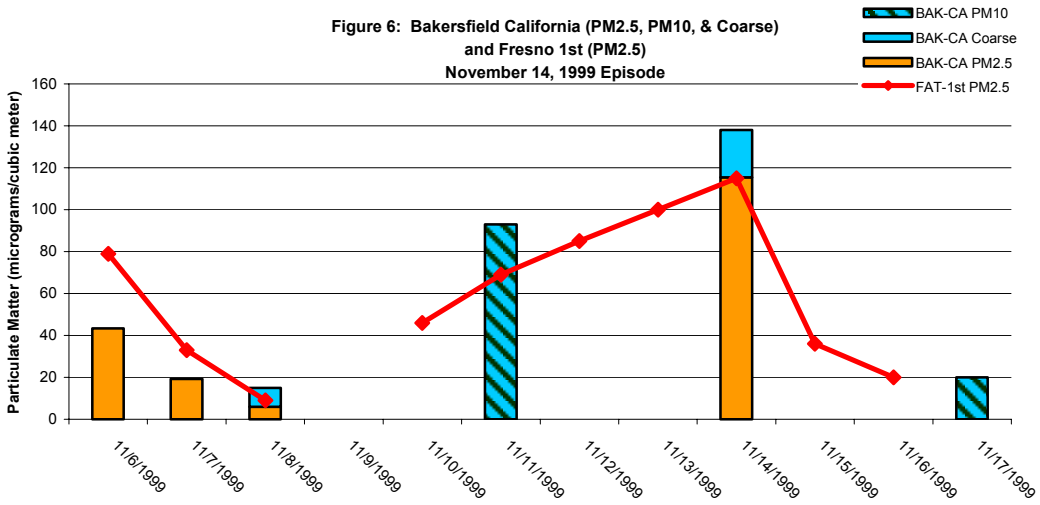
Chemical composition and meteorological data showed limited mixing depths and light and disorganized wind flow resulted in minimal transport and dispersion of pollutants. Solar radiation measurements showed lower levels of intensities on the 21st compared to the 20th, resulting in an anomalous shift of the atmospheric chemistry reactions from an ozone to a particulate-forming regime. Both primary and secondary pollutants from local emissions around Corcoran-Patterson, Fresno-Drummond, and Turlock- S Minaret accumulated, resulting in the exceedance of the 24-hour PM_{10} standard at three monitoring sites on October 21, 1999.

Sunday, November 14, 1999 Episode

The November 14, 1999 particulate episode was characterized by a short period (9 days) of strong stability and light wind flow, which resulted in poor atmospheric dispersion conditions across the San Joaquin Valley. Coarse and fine particulates accumulated during the period, leading to an exceedance of the 24 - hour standard at one monitoring site on November 14, 1999. Concentrations were dominated by the fine particulates ($PM_{2.5}$) of ammonia nitrate and sulfate and were most prevalent in the central and southern San Joaquin Valley. The highest PM_{10} measured was 183 $\mu g/m^3$ (**Figure 5**) at Bakersfield-Golden; whereas, PM_{10} concentrations at other central and southern Valley locations were much lower between 130 to 140 $\mu g/m^3$ (**Figure 6**). During the period, strong high pressure at the surface and aloft resulted in limited afternoon mixing and light offshore wind flow. Cool damp mornings and strong stability contributed to the formation of nitrates and sulfates during the episode. These meteorological conditions led to elevated particulate concentrations. Chemical composition and meteorological data around November 14, 1999, was evaluated and analyzed to identify the characteristics and uniqueness of the exceedance at Bakersfield-Golden.



Although PM_{10} sampling is not conducted daily, information from more frequent $PM_{2.5}$ sampling combined with an assessment of changes in the meteorological conditions suggest that the highest PM_{10} concentration was captured on the sampled day. With no chemical composition data available at the exceedance site, similarities in trends from other sites were analyzed in order to conclude which chemical components were responsible for the exceedance. It appears that the exceedance was driven by high concentrations of ammonium nitrate and sulfate comprising about 50 to 60 % of the PM_{10} mass. The other chemical components of the samples were composed of 10 to 15 % total carbon and 10 to 15% geological of the PM_{10} mass. The size fraction data across the Valley indicated that most of the PM_{10} was in the $PM_{2.5}$ fraction, with an



average $PM_{2.5}/PM_{10}$ mass ratio of greater than 0.8. This was further supported by the high $PM_{2.5}$ concentrations that reached 134 $\mu g/m^3$ at the exceedance site, accounting for 73 percent of the PM_{10} mass, (**Figure 5**). All monitoring sites exceeded the federal $PM_{2.5}$ standard on the exceedance day.

The concentration of coarse material may have been higher at the exceedance site relative to other sites in the Valley, as indicated by the higher coarse fraction at Bakersfield Golden as compared to other sites in the Valley. The coarse mass at Bakersfield-Golden, at 49 $\mu g/m^3$, was 26 $\mu g/m^3$ higher compared to nearby Bakersfield-California, indicating that a larger concentration of urban geological material at Bakersfield-Golden may be responsible for the large disparity in the PM_{10} concentrations. Agriculture burning probably did not contribute to PM on the exceedance day, because November 13 and 14, 1999 were declared No Burn Day's District-wide. However, burn variances and noncompliant agricultural burns may have contributed to a small portion of the samples. Although minimum temperatures were mild compared to later in the middle of winter, overnight temperatures in the mid to upper 40's suggest that residential wood burning may have been a potential source of PM_{10}. PM_{10} and $PM_{2.5}$ concentrations showed that meteorological conditions led to the short pollution buildup. During the buildup time leading to the exceedance on November 14, 1999, carbon concentrations decreased or remained stable, whereas concentrations of geologic, ammonia nitrate, and sulfate increased.

Meteorologically, dispersion worsened and particulate formation conditions strengthened from November 8th to the 14th. After the passage of a cold front on November 8th, which brought 0.31 inches of rainfall to Bakersfield, moisture was available for atmospheric chemistry reactions. Humidity measurements of 85-100% in the morning across the Valley Floor showed a very moist atmosphere, with light to dense fog and haze being reported. The cool damp mornings and strong stability favored the formation of nitrates and sulfates. The eastern Pacific high built over the San Joaquin Valley on November 8th and dominated the region's weather through the

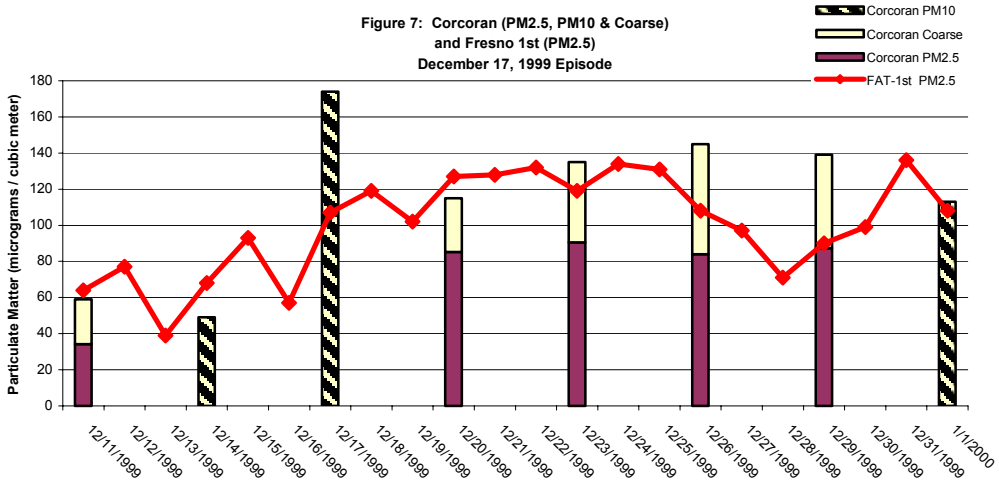
14th. The high strengthened and intensified a few days prior to the 14th, further tightening the lid and trapping pollutants within the San Joaquin Valley boundary layer.

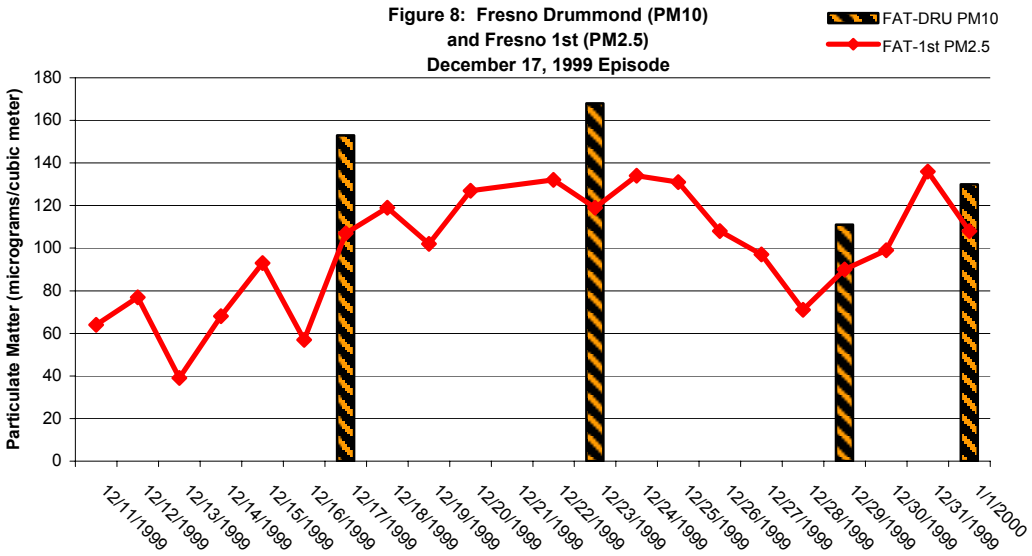
With a strong lid in place and maximum high temperatures in the mid to upper 70's, the afternoon hours were marked by limited mixing, resulting in increasing particulate conditions. Mixing heights at Fresno remained below 500 feet under a strong inversion for 16 hours on November 14, 1999 breaking out by 11:00 AM and reforming shortly after 5:00 P.M. During the afternoon hours, there were higher mixing depths (maximum mixing depth of 2,000 feet), but the bulk of the day had limited mixing. Maximum and minimum temperatures for the November 1999 episode were above normal, further illustrating the intensity of the high pressure system that was controlling the region's weather. Satellite imagery depicted scattered upper level moisture (high cloudiness) over the region and light fog being reported at the Valley surface on the November 14, resulting in slightly lower levels of solar radiation intensity. Along with lower solar radiation intensities due to the low sun angle and decreasing daylight hours, the atmospheric chemistry reactions may have favored the secondary particulate forming regime.

Chemical composition and meteorological data showed limited mixing depths and light and disorganized wind flow resulted in minimal transport and dispersion of pollutants. Both primary and secondary pollutants from local emissions around Bakersfield-Golden accumulated, resulting in the exceedance of the 24-hour PM_{10} standard on November 14, 1999.

December 1999 Episode
Friday, December 17, 1999 and Thursday, December 23, 1999

The December 1999 particulate episode was characterized by a prolonged period (three weeks) of strong stability and light wind flow, which resulted in poor atmospheric dispersion conditions across the San Joaquin Valley. Coarse and fine particulates accumulated during the period, leading to two separate exceedance days on December 17 and 23, 1999. Concentrations were dominated by fine particulates ($PM_{2.5}$) of ammonia nitrate and sulfate and were most prevalent in the central and southern San Joaquin Valley. The highest PM_{10} measured on December 17, 1999 was 174 $\mu g/m^3$ (**Figure 7**) at Corcoran, a federal reference monitoring (FRM) site. PM_{10} at other central and southern Valley locations were elevated but not over the standard. For example, Fresno-Drummond recorded 153 $\mu g/m^3$ on December 17, 1999 (**Figure 8**). Stagnation conditions continued through December 23, 1999, when two MiniVol Samplers, which were part of the California Regional Particulate Air Quality Study (CRPAQS) registered the second and third highest concentrations at Fresno-Drummond at 168 $\mu g/m^3$ and Hanford-South Irwin, at 156 $\mu g/m^3$. The CRPAQS exceedances are not considered for compliance with the standards, but are used in the discussion to provide context to the episode. During the period, strong high pressure at the surface and aloft resulted in limited afternoon mixing and light offshore wind flow. Cool damp mornings and strong stability contributed to the formation of nitrates and sulfates during the episode. Chemical composition and meteorological data around December 17 and 23, 1999 were evaluated and analyzed to identify the characteristics and uniqueness of the exceedances at Corcoran, Fresno-Drummond, and Hanford-South Irwin.





Although PM_{10} sampling is not conducted daily, information from more frequent $PM_{2.5}$ sampling combined with an assessment of changes in the meteorological conditions suggest that the highest PM_{10} concentration was not captured on the sample day. Daily $PM_{2.5}$ sampling and meteorological conditions suggested that the highest PM_{10} concentrations may have occurred on December 18th, when Fresno 1st measured a peak $PM_{2.5}$ concentration of 119 $\mu g/m^3$. With the lack of chemical composition data for the exceedance site, similarities in trends from other sites such as Fresno-Drummond were drawn in order to determine the chemical components responsible for the December 17th exceedance. The analysis shows that the exceedance was driven by high concentrations of ammonium nitrate and sulfate that comprised of 55 to 75 % of the PM_{10} mass. The other major chemical components of the samples were 25 to 30 % total carbon and 20 to 25 % geological of the PM_{10} mass. The size fraction data across the Valley indicated that most of the PM_{10} was in the $PM_{2.5}$ fraction, with an average $PM_{2.5}/PM_{10}$ mass ratio greater than 0.8. This was further supported by the high $PM_{2.5}$ concentrations that reached 107 $\mu g/m^3$ at nearby Fresno-First, (**Figure 7**).

The concentration of total carbon (27% of PM_{10} mass) and coarse material (20% of PM_{10} mass) at Fresno Drummond show the main constituents of the particulate samples on December 17, 1999 may have come from local sources (residential wood burning and urban/agricultural geologic). Light afternoon mixing and wind flow may have allowed some transported contribution from agricultural burning in Merced, Stanislaus, and San Joaquin Counties on December 17th. However a no burn day across the rest of the Valley, indicates that stagnant conditions favored a larger influence from local emissions. Burn variances and noncompliant agricultural burns may have contributed to a small portion of the samples. Overnight minimum temperatures in the low 30's suggest that residential wood burning may have been a significant source of PM_{10}. Analysis of PM_{10} and $PM_{2.5}$ concentrations showed that meteorological conditions led to the pollution buildup. Ammonium nitrate and sulfates, carbon, and geological material increased prior to the exceedance on December 17, 1999 and then later accumulated further leading to two other monitoring sites exceedances on December 23.

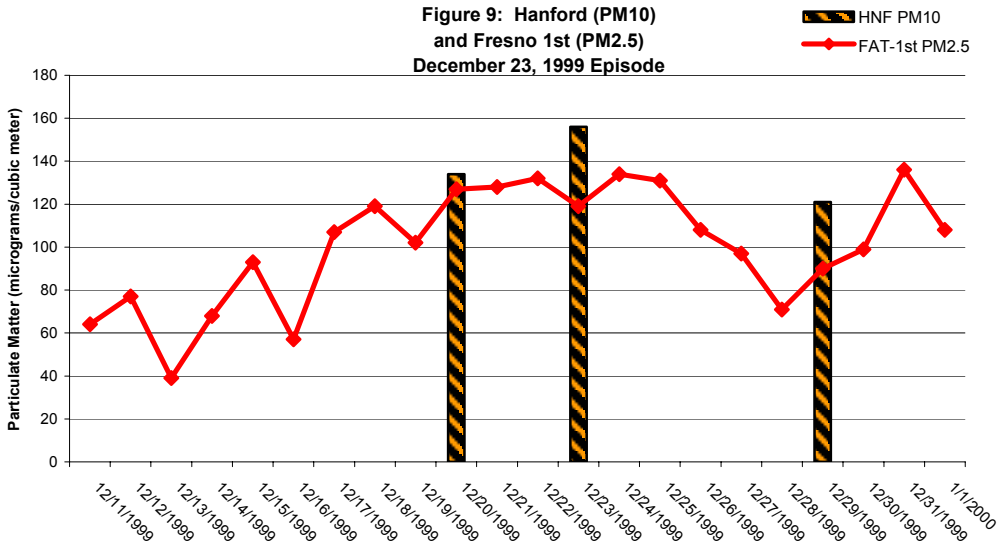
Meteorologically, dispersion worsened and particulate formation conditions strengthened from December 10th to the 17th. After the passage of a weak cold front on December 9th, which brought trace amounts of precipitation to the region, moisture was available for atmospheric chemistry reactions. Humidity measurements of 85 – 100 % in the morning across the Valley Floor showed a moist atmosphere, with light to dense fog and haze being reported. These cool damp mornings and strong stability favored the formation of nitrates and sulfates. Synoptically, the eastern Pacific high built over the San Joaquin Valley on December 10th and dominated the region's weather through the 31st. The high strengthened and intensified a few days prior to the 17th, further tightening the lid and trapping pollutants within the San Joaquin Valley boundary layer.

With a strong lid in place aloft and maximum high temperatures in the upper 50's, the afternoon hours were marked by limited mixing, resulting in increasing particulate potential. Mixing heights at Fresno remained below 500 feet under a strong inversion for 18 hours on December 17th, breaking out after 12:00 P.M and reforming shortly before 5:00 P.M. During the afternoon hours, there were higher mixing depths (maximum mixing depth of 2,000 feet), but the bulk of the day had limited mixing. Maximum and minimum temperatures for this episode were slightly above normal, further illustrating the intensity of the high pressure system that was controlling the region's weather. Light fog was reported at the Valley surface during the early morning hours of December 17th, resulting in slightly lower solar radiation intensities. Along with lower solar radiation intensities due to the early morning fog, lowering sun angle, and decreasing daylight hours, the atmospheric chemistry reactions may have favored the secondary particulate forming regime.

Chemical composition and meteorological data showed limited mixing depths and light and disorganized wind flow resulted in minimal transport and dispersion of pollutants. Both primary and secondary pollutants from local emissions around Corcoran accumulated resulting in the exceedance of the 24- hour PM_{10} standard on December 17, 1999.

Between December 17th through the 23rd, meteorological conditions remained stable leading to elevated particulate conditions continuing across the San Joaquin Valley. Without a significant weather disturbance moving through the area to scour out the particulates, PM_{10} concentrations became a region-wide problem and came very close to the standard at three monitoring sties (Fresno-1st at 154 $\mu g/m^3$, Visalia at 152 $\mu g/m^3$, and Clovis at 151 $\mu g/m^3$) on December 20, 1999. PM_{10} concentrations from Fresno-Drummond and Hanford climbed between December 17ththrough the 23rd, while PM_{10} concentrations at Corcoran lowered during this time frame. Due to the light winds and limited mixing, local emission activity around Corcoran may have lowered leading to decreasing PM_{10} levels. Analysis of total carbon and ammonium nitrates and sulfates indicates that Fresno-Drummond and Hanford registered higher levels compared to Corcoran, indicating potentially that local emissions sources may have impacted these sites. A few days later, two MiniVol Samplers, which were collected as part of the California Regional Particulate Air Quality Study (CRPAQS), measured the second and

third highest concentrations at Fresno-Drummond at 168 μg/m^3 **(Figure 8)** and Hanford-South Irwin, at 156 μg/m^3 **(Figure 9).** The CRPAQS exceedances are not considered for compliance with the standards, but are used in the discussion to provide context to the episode.



Although PM_{10} sampling is not conducted daily, information from more frequent $PM_{2.5}$ sampling combined with an assessment of changes in the meteorological conditions suggest that the highest PM_{10} concentration was not captured on the sampled day. Daily $PM_{2.5}$ sampling and meteorological conditions suggested that the highest PM_{10} concentrations may have occurred on December 24th and 25th, when Fresno 1st measured peak $PM_{2.5}$ concentrations of 134 and 131 μg/m^3, respectively. The exceedances at Fresno-Drummond and Hanford-Irwin were driven by high concentrations of ammonia nitrate and sulfate and/or total carbon, which accumulated between December 17th and the 23rd. The size fraction data across the Valley indicated that most of the PM_{10} was in the $PM_{2.5}$ fraction, with an average $PM_{2.5}/PM_{10}$ mass ratio greater than 0.7. This was further supported by the high $PM_{2.5}$ concentrations that reached 119 μg/m^3 at nearby Fresno-First, (**Figure 8 & 9).**

The concentration at Fresno-Drummond of ammonium nitrate and sulfate (74 μg/m^3), total carbon (44 μg/m^3), and geological (44 μg/m^3), had the highest PM_{10} mass in the Valley. The concentration at Hanford of ammonium nitrate and sulfate (80 μg/m^3), total carbon (35 μg/m^3), and geological (44 μg/m^3), had the second highest PM_{10} mass in the Valley. The main constituents of the particulate samples on December 23, 1999 may have come from local sources (residential wood burning and urban/agricultural geologic). Agricultural burning may not have contributed as a potential source of PM on the exceedance day, because since December 18, 1999 were declared a No Burn Day's District-wide. However, burn variances and noncompliant agricultural burns may have contributed to a small portion of the samples. Overnight minimum temperatures in the low to mid 30's suggest that residential wood burning was likely to be a significant

source of PM_{10}. It appears that potentially residential burning may have been a source of carbon. PM_{10} and $PM_{2.5}$ concentrations showed that meteorological conditions led to the pollution buildup. During the buildup time leading to the two separate exceedances on December 23, 1999, where ammonium nitrate and sulfates, carbon, and geological material increased.

Meteorologically, dispersion conditions began to slightly improve a few days prior to the December 23rd exceedances. The lack of precipitation since December 9th may have contributed to the increasing geological component. Humidity measurements of 85 – 100 % in the morning across the Valley Floor showed a moist atmosphere, with light to dense fog and haze being reported. The cool damp mornings and strong stability favored the formation of nitrates and sulfates. The eastern Pacific high remained strong through the 20th and gradually weakened through the 31st, keeping a tight lid over the San Joaquin Valley trapping the pollutants within the Valley boundary layer.

With a strong lid in place aloft and maximum high temperatures in the low 60's, the afternoon hours were marked by limited mixing, resulting in increasing particulate conditions. Mixing heights at Fresno remained below 500 feet under a strong inversion for 16 hours on the December 23rd, breaking out shortly after 12:00 P.M and reforming before 5:00 P.M. During the afternoon hours, there were higher mixing depths (maximum mixing depth of 2,000 feet), but the bulk of the day had limited mixing. Maximum temperatures for this episode were above normal, further illustrating the intensity of the high pressure system that was controlling the region's weather. Light fog reported at the Valley surface during the early morning hours, resulted in slightly lower solar radiation intensities. Along with lower solar radiation intensities due to the low sun angle and decreasing daylight hours, the atmospheric chemistry reactions may have favored the secondary particulate forming regime.

In summary, chemical composition and meteorological data showed limited mixing depths and light and disorganized wind flow resulted in minimal transport and dispersion of pollutants. Both primary and secondary pollutants from local emissions around Fresno-Drummond and Hanford-Irwin accumulated resulting in the exceedance of the 24-hour PM_{10} standard on December 23, 1999.

January 2001 Episode

Monday, January 1, Thursday, January 4, and Sunday, January 7, 2001
(Episode Duration: Three and a half weeks)

The January 2001 particulate episode was characterized by a prolonged period (three and a half weeks) of strong stability and light wind flow, which resulted in poor atmospheric dispersion conditions across the San Joaquin Valley. Coarse and fine particulates accumulated during the period leading to three separate days exceeding the National Ambient Air Quality Standards (NAAQS). These exceedances occurred on January 1, 4, and 7, 2001 and were measured by Federal Reference Monitoring (FRM) sites and MiniVol Samplers, which were part of the California Regional Particulate Air Quality Study (CRPAQS). The CRPAQS exceedances are not considered for compliance with the Federal Standards, but are used in the discussion to provide context to the episode. PM_{10} and $PM_{2.5}$ concentrations, chemical composition, and meteorological data around January 1, 4, and 7, 2001 were evaluated and analyzed to identify the characteristics and uniqueness of the exceedances at the FRM and CRPAQS PM_{10} monitoring sites.

PM_{10} and $PM_{2.5}$ Mass Concentrations

Daily $PM_{2.5}$ sampling and meteorological conditions suggest that PM_{10} exceedances began on December 31, 2000 and continued through January 7, 2001 at various monitoring sites across the San Joaquin Valley. $PM_{2.5}$ exceedances began a few days earlier on December 25 and 26, 2000, when real-time monitors captured readings above the Federal Standard of 65 $\mu g/m^3$. Although PM_{10} sampling is not conducted daily, information from more frequent $PM_{2.5}$ sampling combined with an assessment of changes in the meteorological conditions suggest that the highest PM_{10} concentrations were not captured on the sampled days. The highest PM_{10} concentrations may have occurred on January 1st and January 6th, when Fresno 1st measured a peak $PM_{2.5}$ concentration of 148 and 129 $\mu g/m^3$, respectively. PM_{10} samples were available on January 1st. However, no PM_{10} data was available on January 6th. Particulate material concentrations were dominated by fine particulates ($PM_{2.5}$) of ammonia nitrate and sulfate and were most prevalent across the entire San Joaquin Valley.

Although dispersion was poor, given the length of the episode and the large contributions from secondary components, there was an underlying regional component to this episode as it progressed through January 7th. Local carbon and geologic contributions added to this regional component and influenced site to site concentration variations. As the episode continued, PM and precursors became more homogeneous across the region. This resulted in $PM_{2.5}$ concentrations at rural sites lagging those of urban sites, and rural concentrations continued to build throughout the episode.

The FRM sites which exceeded the Federal PM_{10} standard on January 1, 2001, were Clovis-Villa 155 $\mu g/m^3$, Fresno-1st 193 $\mu g/m^3$, Fresno-Drummond 186 $\mu g/m^3$, Bakersfield-California 186 $\mu g/m^3$, Bakersfield-Golden 205 $\mu g/m^3$, and Oildale-Manor 158 $\mu g/m^3$ (**Figure 10, 11, 12, and 13** and **Table 2**). PM_{10} at other Valley locations were

elevated but not over the Standard. For example, Stockton-Wagner and Visalia-Church recorded 119 μg/m^3 and 143 μg/m^3, respectively. The size fraction data on January 1st across the Valley indicated that most of the PM_{10} mass was in the $PM_{2.5}$ fraction, with an average $PM_{2.5}/PM_{10}$ mass ratio greater than 0.7. This was further supported by the high $PM_{2.5}$ concentrations that reached 148 μg/m^3 at Fresno-First and 133 μg/m^3 at Bakersfield-Golden (**Figure 10 and 12**).

Stagnation conditions continued through January 4, 2001, when three MiniVol Samplers, which were part of the California Regional Particulate Air Quality Study (CRPAQS) and one federal reference monitor (FRM) registered exceedances of the Federal Standard. The CRPAQS monitors measured at Fresno-Drummond, 159 μg/m^3, at Bakersfield-Golden, 208 μg/m^3, and at Oildale-Manor, 195 μg/m^3 (**Figure 12 and 13** and **Table 2**). The FRM PM_{10} concentration at Bakersfield-California was 190 μg/m^3 (**Figure 11** and **Table 2**). The size fraction data across the Valley on January 4th indicated that most of the PM_{10} was in the $PM_{2.5}$ fraction, with an average $PM_{2.5}/PM_{10}$ mass ratio greater than 0.8. This was further supported by the high $PM_{2.5}$ concentrations that reached 106 μg/m^3 at Fresno-First and 127 μg/m^3 at Bakersfield-California (**Figure 11, 12, & 13**).

Poor dispersion conditions continued through January 7, 2001, when five FRM monitors registered exceedances of the Federal Standard. The FRM sites, which exceeded the Federal PM_{10} Standard on January 7th, were Bakersfield-California, 159 μg/m^3, Bakersfield-Golden, 174 μg/m^3, Corcoran-Patterson, 165 μg/m^3, Hanford-Irwin, 185 μg/m^3, and Modesto-14th, 158 μg/m^3 (**Figure 11, 12, and 13** and **Table 2**). The size fraction data across the Valley on January 7, 2001 indicated that most of the PM_{10} was in the $PM_{2.5}$ fraction, with an average $PM_{2.5}/PM_{10}$ mass ratio greater than 0.75. This was further supported by the high $PM_{2.5}$ concentrations that reached 101 μg/m^3 at Fresno-First and 119 μg/m^3 at Bakersfield-California (**Figure 10 & 11**). Chemical composition data was than analyzed to identify the characteristics and uniqueness of the exceedances at the FRM and CRPAQS PM_{10} monitoring sites.

Figure 10: Fresno-1st (Coarse) and (PM2.5)
January 2001 Episode

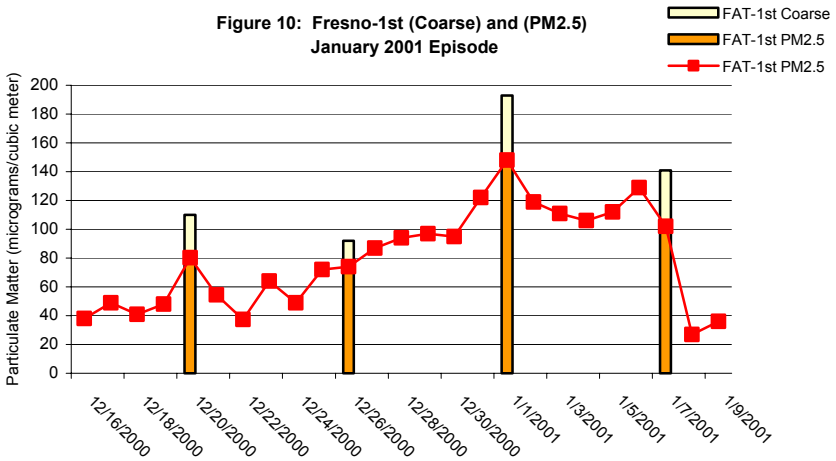


Figure 11: Bakersfield California (Coarse) and (PM2.5)
January 2001 Episode

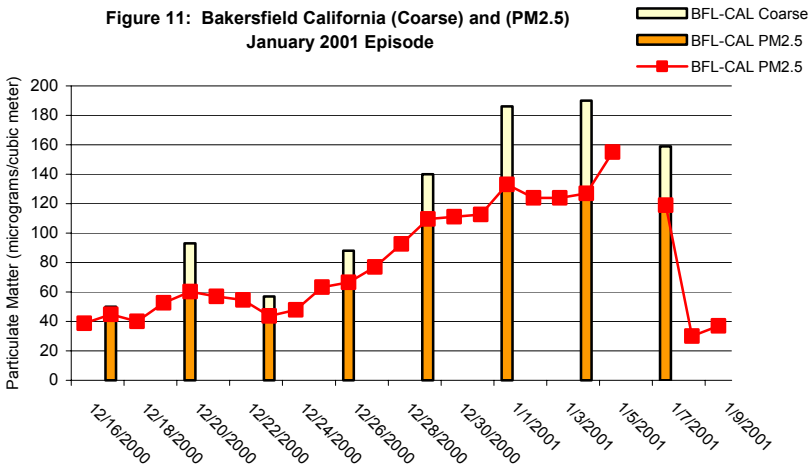


Figure 12: Bakersfield Golden (Coarse), (PM10), and (PM2.5)
and Bakersfield California (PM2.5)
January 2001 Episode

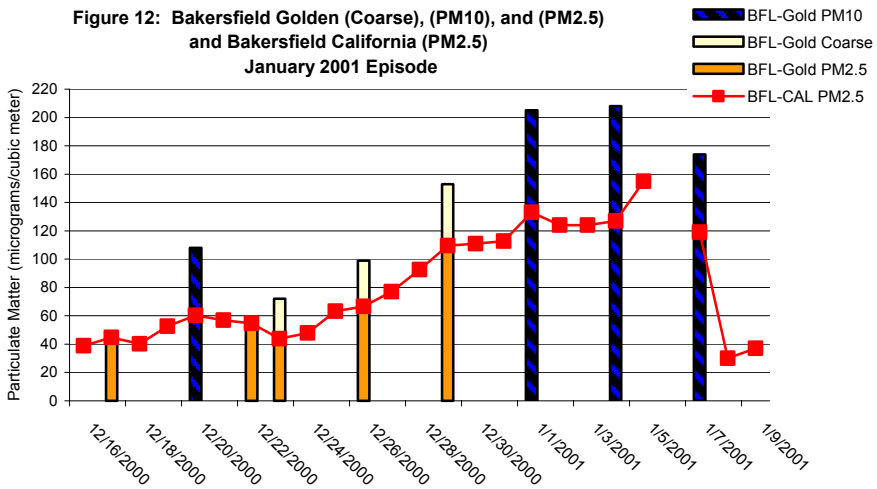


Figure 13: Hanford, Oildale, and Modesto (PM10)
and Fresno-1st & Bakersfield-California(PM2.5)
January 2001 Episode

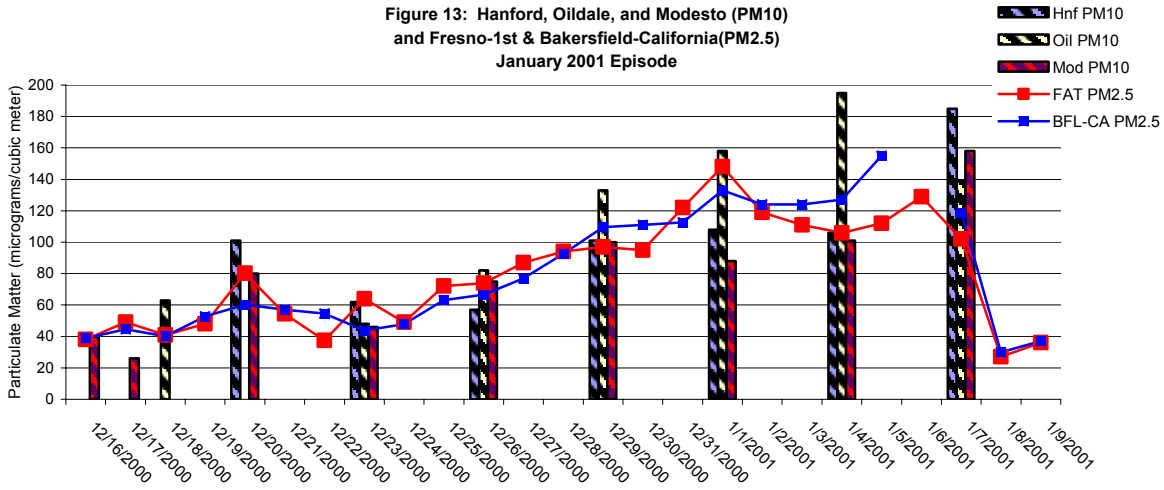


Table 2
PM_{10} Chemical Composition Data[1] for January 1, 4 and 7, 2001
at selected exceedance sites.
Data Collected as part of the Routine and CRPAQS Networks.

SITE NAME	Date	Concentrations (µg/m^3)					Percent of PM10 Mass			
		PM10	PM2.5	Nitrate/ Sulfate	TC	Geo-logical	PM2.5	Nitrate/ Sulfate	TC	Geo-logical
Bakersfield-California	1/1/01	186	*133*	100	33		71	54	18	
Bakersfield-California	1/4/01	190	*127*	98	30		67	51	16	
Bakersfield-California	1/7/01	159	119	81	24		75	51	15	
Bakersfield-Golden	1/1/01	205								
Bakersfield-Golden	*1/4/01*	*208*		*106*	*38*	*47*		51	18	23
Bakersfield-Golden	*1/7/01*	174								
Clovis-N Villa	1/1/01	155	*130*	77			84	50		
Corcoran-Patterson	1/7/01	165	121	93			73	56		
Fresno-1st Street	1/1/01	193	*148*	76	51	7	77	40	26	4
Fresno Drummond	*1/1/01*	186								
Fresno Drummond	*1/4/01*	*159*		*58*	*52*	*29*		37	33	18
Hanford-S Irwin	1/7/01	185		105				57		
Modesto-14th St.	1/7/01	158	*136*	88	26		86	56	16	
Oildale-Manor	1/1/01	158	*141*	96			89	61		
Oildale-Manor	*1/4/01*	*195*		*119*	*28*	*43*		61	14	22

[1] The following fonts were used in the table to distinguish data sources:
- Regular font for routine data (FRM mass and chemical composition)
- Underlined font for mass collected using dichotomous sampler
- Italics font for CRPAQS data

Chemical Composition Data

Ammonium nitrate and sulfates increased prior to the exceedance day on January 1, 2001, whereas total carbon and geological remained stable. Chemical composition data on January 1, 2001 showed the exceedances were driven by high concentrations of ammonium nitrate and sulfate that comprised of 40 to 60 % of the PM_{10} mass. The other major chemical components of the samples were 18 to 26 % total carbon and 4 to 20 % geological of the PM_{10} mass (**Table 2**). At Fresno-First the concentration of total carbon (26 % of PM_{10} mass) and coarse material (4 % of PM_{10} mass) indicated the constituents of the particulate samples on January 1st may predominantly come from local sources, such as residential wood burning (**Table 2**). Since December 2000 No Burn Day's were declared District-wide; consequently, agricultural burning was probably not a contributing source of PM on the exceedance days in January. However, burn variances and noncompliant agricultural burns may have contributed to a small portion of the samples. Overnight minimum temperatures in the low 30's on January 1, 4 and 7, 2001 suggested that residential wood burning may have been a significant source of PM_{10}. The potential of increased residential wood burning on New Year's Day, may have led to elevated concentrations of total carbon in the samples.

Local emission source activity and meteorological conditions led to PM_{10} concentrations at Bakersfield-Golden, Oildale-Manor, and Bakersfield-California climbing between January 1st and the 4th. Fresno-Drummond PM_{10} concentrations lowered during this same period. Because limited mixing and light winds remained over the area, this decrease in PM_{10} at the site may have been due to lower emission activity there. Analysis of ammonium nitrates and sulfates indicates that Oildale-Manor and Bakersfield-California registered higher levels compared to non-exceedance locations, indicating potentially that local emissions sources may have impacted these sites. The exceedances at Fresno-Drummond, Oildale-Manor, and Bakersfield-California and Golden on January 4th, were driven by high concentrations of ammonia nitrate and sulfate and/or total carbon.

The concentration at Bakersfield-Golden of ammonium nitrate and sulfate (106 $\mu g/m^3$), total carbon (18 $\mu g/m^3$), and geological (23 $\mu g/m^3$), was the highest PM_{10} mass in the Valley on January 4th (**Table 2**). The concentration at Oildale-Manor, Bakersfield-California, Fresno-Drummond, were the second, third and fourth highest PM_{10} mass in the Valley (**Table 2**). The constituents of the particulate samples on January 4, 2001 may predominantly come from local sources (residential wood burning and urban / agricultural geologic). The lack of precipitation since December 9th may have also contributed to the increasing geological component. PM_{10} and $PM_{2.5}$ concentrations showed that meteorological conditions led to the pollution buildup. Ammonium nitrate and sulfates, and geological increased prior to the exceedance on January 4, 2001, whereas total carbon remained stable.

Local emission source activity and meteorology led to PM_{10} concentrations at Hanford-Irwin, Corcoran-Patterson, and Modesto-14th climbing between January 4th and the 7th, while PM_{10} concentrations at Bakersfield-Golden and California lowered. Because

dispersion conditions remained poor, local emission activity around Bakersfield may have decreased prior to January 7th leading to lowering PM_{10} levels. Both Bakersfield California and Golden measured lower ammonium nitrate and sulfate levels compared to the 4th, further indicating that potentially local emission source activity may have decreased on the 7th at these sites. Analysis of ammonium nitrates and sulfates indicates that Modesto-14th, Hanford-Irwin, Corcoran-Patterson, registered higher levels compared to non-exceedance locations, indicating potentially that local emissions sources may have impacted these sites.

The exceedances at Bakersfield-California, Bakersfield-Golden, Corcoran-Patterson, Hanford-Irwin, and Modesto-14th were driven by high concentrations of ammonia nitrate and sulfate and/or total carbon, which remained high and elevated between January 4th and January 7th. Ammonium nitrate and sulfates, and total carbon increased prior to the exceedance on January 7, 2001 at Modesto-14th, Corcoran-Patterson, and Hanford-Irwin whereas at Bakersfield-Golden and California ammonium nitrate and sulfates, and total carbon slightly decreased. The concentration at Hanford-Irwin of ammonium nitrate and sulfate (105 $\mu g/m^3$) and no total carbon and geological measurements, had the highest PM_{10} mass in the Valley on January 7th (**Table 2**). The concentration at Bakersfield-Golden, Corcoran-Patterson, Bakersfield-California, Modesto-14th, had the second, third, fourth, and fifth highest PM_{10} mass in the Valley (**Table 2**). The constituents of the particulate samples on January 7, 2001 may predominantly come from local emission sources (residential wood burning and urban / agricultural geologic).

Dispersion Meteorology

During the January 2001 episode, strong high pressure at the surface and aloft resulted in limited afternoon mixing and light offshore wind flow. Cool damp mornings and strong stability contributed to the formation of nitrates and sulfates during the episode. Meteorologically, dispersion worsened and particulate formation conditions strengthened from December 10th to January 7th. After the passage of a weak cold front on December 9, 2000, which brought a few hundredths of an inch of precipitation to the region, moisture became available for atmospheric chemistry reactions. Humidity measurements of 90 – 100 % in the morning across the Valley Floor showed a moist atmosphere, with light fog and haze being reported on the exceedance days. These cool damp mornings and strong stability favored the formation of nitrates and sulfates. Synoptically, the eastern Pacific high built over the San Joaquin Valley on December 10, 2000 and dominated the region's weather through January 7, 2001. The high strengthened and intensified a few days prior to January 1st, further tightening the lid and trapping pollutants within the San Joaquin Valley boundary layer.

With a strong lid in place aloft and maximum high temperatures in the upper 50's to low 60's, the afternoon hours were marked by limited mixing, resulting in increasing particulate potential. Mixing heights at Fresno remained below 500 feet under a strong inversion for 19 hours on January 1st, breaking out after 4:00 P.M and reforming shortly after 7:00 P.M. During the afternoon hours, there were higher mixing depths (maximum mixing depth of 1,000 feet), but the bulk of the day had limited mixing. Maximum and

minimum temperatures for the exceedance day were slightly above normal, further illustrating the intensity of the high pressure system that was controlling the region's weather. Light fog was reported at the Valley surface during the early morning hours of January 1st, resulting in slightly lower solar radiation intensities. Along with lower solar radiation intensities due to the early morning fog, low sun angle, and reduced daylight hours, the atmospheric chemistry reactions may have favored the secondary particulate forming regime. Light fog would be indicative of moderate water content's that favor the formation of ammonium nitrate. Heavier fogs result in the removal or particulates by wet deposition. Chemical composition and meteorological data showed limited mixing depths and light and disorganized wind flow resulted in minimal transport and dispersion of pollutants. Both primary and secondary pollutants from local emissions around Clovis-Villa, Fresno-1st, Fresno-Drummond, Bakersfield-California, Bakersfield-Golden, and Oildale-Manor accumulated resulting in the exceedance of the 24-hour PM_{10} standard on January 1, 2001.

Meteorological conditions remained extremely stable between January 1st through the 4th, leading to elevated particulate conditions continuing across the San Joaquin Valley. Without a significant weather disturbance moving through the area to scour out the particulates, PM_{10} concentrations continued to climb and exceeded the NAAQS at both the FRM and CRPAQS PM_{10} monitoring sites on the second measured exceedance day on January 4th. With a strong lid in place aloft and maximum high temperatures in the low 60's, the afternoon hours on January 4th, were marked by limited mixing, resulting in increasing particulate conditions. Mixing heights at Fresno remained below 500 feet under a strong inversion for 20 hours on January 4th. During the afternoon hours, there were higher mixing depths (maximum mixing depth of 2,000 feet), but the bulk of the day had limited mixing. Maximum temperatures for this exceedance day were above normal, further illustrating the intensity of the high pressure system that was controlling the region's weather. Light fog reported at the Valley surface during the early morning hours, resulted in slightly lower solar radiation intensities. Along with lower solar radiation intensities due to the low sun angle and reduced daylight hours, the atmospheric chemistry reactions may have favored the secondary particulate forming regime. Chemical composition and meteorological data showed limited mixing depths and light and disorganized wind flow resulted in minimal transport and dispersion of pollutants. Both primary and secondary pollutants from local emissions around Fresno-Drummond, Bakersfield-Golden, Oildale-Manor, and Bakersfield-California accumulated resulting in the exceedance of the 24-hour PM_{10} standard on January 4, 2001. The January 4th exceedances recorded the highest PM_{10} levels during the January 2001 episode.

Between January 4th and January 7th, meteorological conditions began to slowly improve leading to slightly lower but continued elevated particulate conditions across the San Joaquin Valley. Without a significant weather disturbance moving through the area to scour out the particulates, PM_{10} concentrations continued to remain high and exceeded the Federal Standard at five FRM PM_{10} monitoring sites on the third measured exceedance day on January 7th. The FRM PM_{10} concentrations at Bakersfield-California (159 $\mu g/m^3$), Bakersfield-Golden (174 $\mu g/m^3$), Corcoran-Patterson

(165 μg/m^3), Hanford-Irwin (185 μg/m^3), and Modesto-14th (158 μg/m^3) were captured on January 7th (**Figure 11, 12, and 13**). Humidity measurements of 85 – 100 % on the morning of January 7th, across the Valley Floor showed a relatively moist atmosphere, with light fog and haze being reported. The cool damp mornings and strong stability favored the formation of nitrates and sulfates. Synoptically, the eastern Pacific high began to slowly weaken and move into the Intermountain Region on January 7, 2001, slightly weakening the lid over the San Joaquin Valley.

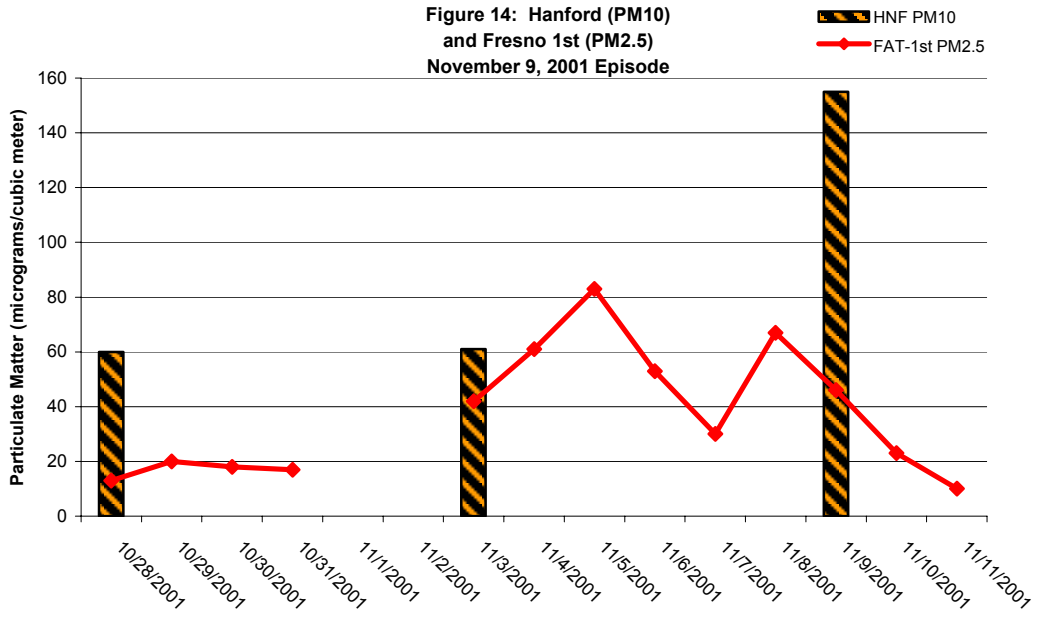
On January 7th a moderately strong lid was in place aloft and maximum high temperatures were in the mid 60's. The afternoon hours were marked by limited mixing, resulting in elevated particulate conditions. Mixing heights at Fresno remained below 500 feet under a strong inversion for 16 hours on January 7th. During the afternoon hours, there were higher mixing depths (maximum mixing depth of 2,000 feet), but the bulk of the day had limited mixing. Maximum temperatures for this exceedance day were above normal, further illustrating the intensity of the high pressure system that was controlling the region's weather. Light fog reported at the Valley surface during the early morning hours, resulted in slightly lower solar radiation intensities. Along with lower solar radiation intensities due to the low sun angle and reduced daylight hours, the atmospheric chemistry reactions may have favored the secondary particulate forming regime. Chemical composition and meteorological data showed limited mixing depths and light and disorganized wind flow resulting in minimal transport and dispersion of pollutants. Both primary and secondary pollutants from local emissions around Bakersfield-California and Golden, Corcoran-Patterson, Hanford-Irwin, and Modesto-14th, accumulated resulting in the exceedance of the 24-hour PM_{10} standard on January 7, 2001.

Conclusion

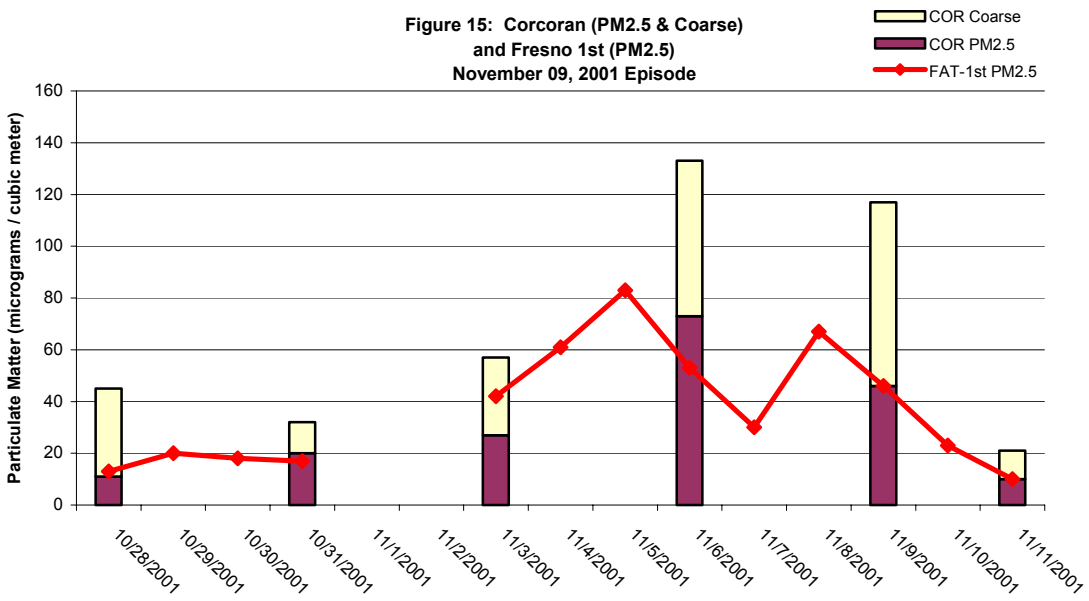
The 2001 episode was marked by a prolonged period of very strong stability and limited mixing, resulting in widespread exceedances of the Federal PM_{10} Standard across the San Joaquin Valley. Although dispersion was poor, given the length of the episode and the large contributions from secondary components, there was an underlying regional component to this episode as it progressed through January 7th. Local carbon and geologic contributions added to this regional component and influenced site to site concentration variations. As the episode continued, PM and precursors became more homogeneous across the region. This resulted in $PM_{2.5}$ concentrations at rural sites lagging those of urban sites, and rural concentrations continued to increase throughout the episode. Historically, the strength of the stability and length of the episode has not occurred often. The January 2001 exceedances were unique in that the meteorology was so strong and lasted for so long, that PM remained trapped and accumulated in the San Joaquin Valley, leading to widespread exceedances of the Federal PM_{10} Standard by the end of the episode.

Friday, November 09, 2001 Episode

The November 9, 2001 particulate episode was characterized by a medium length period (a week and a half) of strong stability and light wind flow, which resulted in poor atmospheric dispersion conditions across the San Joaquin Valley. Coarse and fine particulates accumulated during the period, leading to an exceedance of the 24-hour standard at one air monitoring site on November 9, 2001. Concentrations were dominated by the coarse particulates (PM_{10}) and were most prevalent across Kern County early in the episode then progressively spread northward to Stanislaus and San Joaquin Counties toward the end of the episode. The highest PM_{10} measured was 155 $\mu g/m^3$ (**Figure 14**) at Hanford-S Irwin. PM_{10} at other Valley locations were lower between 115 to 125 $\mu g/m^3$ (**Figure 15**). During the period, strong high pressure at the surface and aloft resulted in limited afternoon mixing and light offshore wind flow. Cool damp mornings and strong stability contributed to the formation of nitrates and sulfates during the episode. These meteorological conditions led to elevated particulate concentrations. Chemical composition and meteorological data around November 9, 2001, was evaluated and analyzed to identify the characteristics and uniqueness of the exceedance at Hanford-S Irwin.



Although PM_{10} sampling is not conducted daily, information from more frequent $PM_{2.5}$ sampling combined with an assessment of changes in the meteorological conditions suggest that the highest PM_{10} concentration was not captured on the sampled day. Daily $PM_{2.5}$ sampling and meteorological conditions suggested that the highest PM_{10} concentrations may have occurred on November 8th, when Fresno 1st measured a peak $PM_{2.5}$ concentration of 67 $\mu g/m^3$. No chemical composition data was available for the exceedance day. However, the size fraction data across the Valley indicated that most of the PM_{10} was in the coarse fraction, with an average $PM_{2.5}/PM_{10}$ ratio of slightly greater than 0.40 at nearby Corcoran (**Figure 15**).



The concentration of coarse material may have been highest at the exceedance site as indicated by the higher coarse fraction at nearby Corcoran compared to other sites in the Valley. In November, many agricultural land preparing and harvesting activities were occurring, potentially contributing to the elevated concentrations of geological material found in the sample. Agricultural burning probably did not contribute to PM on the exceedance day, because November 8 and 9, 2001 were declared No Burn Day's District-wide. However, burn variances and noncompliant agricultural burns may have contributed to a small portion of the samples. Overnight minimum temperatures in the mid to upper 40's suggest that residential wood burning may have been a source of PM_{10}. The $PM_{2.5}$ temporal patterns across the Valley showed highest concentrations in Bakersfield on November 3 and 4 followed by peak concentrations on November 5 at Fresno, then the following day on November 6 at Corcoran. A few days later on November 9, the exceedance day at Hanford, peak $PM_{2.5}$ concentrations were recorded in the northern portions of the Valley (Modesto and Stockton). As discussed below, both PM_{10} and $PM_{2.5}$ concentrations showed that meteorological conditions led to the temporal variability and pollution buildup.

Meteorologically, dispersion worsened and particulate formation conditions strengthened from November 2nd to the 7th. However, on November 8th the day before the exceedance day at Hanford, dispersion conditions began to slightly improve under weaker stability. After the passage of a cold front on October 30th, which brought 0.16 inches of rainfall to Hanford, moisture was available for atmospheric chemistry reactions. Humidity measurements of 80 – 95% in the morning across the Valley Floor showed a moist atmosphere, with light fog and haze being reported. The cool damp mornings and strong stability favored some formation of nitrate and sulfate particulates. The eastern Pacific high built over the San Joaquin Valley on November 2nd, and dominated the region's weather through the 10th. The high began to slowly break down on the 8th, but remained strong through the exceedance day (November 9th), trapping pollutants within the San Joaquin Valley boundary layer.

With a strong lid in place and maximum high temperatures in the upper 70's to low 80's on November 9, the afternoon hours were marked by limited mixing, resulting in elevated particulate conditions. Mixing heights at Fresno remained below 500 feet under a strong inversion for 16 hours on November 9, 2001 breaking out by 10:00 A.M. and reforming by 5:00 P.M. During the afternoon hours, there were higher mixing depths (maximum mixing depth of 2,000 feet), but the bulk of the day had limited mixing. Maximum temperatures were above normal for the November 2001 episode, further illustrating the intensity of the high pressure system that was controlling the region's weather. Light fog being reported at the Valley surface on November 9th, resulted in slightly lower levels of solar radiation intensity. Along with lower solar radiation intensities due to the low sun angle and decreasing daylight hours, atmospheric chemistry reactions may have favored the secondary particulate forming regime.

Chemical composition and meteorological data showed that limited mixing depths and light and disorganized wind flow resulted in minimal transport and dispersion of pollutants. Due to the seasonality of the November 9th exceedance, the PM_{10} concentration at Hanford had a dominant coarse fraction compared to exceedances, which occur later in the winter. The duration, moisture availability, light winds, and maximum and minimum temperatures influenced the atmospheric chemistry reactions, during the episode. This led to higher coarse fractions and geological components compared to episodes later in the year. With stagnant weather conditions, local geological sources around Hanford led to the exceedance. Both primary and secondary pollutants from local emissions around Hanford-S Irwin accumulated, resulting in the exceedance of the 24-hour PM_{10} standard on November 9, 2001.

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