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 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.

December 31, 1998 and January 12, 1999
(December 20, 1998 – January 16, 1999)

The period from December 20, 1998 to January 16, 1999 was marked by 28 days of strong stability and poor atmospheric dispersion conditions. Strong high pressure over the Intermountain Region and eastern Pacific dominated the period, leading to limited dispersion. The period began with the passage of a cold, arctic front and trough on the 20th. Between the 20th and the 31st, increasing stability and poor dispersion conditions resulted in a PM_{10} (Particulate Matter) exceedance at Bakersfield Golden and Visalia Church on the 31st, **Figure 1**.

At Bakersfield Golden and at Visalia Church, a 24-hour PM_{10} concentration of 159 and 160 µg/m^3 were measured, respectively. **Table 2** outlines federal reference method (FRM) Daily Average Particulate Matter Measurements for sites across the San Joaquin Valley (SJV). In order to understand the variability of these measurements, an in depth examination of the synoptic pattern and surface winds and observations, and aircraft soundings leading to the episode were analyzed.

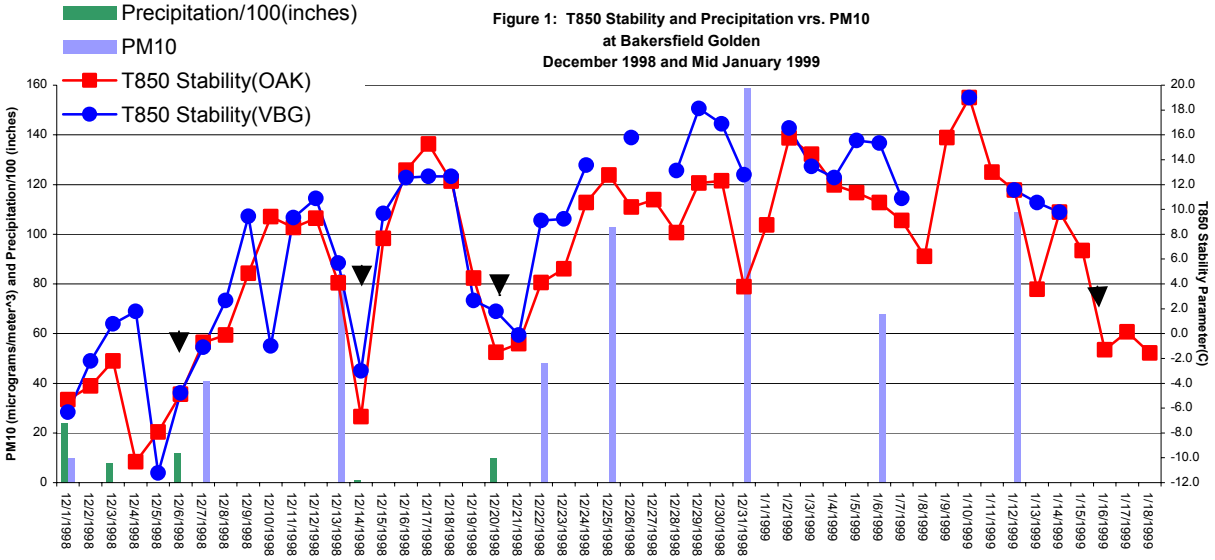


TABLE 2: Federal Reference Method (FRM) Daily Average Particulate Matter Measurements for sites across the SJV for December 31, 1998.

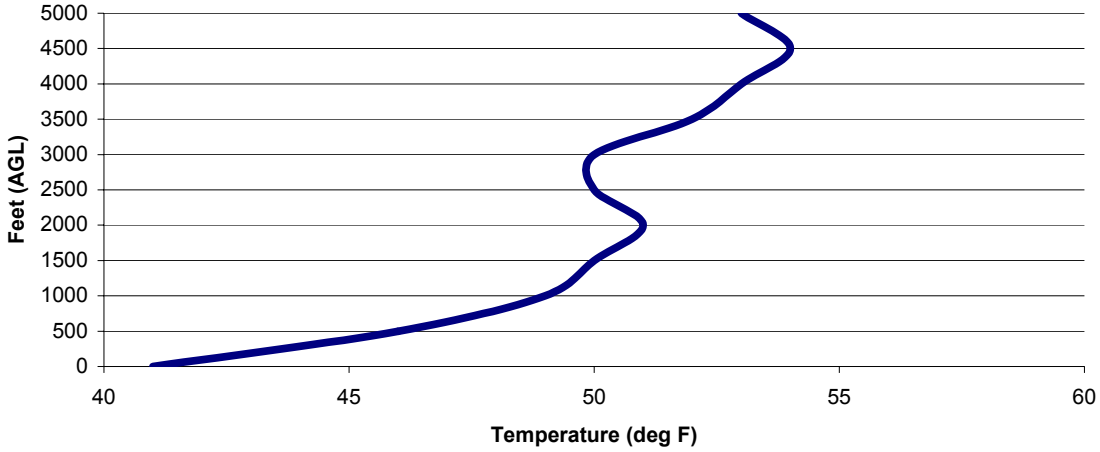
	FRM		FRM		FRM
Site Name	24-Avg.	Site Name	24-Avg.	Site Name	24-Avg.
Bakersfield-Gold	159	Turlock	87	Hanford	109
Bakersfield-CA	148	Modesto	80	Stockton#	99
Visalia	160	Taft	73	Stockton**	95
Fresno-1st	104	Fresno-Drum	117	Corcoran*	116

*-Patterson #-Wagner, **- Hazleton units in µg/m^3

The meteorological synoptic analysis showed after a period of strong atmospheric stability from December 20th through the 31st, a weak disturbance from the eastern Pacific approached the region. Ahead of the weak trough, stability lingered over the southern parts of the San Joaquin Valley trapping particulates within the Valley boundary layer. The afternoon surface charts on the 31st depicted a surface ridge extending southeastward across southern California from a strong high 200 NM west of Eureka. A weak cold front was draped northwestward along the Sierra Nevada Mountain range from near Bishop to Reno. The 0Z surface pressure gradient was +13.0 millibars from San Francisco (SFO) to Las Vegas (LAS), with isobars(constant surface pressure) orientated northeast to southwest. With the alignment of the isobars and the +13.0 millibars pressure gradient, this represents light to moderate north-northeasterly flow across the San Joaquin Valley. Visibilities throughout the day across the San Joaquin Valley were reporting haze.

The morning temperature aircraft sounding over Bakersfield showed multiple inversions, with a moderately strong inversion (stable layer) of 10 degrees Fahrenheit from the surface up to 2,000 feet, with a secondary inversion of 4 degrees Fahrenheit from 2,500 to 4,500 feet as is evident in **Figure 2.** The temperature sounding on the 31st, is conducive of elevated PM levels due to low mixing depths and multiple inversions, which keep pollutants trapped near the surface. At surface observations across the San Joaquin Valley, minimum temperature at Fresno was 38 degrees Fahrenheit and Bakersfield was 37 degrees Fahrenheit. These cold and poor dispersion conditions generally result in elevated concentrations of ammonia nitrate. Also on New Year's Eve (December 31), there is a great amount of residential wood combustion in the area.

Figure 2: Atmospheric Temperature Profile at Bakersfield on December 31, 1998



Upper level charts indicated a strong high 600 NM west of Santa Barbara, with a ridge building northward into the eastern Gulf of Alaska. A weak trough over the Intermountain region extended southwestward across northern California. Weak pressure gradients across the San Joaquin Valley strengthened during the afternoon hours, with the approach of the cold front.

Table 3 shows the 24-hour daily average wind speeds at SJVAPCD monitoring sites, ASOS, and CIMIS sites for December 31, 1998.

SJVAPCD Monitoring Sites		ASOS		CIMIS			
	WS mph		WS mph		WS mph		WS mph
Clovis	5.5	Fresno	6.5	Shafter/USDA	3.0	Famoso	3.2
Fresno SSP	3.0	Bakersfield	4.0	Firebaugh/Telles	5.4	Westlands	6.5
Corcoran	4.7	Hanford	4.7	Stratford	3.8	Panoche	5.6
Edison	4.3			Kettleman	3.6	Arvin-Edison	3.0
Parlier	5.3			Visalia/Americas	2.8	Lindcove	2.1
Arvin	3.6			Parlier	4.2	Kesterson	5.0
Visalia	1.8			Blackwells Corner	3.3	Lodi West	3.9
				Los Banos	6.3	Modesto	5.6
				Manteca	4.9	Fresno State	5.2

Due to the strong stability lasting for over 11 days, PM_{10} steadily increase region-wide until December 31st. With the approach of the weak upper level trough from northern California, moderately strong stability lingered over the southern parts of the San Joaquin Valley. This resulted in local PM_{10} concentrations at Bakersfield-Golden and Visalia to increase above the Federal 24-hour PM_{10} standard to 159 and 160 $\mu g/m^3$, respectively. Due to the tightening pressure gradient in the northern part of the San Joaquin Valley and weak upper level trough passage, widespread San Joaquin Valley PM10 exceedances did not occur on this date. The weak upper level trough traversed the entire region late on the 31st bringing slightly better dispersion conditions to the entire San Joaquin Valley on January 1st, resulting in lower PM Valley-wide.

After the weak upper level trough passage on the 31st, strong high pressure rebuilt into the region from the Great Basin and eastern Pacific, with increasing stability and poor dispersion conditions through the next exceedance date on January 12th at Oildale, **Figure 1**. At Oildale, a 24-hour PM_{10} (Particulate Matter) concentration of 156 $\mu g/m^3$ was measured.

Table 4 outlines federal reference method (FRM) Daily Average Particulate Matter Measurements for sites across the San Joaquin Valley (SJV). In order to understand the variability of these measurements, an in depth examination of the synoptic pattern and surface winds and observations, and aircraft soundings leading to the episode were analyzed.

TABLE 4: Federal Reference Method (FRM) Daily Average Particulate Matter measurements for sites across the SJV for January 12, 1999.

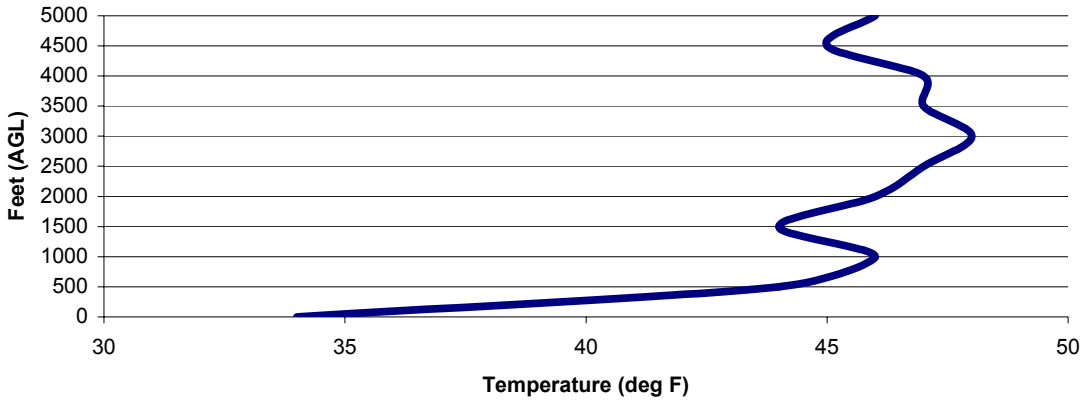
	FRM		FRM		FRM
Site Name	24-Avg.	Site Name	24-Avg.	Site Name	24-Avg.
Bakersfield-Gold	109	Turlock	53	Oildale	156
Bakersfield-CA	92	Modesto	48	Stockton#	39
Visalia	82	Taft	70	Stockton**	48
Fresno-1st	85	Fresno-Drum	76	Corcoran*	51

*-Patterson #-Wagner, **- Hazleton units in $\mu g/m^3$

The meteorological synoptic analysis showed after a period of strong atmospheric stability from December 31st through the 12th, a weak upper level disturbance from the eastern Pacific approached the region. Ahead of the weak trough, mid-tropospheric stability lingered over the southern parts of the San Joaquin Valley trapping particulates within the Valley boundary layer. The morning surface charts of January 12th depicted a surface ridge extending southeastward across the central San Joaquin Valley from a strong high just west of San Francisco. The 12Z surface pressure gradient was +9.0 millibars from San Francisco (SFO) to Las Vegas (LAS), with isobars (constant surface pressure) orientated northeast to southwest. With the alignment of the isobars and the +9.0 millibars pressure gradient, this represents light to moderate north-northeasterly flow across the San Joaquin Valley. Visibilities across the San Joaquin Valley in the morning reported fog turning to haze by the afternoon.

The morning temperature aircraft sounding over Bakersfield showed multiple inversions, with a moderately strong inversion (stable layer) of 12 degrees Fahrenheit from the surface up to 1,000 feet, with a secondary inversion of 4 degrees Fahrenheit from 1,500 to 3,000 feet as is evident in **Figure 3.** The temperature sounding on the January 12th, is conducive of elevated PM levels due to low mixing depths and multiple inversions, which trap pollutants near the surface. At surface observations across the San Joaquin Valley, minimum temperature at Fresno was 30 degrees Fahrenheit and Bakersfield was 29 degrees Fahrenheit.

Figure 3: Atmospheric Temperature Profile at Bakersfield on January 12, 1998



Upper level charts indicated a moderate high well off of Baja, with a ridge draped northeastward across central California. A weak trough bends southward along the Pacific Northwest Coast from a low over the eastern Gulf of Alaska. Pressure gradients weakened slightly during the afternoon hours further decreasing boundary layer flow in the San Joaquin Valley.

Table 5 shows the 24-hour daily average wind speeds at SJVAPCD monitoring sites, ASOS, and CIMIS sites for January 12, 1999.

SJVAPCD Monitoring Sites		ASOS		CIMIS			
	WS mph		WS mph		WS mph		WS mph
Clovis	2.6	Fresno	1.8	Shafter/USDA	2.6	Famoso	2.7
Fresno SSP	1.5	Bakersfield	4.8	Firebaugh/Telles	2.5	Westlands	3.1
Corcoran	3.0	Hanford	1.3	Stratford	2.9	Panoche	3.1
Edison	4.0			Kettleman	3.2	Arvin-Edison	2.9
Parlier	2.9			Visalia/Americas	2.4	Lindcove	2.0
Arvin	3.3			Parlier	2.5	Kesterson	2.4
Visalia	1.4			Blackwells Corner	2.5	Lodi West	2.7
				Los Banos	2.9	Modesto	4.5
				Manteca	4.0	Fresno State	2.7

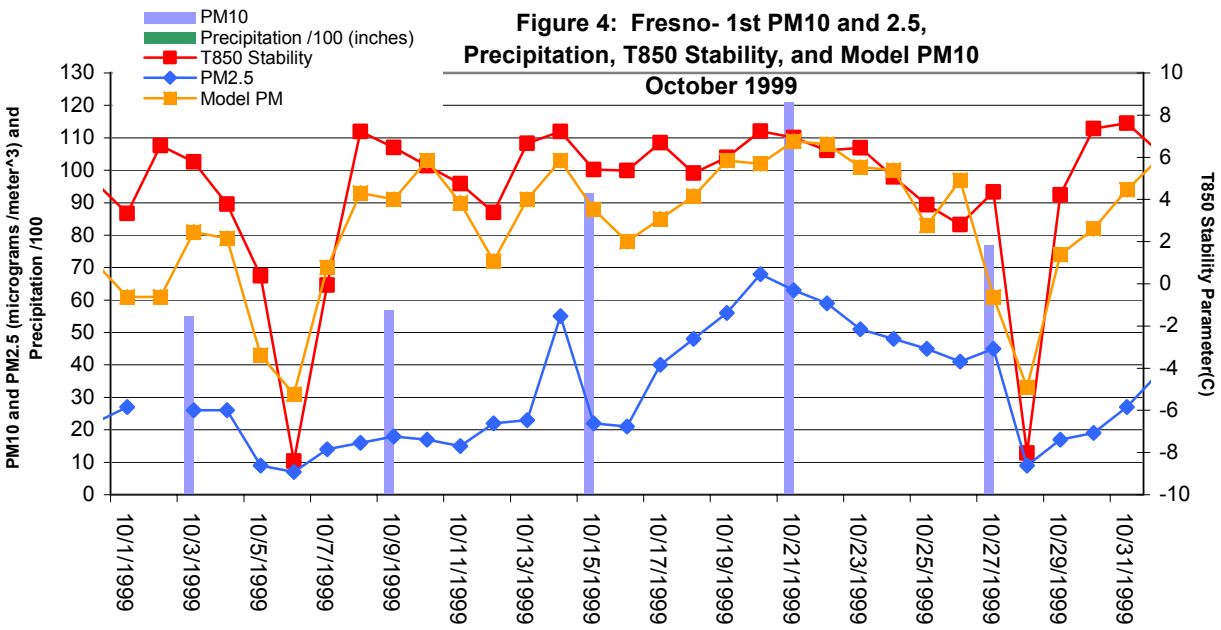
Due to the strong stability lasting for over 24 days, PM_{10} steadily increase region wide until January 12th. With the approach of the weak trough from northern California, moderately strong stability lingered over the southern parts of the San Joaquin Valley leading to local PM concentrations at Oildale increasing above the Federal 24-hour PM_{10} standard at 156 $\mu g/m^3$. Due to the increasing dispersion aloft from the weak upper level trough passage, widespread San Joaquin Valley PM10 exceedances did not occur on this date; thus the exceedance at Oildale was representative of local emissions driving the particulate measurement. Weak upper level disturbances continued to traverse the region through January 16th, bringing better dispersion conditions and an end to the PM episode that recorded exceedances at Bakersfield and Visalia on December 31st, 1998 and Oildale on January 12th, 1999.

October 21, 1999 Episode Synoptic Discussion
(October 07-October 28, 1999)

Throughout the San Joaquin Valley on October 21, 1999, several sites exceeded the Federal 24-hour PM_{10} Standard. These sites included: Fresno-Drummond Street at 162 $\mu g/m^3$, Corcoran-Patterson Avenue at 174 $\mu g/m^3$, and Turlock – S Minaret Street at 157 $\mu g/m^3$. In order to better understand the region wide occurrence of Particulate Material (PM) during this event, the synoptic meteorology, stability parameters, satellite imagery, atmospheric temperature profiles, and solar intensity measurements were investigated to determine the cause for the exceedances, which occurred on October 21, 1999.

Strong high pressure aloft and at the surface dominated the region's weather throughout the month of October 1999. This month was characterized by above normal temperatures (+3.4 ^0F) and below normal rainfall (-0.53 inches). The October 21, 1999 episode was preceded by deteriorating stability conditions after the passage of a weak trough into the Pacific Northwest on the 5th. **Figure 4** shows precipitation, $PM_{2.5}$, PM_{10}, Model PM, and stability parameters for the October 1999 episode at the Fresno-1st site.

Figure 4 also shows that the October 21st, 1999, episode was marked by a long period (21 days) of stable weather, with an average 500 MB height of 5,820 meters and 850 MB temperature of +16.4^0C. According to Hackney et. al., both the 500 MB height and 850 MB temperature were highly suggestive of a PM_{10} episode occurring. The San Joaquin Valley Air District uses regression equations to forecast PM_{10}. As is evident in **Figure 4**, Modeled PM_{10} tracked closely with both the measured PM_{10} and meteorological parameters. $PM_{10}/PM_{2.5}$ ratios showed an increasing amount of fine particulates within the sample, representing a change from a more typical coarse dominate fall regime to an increasingly dominated fine particulate regime of late November as is illustrated in **Figure 4**.

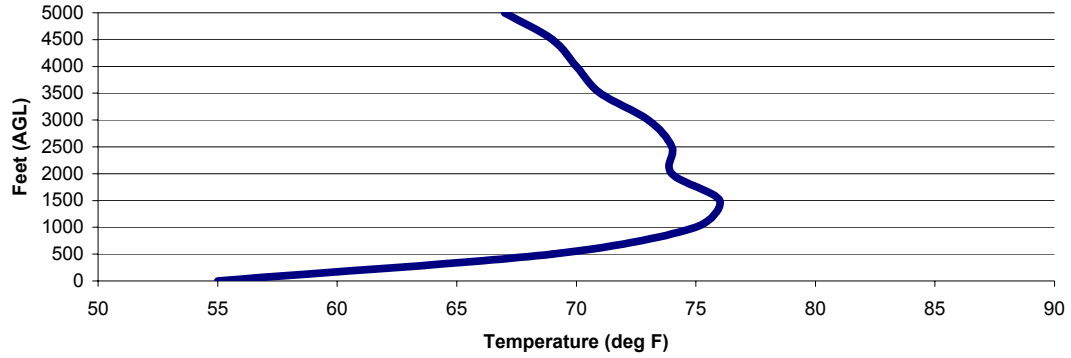


Next, winds speeds were analyzed during the exceedance date across the Valley. For example, at the Clovis monitoring site the 24-hour average wind speed was less than 2.2 knots (2.4 miles per hour). Since there was a strong high positioned across the region, the winds were calm in the morning becoming light thermally driven during the afternoon, resulting in minimal transport and dispersion. These weak winds are indicative of historical PM_{10} episodes.

These strong stable conditions continued through the 24th until the ridge began to breakdown and move eastward on the 25th. A cool, dry trough moved into the Pacific Northwest on the 28th, bringing good dispersion conditions, moderate to high boundary layer mixing heights and an end to the October 1999 episode.

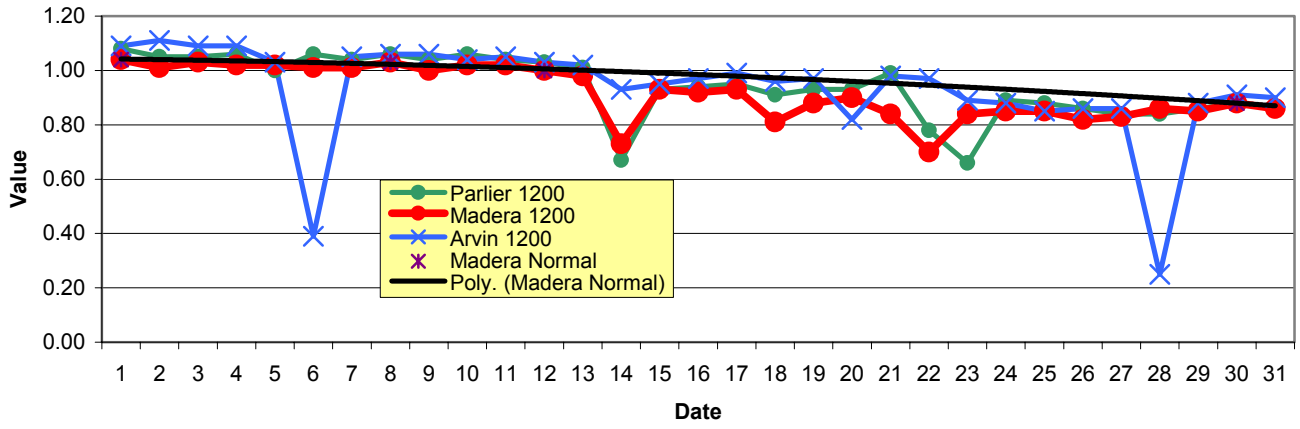
The morning temperature profiles from several sites were also investigated to determine the inversion strength and potential mixing depth. As is evident in **figure 5**, the morning temperature profile measured at 4:00 a.m. from Fresno depicts a very strong inversion of 21 degrees Fahrenheit from the surface up to 1,500 feet, turning slightly isothermal (constant temperature) up to 3,000 feet. This type of strong trapping inversion was also evident in Sacramento (22 degrees Fahrenheit from the surface up to 1,500 feet) and Bakersfield (12 degrees Fahrenheit from the surface up to 2,000 feet). The strong morning inversions present across the region coupled with very light wind flow, trapped most pollutants near the surface in a very low mix layer throughout most of the day resulting in the elevated PM_{10} measurements.

Figure 5: Atmospheric Temperature Profile at Fresno on October 21, 1999



Another meteorological parameter investigated was solar intensity. Solar intensity for the month of October was also analyzed to determine if particulate material aloft or at the surface was lowering the solar radiation input, which drives both photochemical reactions and particulate matter formation. As is evident in **figure 6**, three sites were analyzed; Madera, Parlier, and Arvin. It is evident especially with the solar intensity plot for Madera, that particulate matter was present over Madera, thus reducing the solar intensity measurement to below normal levels. This in effect, would change the atmospheric chemistry reactions from a more photochemistry-ozone forming regime to a more particulate regime that occurs during late November.

Figure 6: October 1999 Solar Intensity

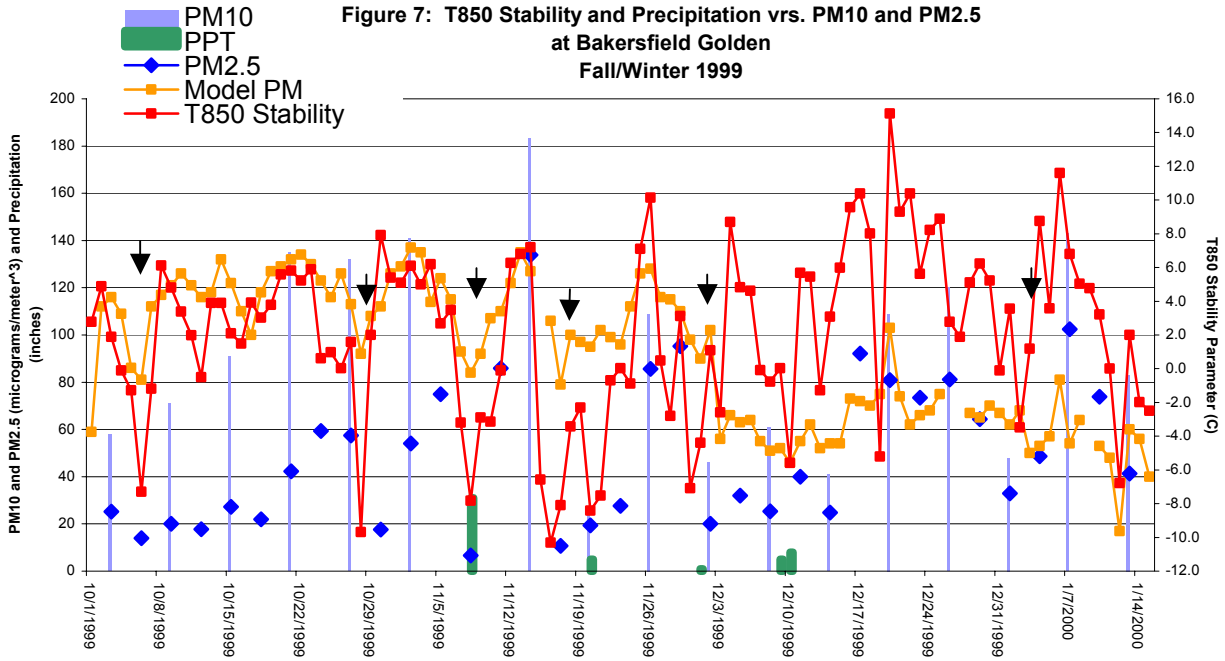


Satellite imagery analysis showed a weak low well off of Baja, drawing upper level moisture across the region. Varying amounts of high cloudiness were evident preceding the peak episode day and occurring through the 22nd. These clouds coupled with particulate aloft, drove the photochemistry reactions in the atmosphere into a fine particulate forming regime rather than an ozone forming regime.

Upon investigating the synoptic meteorology, stability parameters, atmospheric temperature profiles, and satellite imagery, these all are indicative of a widespread PM_{10} event, occurring in the San Joaquin Valley on October 21, 1999.

November 14, 1999 Episode Synoptic Discussion
(November 8 – November 17, 1999)

After the trough passage on November 8th, which brought 0.31 inches of rainfall at Bakersfield, strong surface high pressure from the Intermountain Region and a 500 MB ridge from northwestern Mexico built into the region. These conditions lead to increasing stability and poor dispersion conditions through the exceedance date on November 14th, **Figure 7.**



At Bakersfield, Golden, a 24-hour PM_{10} (Particulate Matter) concentration of 183 $\mu g/m^3$ was measured on the 14th. **Table 6** outlines federal reference method (FRM) Daily Average Particulate Matter Measurements for sites across the San Joaquin Valley (SJV). In order to understand the variability of these measurements, an in depth examination of the synoptic pattern and surface winds and observations, and aircraft soundings leading to the episode were analyzed.

TABLE 6: Federal Reference Method (FRM) Daily Average Particulate Matter Measurements for sites across the SJV for November 14, 1999.

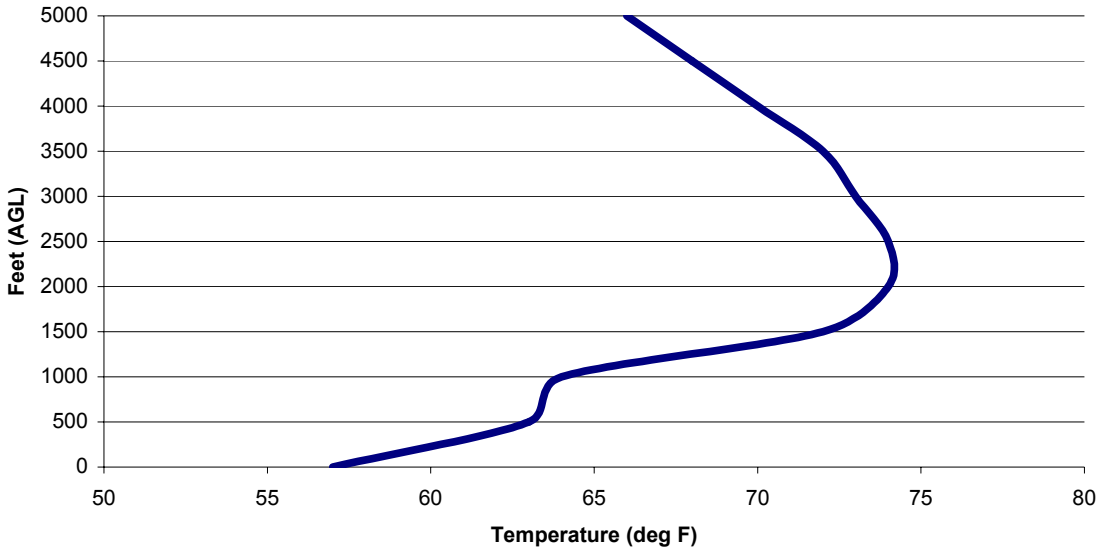
	FRM			FRM			FRM	
Site Name	24-Avg.		Site Name	24-Avg.		Site Name	24-Avg.	
	10	**2.5**		**10**	**2.5**		**10**	**2.5**
Bakersfield-Gold	183	134	Modesto	67	70	Hanford	138	
Bakersfield-CA	138	115	Merced-M St.	75	67	Stockton**	60	55
Visalia	137	121	Taft	70		Clovis	108	98
Fresno-1st	124	115	Fresno-Drum	130		Corcoran*	142	114

*-Patterson **- Hazleton units in $\mu g/m^3$

The meteorological synoptic analysis showed after a period of moderately strong atmospheric stability from November 8th through the 17th, an upper level closed low from the eastern Pacific approached the region. Ahead of the closed low, strong stability occurred over the San Joaquin Valley trapping particulates within the Valley boundary layer. The morning surface charts on the 14th depicted a surface high pressure ridge draped across Central California from the Great Basin to San Francisco. The 12Z surface pressure gradient was –3.6 millibars from San Francisco to Las Vegas (SFO-LAS), with isobars (constant surface pressure) orientated northwest to southeast. With the alignment of the isobars and the –3.6 millibars pressure gradient, light offshore flow resulted in weak disorganized wind flow across the San Joaquin Valley. Visibilities throughout the day across the San Joaquin Valley were reporting haze.

The morning temperature aircraft sounding over Bakersfield showed a strong inversion (stable layer) of 17 degrees Fahrenheit from the surface up to 2,000 feet as is evident in **Figure 8.** At Fresno the temperature sounding showed a similar strong inversion of 24 degrees Fahrenheit from the surface up to 2,000 feet. The temperature soundings on the 14th are conducive of elevated PM levels due to low mixing depths, which keep pollutants trapped near the surface. At surface observations across the San Joaquin Valley, minimum temperature at Fresno was 48 degrees Fahrenheit and Bakersfield was 49 degrees Fahrenheit.

Figure 8: Atmospheric Temperature Profile at Bakersfield on November 14, 1999



Upper level charts indicated a strong high over the Four Corners Region, with a ridge extending westward across California. At 850 MB a temperature ridge built northwestward across the San Joaquin Valley from southern California. A closed low was positioned 600 NM west of Santa Barbara. The pressure gradient across the San Joaquin Valley remained weak during the day leading to light and disorganized wind flow across the region. **Table 7** shows the 24-hour daily average wind speeds at SJVAPCD air monitoring, ASOS, and CIMIS sites for November 14, 1999. The 24-hour daily average wind speeds across the Valley floor were conducive to elevated PM readings over the central and southern parts of the San Joaquin Valley.

Table 7 shows the 24-hour daily average wind speeds at SJVAPCD monitoring, ASOS, and CIMIS sites for November 14, 1999.

SJVAPCD Monitoring Sites		ASOS		CIMIS			
	WS mph		WS mph		WS mph		WS mph
Clovis	3.9	Fresno	4.1	Shafter/USDA	3.5	Famoso	3.1
Fresno SSP	2.0	Bakersfield	6.1	Firebaugh/Telles	3.5	Westlands	3.9
Corcoran	3.0	Hanford	2.9	Stratford	3.0	Panoche	4.5
Edison	2.3			Kettleman	4.1	Arvin-Edison	3.2
Parlier	3.6			Visalia/Americas	2.4	Lindcove	1.9
Arvin	2.1			Parlier	3.0	Kesterson	3.2
Visalia	1.4			Blackwells Corner	5.4	Fresno State	3.4
				Los Banos	4.2	Modesto	3.1
				Manteca	2.9		

Due to the strong stability lasting for over 9 days, PM_{10} steadily increased region-wide until November 14th, 1999. Light disorganized wind flow, a strong morning inversion,

limited mixing depths, and strong stability aloft; lead to limited dispersion conditions on the 14th causing local PM emissions in Bakersfield Golden to increase past the Federal 24-hour PM_{10} standard to 183 $\mu g/m^3$. Since the other FRM Monitoring sites did not register above the Federal 24-hour PM_{10} standard on the 14th, the Bakersfield Golden PM_{10} measurement may signify impacts from local emission sources.

Other FRM Monitoring sites across the central and southern San Joaquin Valley (Visalia, Fresno, Hanford, Clovis, and Corcoran) measured 24-hour PM_{10} above 100 $\mu g/m^3$, but did not exceed the Federal 24-hour PM_{10} standard. A weak upper level disturbance moved through the region late on the 14th and 15th, bringing better dispersion conditions and lowering Bakersfield's PM measurements to less the National Ambient Air Quality Standard.

December 17, 1999 and December 23, 1999
(December 10 – December 31, 1999)

The period from December 10, 1999 through December 31st, 1999 was marked by 21 days of strong stability and poor atmospheric dispersion conditions. Strong high pressure over the Intermountain Region dominated the period, leading to light and disorganized wind flow and limited dispersion. The period began with the passage of a weak cold front and trough on the 9th. Between the 10th and the 17th, increasing stability and poor dispersion conditions resulted in a PM_{10} exceedance at Corcoran on the 17th, **Figure 9.**

At Corcoran, a 24-hour PM_{10} (Particulate Matter) concentration of 174 $\mu g/m^3$ was measured. **Table 8** outlines federal reference method (FRM) Daily Average Particulate Matter measurements for sites across the San Joaquin Valley (SJV). In order to understand the variability of these measurements, an in depth examination of the synoptic pattern and surface winds and observations, and aircraft soundings leading to the episode were analyzed.

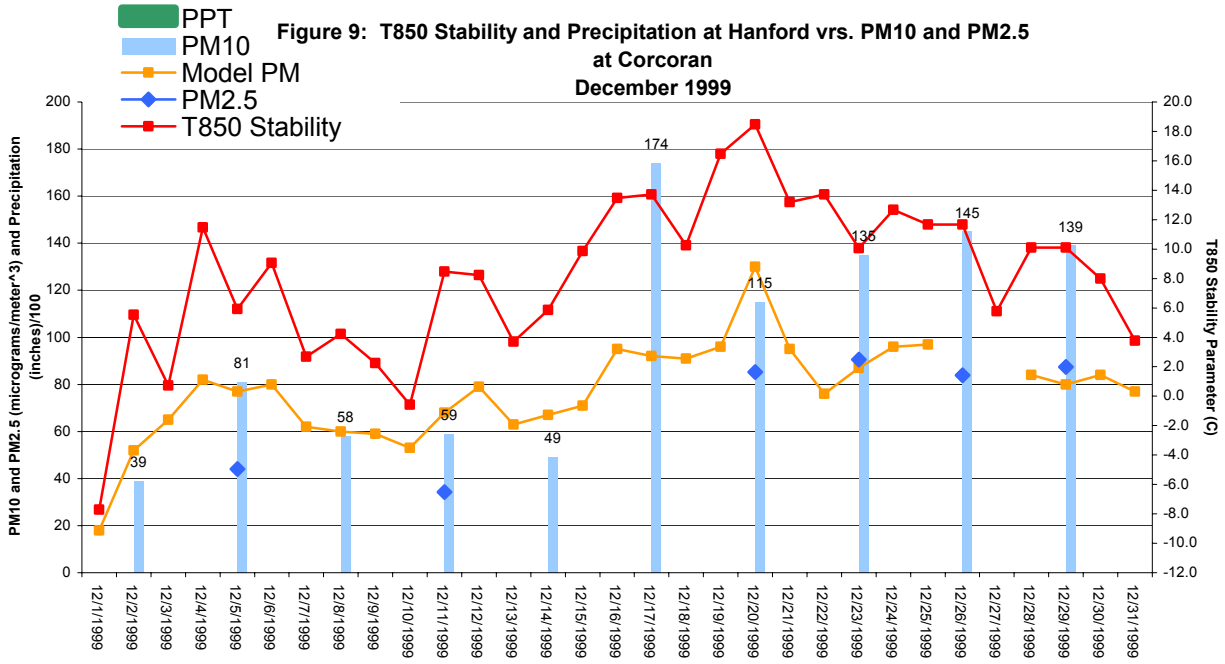


TABLE 8: Federal Reference Method (FRM) Daily Average Particulate Matter measurements for sites across the SJV for December 17, 1999.

	FRM			FRM			FRM	
Site Name	24-Avg.		Site Name	24-Avg.		Site Name	24-Avg.	
	10	**2.5**		**10**	**2.5**		**10**	**2.5**
Bakersfield-Gold		92	Modesto	99	93	Corcoran*	174	
Bakersfield-CA	111	90	Merced-M St.		75	Stockton**		78
Visalia		114	Clovis		18	Fresno-1st		107

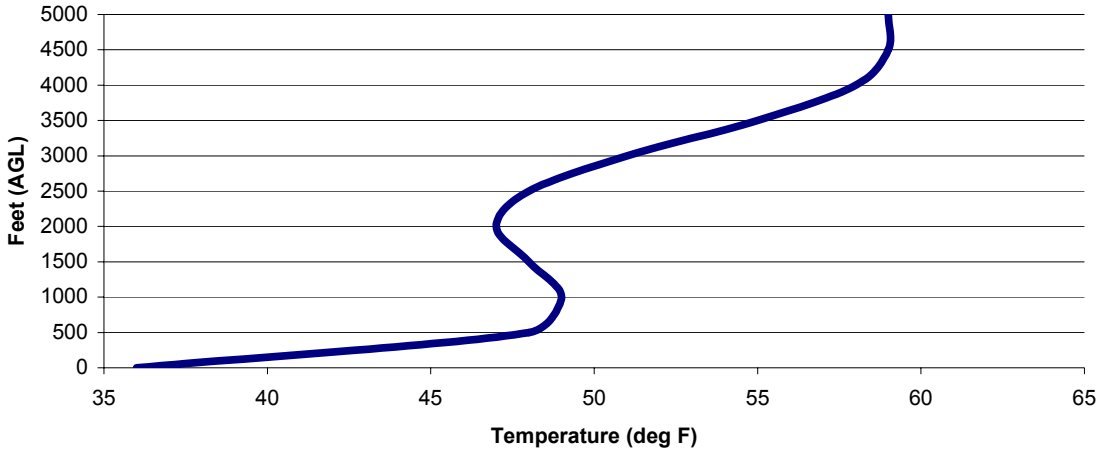
***-Patterson **- Hazleton units in $\mu g/m^3$

The meteorological synoptic analysis showed a period of moderately strong atmospheric stability from December 10th through the 17th. Ahead of a developing trough over the eastern Pacific, a strong mid and upper level ridge developed over the region on the 17th. This ridge strengthened the inversion over the San Joaquin Valley trapping particulates within the Valley boundary layer. The morning surface charts of the 17th depicted a strong surface high over the Great Basin and Intermountain Region. The 12Z (4 a.m.) surface pressure gradient was +1.8 millibars from San Francisco (SFO) to Las Vegas (LAS), with isobars (constant surface pressure) orientated west to east. The alignment of the isobars and the +1.8 millibars pressure gradient represents light and disorganized wind flow across the San Joaquin Valley. Visibilities throughout the day across the San Joaquin Valley were reporting haze.

The morning temperature aircraft sounding over Fresno on the 17th showed multiple inversions, with a strong inversion (stable layer) of 13 degrees Fahrenheit from the surface up to 1,000 feet, with a secondary strong inversion of 11 degrees Fahrenheit from 2,500 to 5,000 feet as is evident in **Figure 10.** The morning temperature sounding over Bakersfield also showed multiple inversions, with a strong inversion of 15 degrees Fahrenheit from the surface up to 3,000 feet, with a secondary strong inversion of 11 degrees Fahrenheit from 4,500 feet to 5,000 feet. The temperature sounding on the 17th, is conducive of elevated PM levels due to low mixing depths and multiple inversions, which keep pollutants trapped near the surface. During the early morning surface observations across the San Joaquin Valley were cold. The minimum temperatures recorded at Fresno and Bakersfield was 33 degrees Fahrenheit. The maximum high temperatures recorded at Fresno and Bakersfield was 59 degrees Fahrenheit. Fresno hourly temperature data shows very limited mixing conditions below 500 feet for over 18 hours of the day, increasing with minor afternoon heating to a

maximum mixing depth of 2,000 feet on the 17th.

Figure 10: Atmospheric Temperature Profile at Fresno on December 17, 1999



Upper level charts indicated a strong high just west of Santa Barbara, with a ridge building northeastward into the Great Basin. A weak trough over the extreme Pacific Northwest extended southward to near Eureka. Weak pressure gradients across the San Joaquin Valley remained rather flat through the day, leading to light and disorganized wind flow across the San Joaquin Valley.

Table 9 shows the 24-hour daily average wind speeds at SJVAPCD monitoring, ASOS, and CIMIS sites for December 17, 1999.

SJVAPCD Monitoring Sites		ASOS		CIMIS			
	WS mph		WS mph		WS mph		WS mph
Clovis	2.2	Fresno	1.7	Shafter/USDA	2.1	Famoso	2.4
Fresno SSP	1.4	Bakersfield	3.4	Firebaugh/Telles	2.2	Westlands	2.6
Corcoran	2.8	Hanford	1.0	Stratford	2.4	Panoche	2.6
Edison	3.3			Kettleman	2.6	Arvin-Edison	2.3
Parlier	3.2			Visalia/Americas	2.1	Lindcove	1.8
Arvin	2.2			Parlier	2.2	Kesterson	2.4
Visalia	1.6			Blackwells Corner	2.0	Lodi West	1.8
				Los Banos	2.8	Modesto	2.9
				Manteca	2.4	Fresno State	2.2

Due to the strong stability lasting for over 7 days, PM_{10} steadily increase region-wide until the sampling day on December 17th. With the mid and upper level stability aloft, surface based inversion, and light and disorganized wind flow, this weather pattern was conducive of an elevated region-wide PM_{10} measurements. At Visalia and Fresno 1st, fine particulates were above 100 $\mu g/m^3$, further suggesting a widespread PM event across the San Joaquin Valley.

After a weak upper level trough passage on the 18th, strong high pressure rebuilt into the region from the eastern Pacific, with increasing stability and poor dispersion conditions through the next exceedance date on December 23rd at Fresno-Drummond Street and Hanford-Irwin Street. At Fresno-Drummond, a 24-hour PM_{10} concentration of 168 $\mu g/m^3$ and at Hanford a 24-hour PM_{10} concentration of 156 $\mu g/m^3$ was measured. **Table 10** Federal Reference Method (FRM) Daily Average Particulate Matter and **Table 11** California Regional Particulate Air Quality Study (CRPAQS) Measurements shows for sites across the San Joaquin Valley (SJV) for December 23. In order to understand the variability of these measurements, an in depth examination of the synoptic pattern and surface winds and observations, and aircraft soundings leading to the episode were analyzed.

TABLE 10: Federal Reference Method (FRM) Daily Average Particulate Matter Measurements for sites across the SJV for December 23, 1999.

	FRM			FRM			FRM	
Site Name	24-Avg.		Site Name	24-Avg.		Site Name	24-Avg.	
	10	**2.5**		**10**	**2.5**		**10**	**2.5**
Bakersfield-Gold		74	Modesto	119	95	Corcoran*	135	91
Bakersfield-CA	109	72	Merced-M St.		83	Stockton**		79
Visalia		85	Clovis		22	Fresno-1st		119

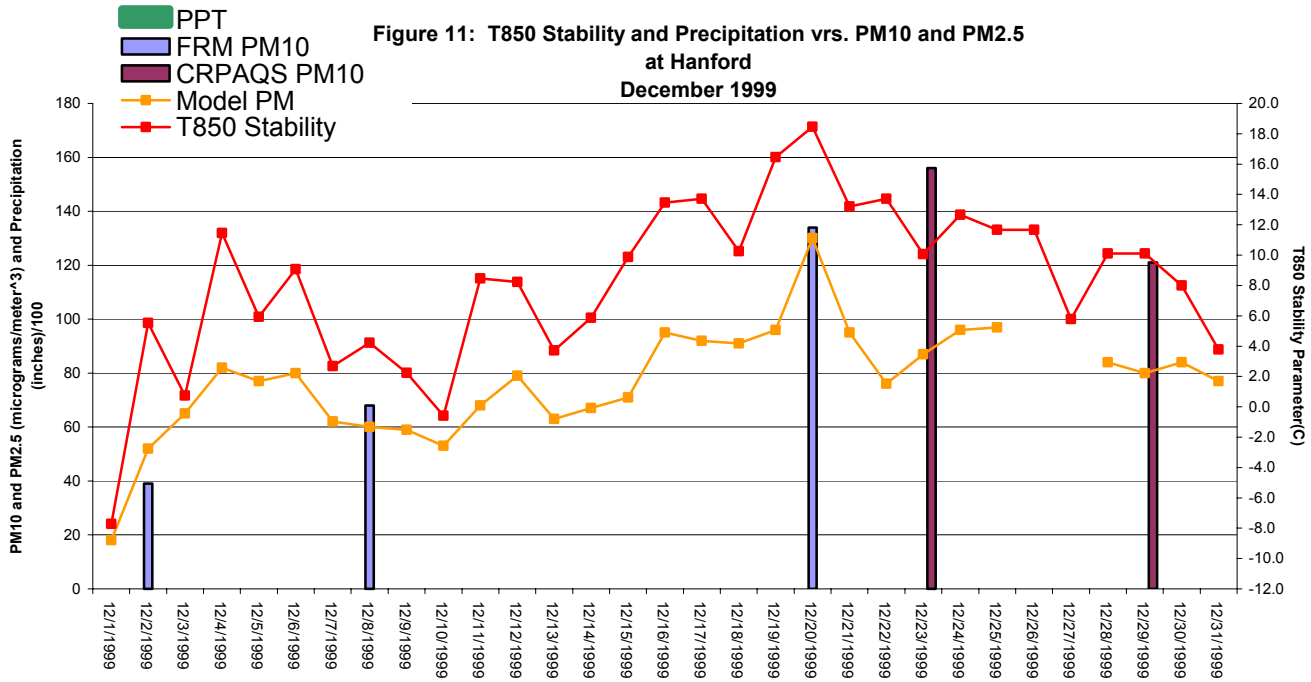
* -Patterson #-Wagner, **- Hazleton

TABLE 11: California Regional Particulate Air Quality Study (CRPAQS) Daily Average Particulate Matter Measurements for Fresno-Drummond and Hanford-Irwin for December 23, 1999.

	CRPAQS
Site Name	24-Avg.
	10
Fresno-Drummond	168
Hanford-Irwin	156

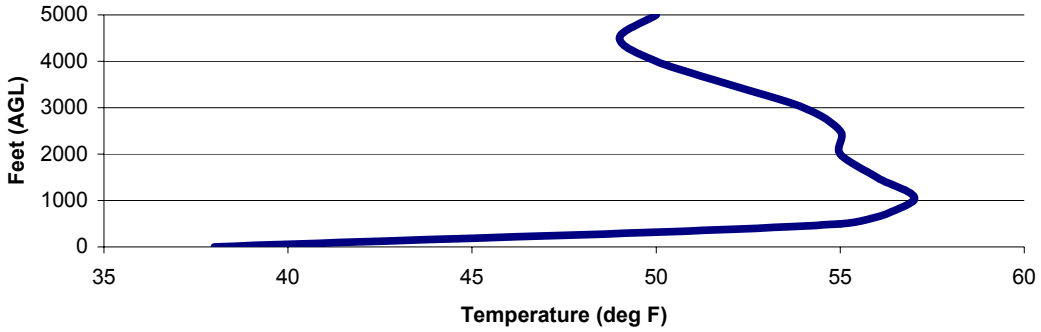
units in $\mu g/m^3$ for Table 10 and 11

The meteorological synoptic analysis showed after a period of strong atmospheric stability from December 18th through the 23rd, increasing stability and poor dispersion conditions lead to two exceedances measured using CRPAQS monitors at Fresno-Drummond and Hanford, **Figure 11**. The morning surface charts on the 23rd depicted a surface ridge extending southwestward across the central San Joaquin Valley from strong highs anchored over the Intermountain Region. The morning surface pressure gradient was –1.6 millibars from San Francisco to Las Vegas (SFO-LAS), with isobars (constant surface pressure) orientated southeast to northwest. With the alignment of the isobars and –1.6 millibars pressure gradient, this represents light southeasterly wind flow across the San Joaquin Valley. Visibilities across the San Joaquin Valley throughout the day reported hazy conditions.



The morning temperature aircraft sounding over Fresno depicted a strong inversion (stable layer) of 19 degrees Fahrenheit from the surface up to 1,000 feet as is evident in **Figure 12.** Bakersfield showed a strong inversion of 12 degrees Fahrenheit from the surface up to 1,000 feet turning isothermal up to 3,000 feet. The temperature soundings on the 23rd are indicative of elevated PM levels due to low mixing depths and strong inversions, which trap pollutants near the surface. During the early morning surface observations across the San Joaquin Valley were cold. The minimum temperatures recorded at Fresno and Bakersfield were 34 and 36 degrees respectively. The maximum high temperatures recorded at Fresno and Bakersfield were 62 and 64 degrees Fahrenheit respectively. Fresno hourly temperature data shows very limited mixing conditions below 500 feet for over 16 hours of the day, increasing with minor afternoon heating to a maximum mixing depth of 2,000 feet on the 23rd

Figure 12: Atmospheric Temperature Profile at Fresno on December 23, 1999



Upper level charts indicated a strong high 600 NM west of Santa Barbara, with a ridge building northward along the West Coast into the eastern Gulf of Alaska. Pressure gradients remained weak throughout the day leading to poor dispersion conditions across the San Joaquin Valley.

Table 12 shows the 24-hour daily average wind speeds at SJVAPCD monitoring, ASOS, and CIMIS sites for December 23, 1999.

SJVAPCD Monitoring Site		**ASOS**		**CIMIS**			
	WS mph		**WS mph**		**WS mph**		**WS mph**
Clovis	2.5	Fresno	1.5	Shafter/USDA	2.5	Famoso	2.5
Fresno SSP	2.1	Bakersfield	3.1	Firebaugh/Telles	2.5	Westlands	3.0
Corcoran	3.3	Hanford	1.6	Stratford	3.3	Panoche	2.7
Edison	3.7			Kettleman	3.3	Arvin-Edison	2.6
Parlier	3.9			Visalia/Americas	2.5	Lindcove	1.8
Arvin	2.4			Parlier	2.7	Kesterson	2.1
Visalia	1.7			Blackwells Corner	2.1	Lodi West	1.7
				Los Banos	2.8	Modesto	2.4
				Manteca	2.4	Fresno State	2.3

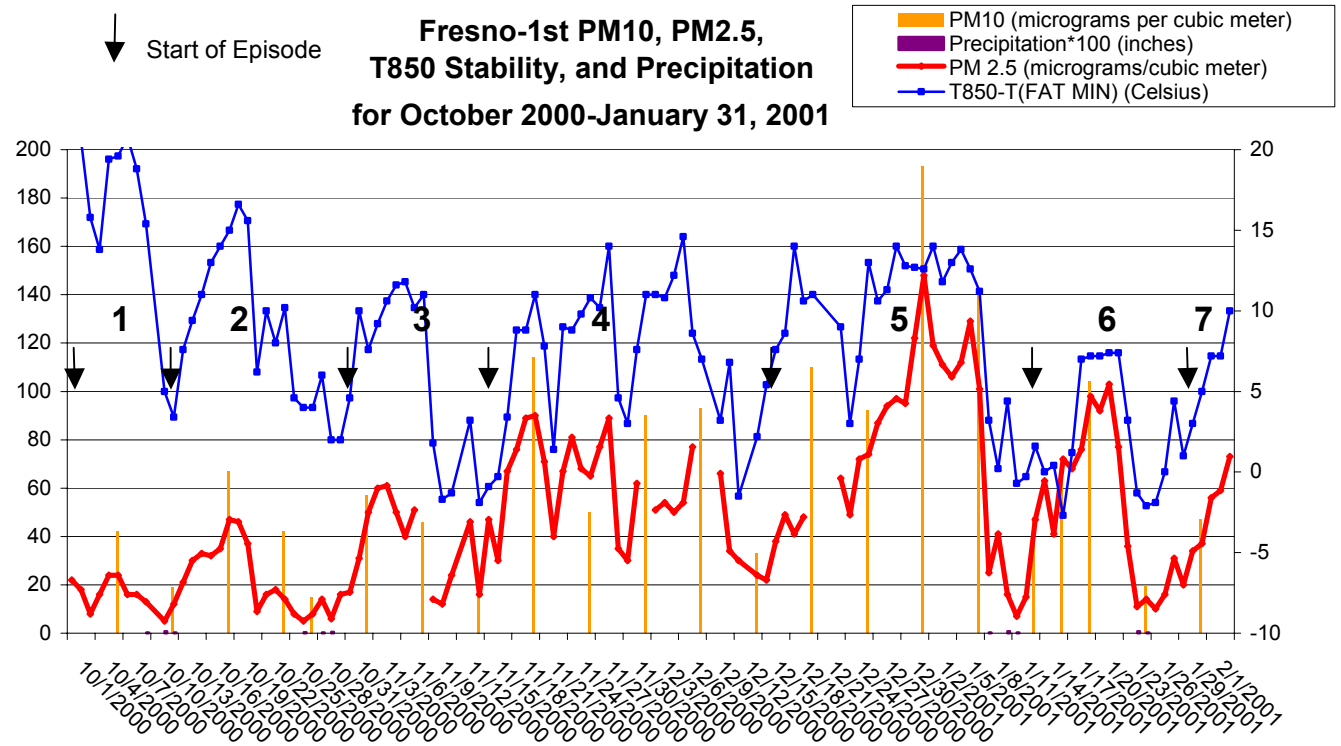
The period of December 10, 1999 through December 31st, 1999, marked one of the longest periods of strong stability in recent history. This pattern was similar to the one experienced during the California Regional Particulate Air Quality Study. The main difference between the two episodes was the CRPAQS event began a week later and continued into the early part of January. During the exceedances of 1999, they were preceded by an exceptionally dry fall. After a weak frontal passage on the 10th, which brought a cold air mass to the Valley, this air remained trapped within the Valley boundary layer resulting in strong surface based inversions. Coupled with the synoptic and surface pattern, which was indicative of light and disorganized wind flow, PM became a region-wide problem until a weak trough scoured out the area on New Year's Eve. As is evident in the PM data, local emissions contributed to the exceedance of the National Ambient Air Quality Standards at Corcoran on the 17th and Fresno-Drummond, and Hanford on the 23rd. If monitoring were done on a daily basis, more exceedances would have been recorded during this time frame at other San Joaquin Valley locations.

CRPAQS SYNOPTIC SUMMARY
(October 1, 2000 through February 3, 2001)

The CRPAQS fall and winter measurement periods can be divided into seven distinct episodes. These episodes, characterized by limited atmospheric dispersion, were separated by vigorous trough passages. Analysis of synoptic events shows that once a particulate episode begins, a deep trough must traverse the region at both the upper levels of the atmosphere and at the surface as a cold frontal boundary in order to significantly decrease Particulate Matter (PM) concentrations. These types of troughs are normally associated with strong vertical mixing, moderate to high boundary layer mixing heights, precipitation, and wind speed and directional sheer within the boundary layer.

The meteorological analysis for CRPAQS utilized synoptic analyses, precipitation patterns, and atmospheric stability parameters to determine episode strength and periodicity. Analysis of $PM_{2.5}/PM_{10}$ ratios and nitrate levels reveal that when the overnight minimum temperature decreased to below 40 degrees Fahrenheit, coupled with significant warming aloft, fine particulate levels climbed. When prolonged periods of these conditions occurred, $PM_{2.5}$ levels climbed above the NAAQS. In even stronger more persistent stability regimes, PM_{10} exceeded the NAAQS. **Figure 13** shows precipitation, $PM_{2.5}$, PM_{10}, and stability parameters for the CRPAQS period at the Fresno-1st site. General patterns in these parameters where also evident at other sites. Precipitation events also influenced PM concentrations during CRPAQS. For the CRPAQS period, when a frontal system was strong enough to produce precipitation of 0.10 inch or more of liquid water, 24 hour averaged $PM_{2.5}$ concentrations dropped to below 15 $\mu g/m^3$.

Figure 13.



The synoptic meteorological parameters analyzed to determine the behavior of particulate matter were 850 MB temperature stability (T850 Stability ^{0}C), 500 MB height (decameters), and precipitation (inches). The 850 MB temperature stability parameter was utilize because 850 MB temperature (approximately 5,000 feet) minus the minimum surface temperature is a good indicator of the inversion strength, the mixing layer depth, and whether air is being warmed from a synoptic subsidence inversion aloft. This inversion is commonplace when a ridge builds along the West Coast of California, providing general adiabatic warming of subsiding air over the region. In Hackney, et al, an analysis was conducted on the relationship of historical 850 MB temperatures and PM measurements. Hackney, et al, determined that in the San Joaquin Valley, when 850 MB temperatures in the fall were above +15^{0} C and +10^{0}C during the winter (late November or December to February) an episode was possible. A stronger indication for a PM episode to occur is when 850 MB temperatures were above +18^{0}C in the fall and above +14^{0}C in the winter.

500 MB height is also important in that it is directly correlated to the temperature of the entire column of air. During periods of high pressure aloft, flows at the surface are usually light and accompanied by low mixing depths. The 500 MB height and placement of the mean ridge and trough patterns reflect PM amounts and trends. In Hackney, et al, it was determined that a height of 5,760 meters in the San Joaquin Valley is sufficient to suspect an episode, and that a height of 5,820 meters or more in the Valley made an episode occurrence a likelihood.

Precipitation measurements were also analyzed as an indicator of the vigorous trough passages, which provided enough vertical mixing to produce rainfall. As mentioned before, the strength of the frontal system and trough was a good indicator of how much PM dispersion occurred.

Table 13 shows for each peak day within the seven episodes, the PM values, meteorological parameters, and episode duration. The major episode of CRPAQS, when PM10 exceeded the NAAQS, was manifested by cool overnight lows near 32 degrees Fahrenheit and warm air aloft for an extended period of time. These conditions persisted from December 17th through January 7th. During this time, PM steadily increased to a peak value at Fresno ($PM_{2.5}$ = 148 $\mu g/m^3$ and PM_{10} = 193 $\mu g/m^3$) and Bakersfield-Residential ($PM_{2.5}$ =133$\mu g/m^3$) on the 1st of January. During this period in urban areas, initial analysis of speciation data show high carbon and ammonium nitrate levels. The combination of an 850 MB temperature ridge aloft along with low minimum temperatures resulted in strong inversions trapping pollutants in a shallow mix layer. The high carbon levels could have been due to holiday residential wood combustion. In addition, under these cold and poor dispersion conditions, nitrate levels measured on the real-time instruments were the highest of the study.

TABLE 13: CRPAQS EPISODE EVENT SUMMARY TABLE

Episode Number	Date	PM10	PM2.5	T850 Stability (^{0}C)	Minimum (^{0}F)	500 MB Height	Episode Duration (days)
1	10/1-10/12	42(6th)	24(5th&6th)	2.4	63	578	**12**
2	10/13-10/30	67(18th)	47(18th)	6.8	54	578	18
3	10/31-11/15	57(2nd)	61(4th)	2.3	47	575	17
4	11/16-12/15	114(20th)	90(20th) 89(28th)	9.3 6.2	35 46	576 572	28
5	12/16-01/12	193(1st)	148(1st)	12.6	32	574	26
6	01/13-01/27	104(19th)	103(21st)	3.9(19th) 6.8(21st)	38(19th) 33(21st)	571(19th) 569(21st)	15
7	01/28-02/03	47(31st)	73(3rd)	3.9(31st) 6.1(3rd)	34(31st) 39(3rd)	568(31st) 580(3rd)	**7**

One basis for understanding the behavior of particulate matter evolution is to analyze the synoptic situation that is driving the local effects of dispersion and transport. These synoptic descriptions follow.

Episode 1: Sunday, October 1 -Thursday, October 12

From the 1st to the 8th, episode #1 was marked by a mean, broad ridge anchored across the eastern Pacific and California, which brought moderate stability and low to moderate mixing heights. This ridge was low in amplitude, resulting in moderate subsidence. An inverted thermal surface trough developed from Bakersfield curving northwestward to Redding. This pressure pattern was representative of calm overnight winds, and thermally driven light afternoon northwesterly flow. During this initial episode, $PM_{2.5}$ values average near 20 $\mu g/m^3$ and measured PM_{10} concentration at Fresno was 42 $\mu g/m^3$ on the 6th. The 500 MB height of 578 dm on the 6th was conducive of a high PM event, whereas, the 850 MB stability parameter of +2.4 Celsius (T850 MB = $+20^0$C) was indicative of the likelihood of an event. As is evident in the low T850 MB stability parameter, the inversion and resulting stability was not strong enough to trap and elevate PM readings, thus resulting in PM levels remaining well below the standard.

A significant early season trough moved into the region on the 9th, bringing increasing instability and boundary layer flow. Within the next couple of days, the 9th to the 12th, a series of disturbances embedded within the mean trough traversed central California bringing increased wind flow, higher boundary layer mixing heights, and precipitation. The most noteworthy precipitation during this period occurred on the 11th, when a second short wave embedded within the mean trough across California crossed the Valley and produced 0.76 inches of precipitation.

Episode 2: Friday, October 13 –Monday, October 30

Episode #2 was marked by high pressure rapidly building into the region on the 13th and persisting through the 20th. This episode was unique in that the central California was under the influence of both the eastern Pacific and Four Corners ridge during the peak episode day. This pattern resulted in weak thermally driven flow at the surface and general synoptic subsidence aloft. As a result, under light to moderate stability, T850 stability parameter of +2.8 ^{0}C (T850 MB = 15^0C), moderately high 500 MB heights (578 MB) and low mixing depths, PM climbed and reached a maximum concentration in Fresno at PM_{10} – 67 $\mu g/m^3$ and $PM_{2.5}$ – 47 $\mu g/m^3$ and Bakersfield at $PM_{2.5}$ – 30 $\mu g/m^3$ on the 18th. According to Hackney, et, al, the 850 MB temperature and 500 MB heights reached the criteria to suspect an episode. As is evident in the PM measurements the state standard was exceeded in Fresno on the 18th.

The ridge began to breakdown on the 20th as weak disturbances traversed the ridge and formed a closed low over the Great Basin on the 24th. Another stronger trough moved into the region on the 25th bringing moderate boundary layer flow, vigorous vertical mixing, and periods of precipitation through the 30th. With the trough passage on the 29th, Fresno recorded the maximum amount of precipitation during the episode of 0.55 inches.

Episode 3: Tuesday, October 31 –Wednesday, November 15

Episode #3 began on the 31st as a strong ridge developed along the West Coast. The ridge axis remained offshore during this episode leading to downstream subsidence and increasing stability. During the peak PM event of episode #3, Bakersfield's PM values were lower than Fresno due to a closed low circulation over northern Baja, creating some upper level mixing and neutral to light instability over southern California. As a result, the peak $PM_{2.5}$ levels at Bakersfield Residential were 45 $\mu g/m^3$, with a T850 MB stability parameter of +1.4 ^0C (T850 MB = +9.2 ^0C) and 500 MB height of 575 dm on the 3rd and at Fresno First PM_{10} measurement of 57 $\mu g/m^3$ on the 2nd and $PM_{2.5}$ measurement 61 $\mu g/m^3$, with a 850 MB stability parameter of +2.3 ^0C (T850 MB = +10.6 ^0C) and 500 MB height of 575 dm on the 4th.

In both Fresno and Bakersfield, according to Hackney et, al, the T850 MB and 500 MB heights do not suggest an episode under a fall regime; however, the PM10 measurement in Fresno exceeded the standard on the 2nd. Whereas, comparing Hackney et al, results under a winter regime to the observed T850 MB, their conclusion supported a minor PM episode. Due to early season rainfall and a general cooling of the lower levels of the atmosphere, the transition from the fall to the winter regime took place during this time.

PM levels steadily lowered as the upper level ridge and surface high pressure gradually weakened and moved eastward. An unseasonably cold trough (540 dm at OAK) and a vigorous, dry cold front from the Gulf of Alaska moved into the region on the 9th, bringing increased boundary layer flow and deep mixing. This system was moisture starved and resulted in trace amounts of precipitation across the region. The frontal system and accompanying trough were strong enough to bring an end to the 3rd episode as deep mixing scoured the area. Multiple embedded disturbances within this trough traversed the region bringing unstable conditions, good dispersive conditions, and moderate boundary layer flow and mixing heights into the 15th.

Episode 4: Thursday, November 16 –Friday, December 15

Episode #4 began on the 16th and was marked by a moderate ridge building along the West Coast bringing increasing stability and offshore flow. During CRPAQS the 4th episode was the longest period at 28 days.

Stability and PM values steadily increased to the highest measured values of the episode on the 20th and 21st of November, with a secondary peak occurring on the 28th. This episode was separated into two peaks due to a trough developing over the Great Basin on the 22nd dispersing some of the PM which had built up over the region. Fresno and Bakersfield peak $PM_{2.5}$ measurements were observed on the 20th at 90 $\mu g/m^3$ and on the 21st at 96 $\mu g/m^3$, respectively. The highest measured PM_{10} during this episode was at Fresno on the 20th with a value of 114 $\mu g/m^3$. Fresno $PM_{2.5}$ measurement reached a secondary peak on the 28th at 89 $\mu g/m^3$. This episode was separated into

two peaks due to a trough developing over the Great Basin on the 22nd dispersing some of the PM which had built up over the region.

According to Hackney, et., al, the 850 MB temperature measured +11^{0}C and +14^{0}C on the 20th and 28th, respectively, were representative of an PM episode occurring, whereas, the 500 MB heights of 576 and 572 dm, were indicative of a weak PM episode. During this episode, the state standard was exceeded.

This episode was characterized by a mean mid-tropospheric ridge positioned along the West Coast, with brief drop in the PM measurements on the 29th and 30th, when a dry, front passed to the north of the area dropping to $PM_{2.5}$ measurements at Fresno to 35 $\mu g/m^3$ on the 30th and Bakersfield to 22 $\mu g/m^3$ on the 29th.

The ridge began to breakdown late on the 7th, bringing decreasing stability, better dispersion, and lowering PM concentrations. A series of weak disturbances traversed the region from the 7th through the 15th, bringing very light precipitation to Fresno (total = 0.07 inches), increased boundary layer flow and mixing depths, which brought an end to the episode #4.

Episode #5: Saturday, December 16 –Friday, January 12

Episode #5 began on the 16th and was marked by the West Coast ridge building into California, resulting in lowering boundary layer mixing heights and increasing stability. PM region-wide uniformly increased with 500 MB heights and stability, with a minor intra-episode peak, with PM_{10} measurement at Fresno of 110 $\mu g/m^3$ and $PM_{2.5}$ measurement at Bakersfield Residential of 58 $\mu g/m^3$, occurring on the 20th. A weak upper level disturbance briefly broke down the ridge on the 24th resulting in slightly lower $PM_{2.5}$ measurements in Fresno at 49 $\mu g/m^3$ and Bakersfield 40 $\mu g/m^3$. After this weak trough passage, the ridge rebuilt in earnest and moderate stability and low mixing heights continued through the end of the episode on January 7th.

During this episode the maximum PM measurements of the CRPAQS period were observed. The general synoptic pattern during this episode was strong high pressure aloft positioned along the West Coast providing a general area of subsidence and stable weather over the region, with an accompanying strong surface high located over Idaho. With high pressure over the Intermountain Region and lower pressures over the eastern Pacific, moderate offshore flow developed. Typically with this type of flow pattern, the normal nocturnal inversion at the surface is reinforced with a subsidence inversion aloft, created by adiabatic warming off the Sierra's and general subsidence from the ridge.

The peak measurements of the fifth episode were recorded on the 1st and 7th with PM_{10} measurements at Fresno of 193 $\mu g/m^3$ (1st) and 141$\mu g/m^3$ (7th). $PM_{2.5}$ measurements at Fresno of 148 $\mu g/m^3$ (1st) and 101 $\mu g/m^3$ (7th) and Bakersfield Residential at 133 $\mu g/m^3$ (1st) were also recorded. These high PM values corresponded with the highest 850 MB stability (+13.4 C at Oakland) measured during the CRPAQS period, which occurred on the 2nd. The 850 MB temperature was very warm during this episode. At Oakland

at 12Z, the 850 MB temperature was +13 ^{0}C. This is representative of a strong PM episode. The 500 MB height was not indicative of a strong episode. At 574 dm, the value was not conducive to a significant PM episode. The combination of weak offshore flow and mid-tropospheric stability, elevated the PM readings experienced across central California.

A significant trough moved into the region on the 8th, with accompanying rainfall in Fresno of 0.31 inches and Bakersfield of 0.29 inches. A series of disturbances within the trough traversed the region from the 8th to the 12th adequately dispersing the PM that had built up over the region during the episode and lowered $PM_{2.5}$ measurements into the upper teens by the 10th in both Fresno and Bakersfield.

Episode 6: Saturday, January 13 –Saturday, January 27

High pressure and increasing subsidence once again moved into the region on the 13th bringing increasing PM levels and leading to the beginning of the episode #6. This episode was characterized by ridging through the 17th, resulting in building $PM_{2.5}$ values into the lower 60's $\mu g/m^3$ range. Shortly thereafter, more pronounced ridging and decreasing dispersion occurred on the 18th, when 500 MB heights climbed to near 578 dm with an 850 MB stability indices of +7 °C (850 MB temperature of +7^{0}C). The 500 MB height was conducive of an episode occurring, but the 850 temperature was not conducive of an episode. This peak in meteorological parameters corresponded with the highest recorded PM_{10} measurement of the episode at Fresno at 104 $\mu g/m^3$ on the 19th.

$PM_{2.5}$ peaked at Fresno on the 21st with a measurement of 103 $\mu g/m^3$ and also in Bakersfield Residential on the 22nd at 103 $\mu g/m^3$. The southward progression of the peak $PM_{2.5}$ values can be accounted for by the pre-frontal / trough stability that progressively moved down-valley with the approach of the next system from the eastern Pacific on the 23rd.

A series of disturbances embedded within the trough moved through the region from the 23rd to the 27th, with adequate boundary layer mixing heights, moderate instability, and moderate southeasterly flow, dispersing PM levels into the low teens. From the 23rd to the 25th, a series of strong cold frontal systems brought 1.19 inches of rainfall at Fresno, bringing an end to the 6th episode. The highest recorded rainfall during the trough passage occurred on 0.85 inches on the 24th.

Episode 7: Sunday, January 28 –Saturday, February 3

The final (7th) episode of CRPAQS began on the 28th, when strong high pressure built along the West Coast. Light boundary layer flow and increasing 850 MB stability resulted in $PM_{2.5}$ levels gradually climbing into the early part of February. $PM_{2.5}$ measurements of 73 $\mu g/m^3$ in Fresno on the 3rd and 92 $\mu g/m^3$ in Bakersfield on the 4th marked the buildup that occurred during this episode.

November 9, 2001
(October 31, 2001- November 10, 2001)

The period from October 31 through November 10, 2001 was marked by 11 days of strong stability and poor atmospheric dispersion conditions. Strong high pressure both at the surface and aloft over the Intermountain Region dominated the period, leading to light and disorganized wind flow and limited dispersion. The period began with the passage of a vigorous cold front and upper level trough on the 31st, **Figure 14**. Between the 31st and the 10th, strong stability, light and disorganized wind flow, and poor dispersion conditions resulted in a PM_{10} exceedance at Hanford on November 9th.

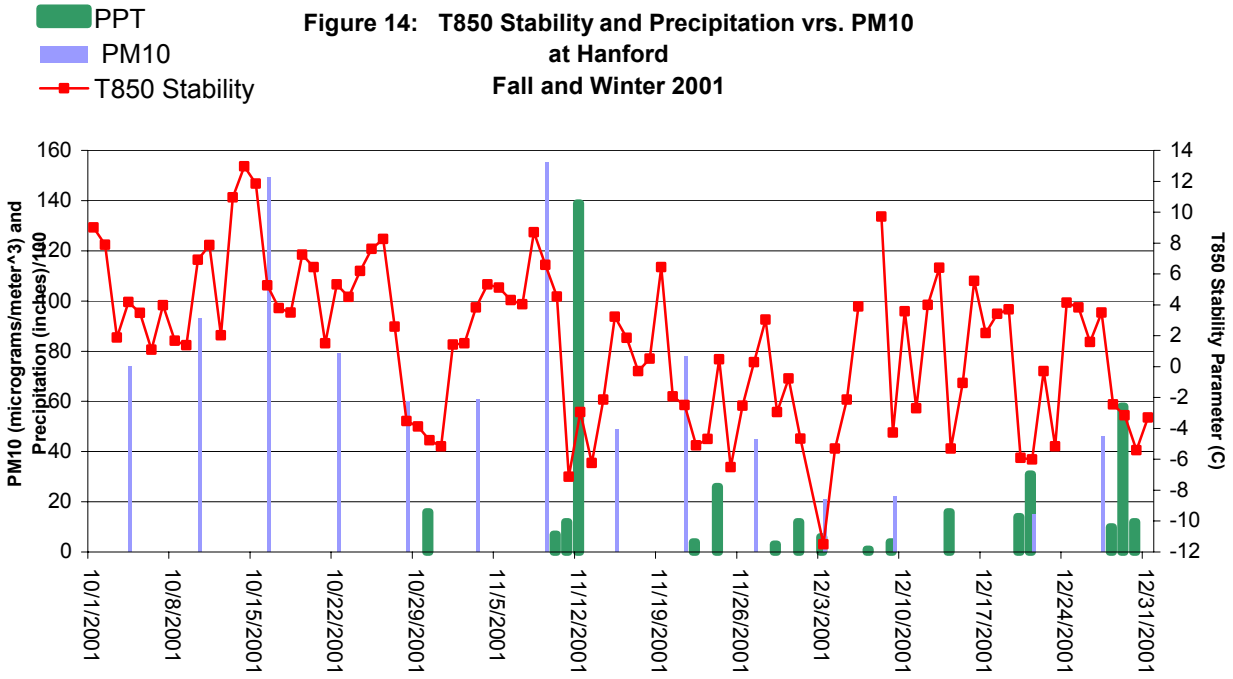


Figure 14: T850 Stability and Precipitation vrs. PM10 at Hanford Fall and Winter 2001

At Hanford, a 24-hour PM10 (Particulate Matter) concentration of 155 mg/m3 was measured. **Table 14** outlines federal reference method (FRM) Daily Average Particulate Matter measurements for sites across the San Joaquin Valley (SJV). In order to understand the variability of these measurements, an in depth examination of the synoptic pattern and surface winds and observations, and aircraft soundings leading to the episode were analyzed.

TABLE 14: Federal Reference Method (FRM) Daily Average Particulate Matter measurements for sites across the SJV for November 9, 2001.

	FRM			FRM			FRM	
Site Name	24-Avg.		Site Name	24-Avg.		Site Name	24-Avg.	
	10	**2.5**		**10**	**2.5**		**10**	**2.5**
Bakersfield-Gold	102		Modesto	115	69	Corcoran*	117	46
Bakersfield-CA		38	Merced-M St.	69	34	Stockton**	97	55
Visalia	74	38	Clovis	68	32	Fresno-1st	70	46
Hanford	155		Fresno-Drum	97		Turlock	124	

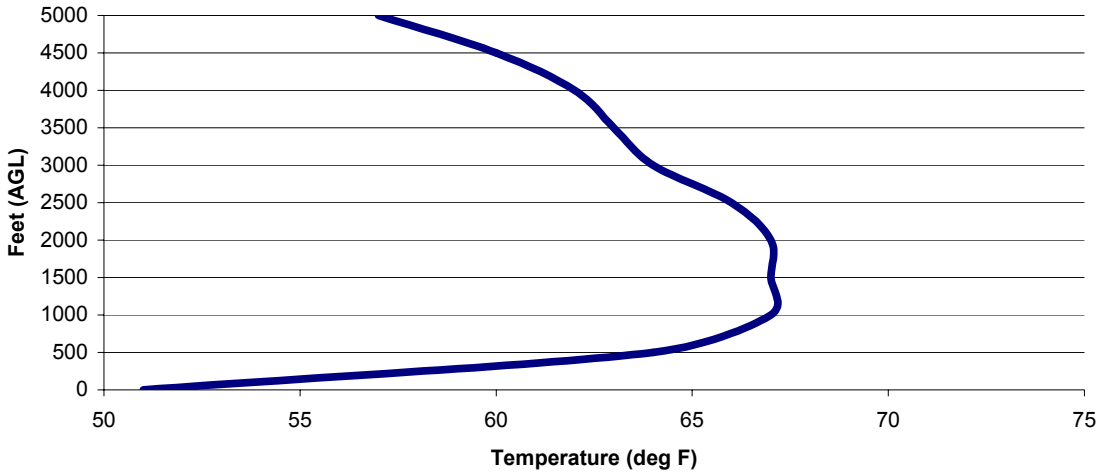
*-Patterson **- Hazleton units in $\mu g/m^3$

The meteorological synoptic analysis showed a period of moderately strong atmospheric stability from October 31st through the November 10th. Ahead of a developing trough over the eastern Pacific, a strong mid and upper level ridge developed over the region on the 9th. This ridge strengthened the inversion over the San Joaquin Valley trapping particulates within the Valley boundary layer. The morning surface charts of the 9th depicted a strong surface high over the Intermountain Region, with a surface ridge extending southwestward across central California. The 12Z (4 a.m.) surface pressure gradient was –4.1 millibars from San Francisco (SFO) to Las Vegas (LAS), with isobars (constant surface pressure) orientated southeast to northwest. The alignment of the isobars and the –4.1 (SFO-LAS) millibars pressure gradient, represents light southeasterly wind flow across the San Joaquin Valley. Visibilities throughout the day across the San Joaquin Valley were reporting haze.

The morning temperature aircraft sounding over Fresno on the 9th showed a strong inversion (stable layer) of 16 degrees Fahrenheit from the surface up to 1,000 feet, turning isothermal (constant temperature) up through 2,500 feet as is evident in **Figure 15.** The morning temperature sounding over Bakersfield showed a very strong inversion of 22 degrees Fahrenheit from the surface up to 1,500 feet. The temperature sounding on the 9th, is conducive of elevated PM levels due to low mixing depths and very strong surface based inversions, which keep pollutants trapped near the surface. During the early morning surface observations across the San Joaquin Valley were cold. The minimum temperature recorded at Fresno was 49 degrees Fahrenheit. The minimum temperatures recorded at Bakersfield and Hanford was 45 degrees Fahrenheit. The maximum high temperatures recorded at Fresno and Hanford was 80 degrees Fahrenheit. The maximum high temperature recorded in Bakersfield was 83 degrees Fahrenheit. Fresno hourly temperature data shows very limited mixing conditions below 1,000 feet for over 18 hours of the day, increasing with afternoon

heating to a maximum mixing depth of 2,000 feet on the 9th.

Figure 15: Atmospheric Temperature Profile at Fresno on November 9, 2001



Upper level charts indicated a strong high over the Intermountain Region, with a ridge extending westward across central California. An upper level trough 750 NM west of San Francisco developed and moved closer to the Californian coastline on the 9th. Weak pressure gradients over the region remained rather flat through the day, leading to light southeasterly wind flow across the San Joaquin Valley.

Table 15 shows the 24-hour daily average wind speeds at SJVAPCD monitoring, ASOS, and CIMIS sites for November 09, 2001.

SJVAPCD Monitoring Sites		ASOS		CIMIS			
	WS mph		WS mph		WS mph		WS mph
Clovis	2.4	Fresno	1.5	Shafter/USDA	3.0	Famoso	2.3
Fresno SSP	2.2	Bakersfield	5.3	Firebaugh/Telles	2.3	Westlands	4.1
Corcoran	2.3	Hanford	1.2	Stratford	1.8	Panoche	2.4
Edison	3.6	Madera	3.9	Kettleman	2.8	Arvin-Edison	3.0
Parlier	2.9	Merced	3.6	Visalia/Americas	2.1	Lindcove	2.1
Arvin	2.5			Parlier	1.2	Kesterson	2.4
Visalia	1.4			Blackwells Corner	3.5	Lodi West	1.3
				Los Banos	2.5	Modesto	3.4
				Manteca	2.8	Fresno State	2.3

Due to the strong stability lasting for over 10 days, PM_{10} steadily increase region-wide until the sampling day on November 9th. With the mid and upper level stability aloft, surface based inversion, and light southeasterly wind flow, this weather pattern was conducive of elevated PM_{10} measurements. As is evident in the PM data, local emissions contributed to the exceedance of the National Ambient Air Quality Standards (NAAQS) at Hanford on the 9th. The preceding day (the 8th) had higher atmospheric stability compared to the 9th, thus PM measurements would have been higher Valley

wide. Due to decreasing stability and increasing dispersion conditions into the 10th, PM gradually lowered with the approach of the trough from the eastern Pacific. Widespread showers developed across the region on the 10th, bringing an end to the November 9th PM event.

References

Hackney, Rich, Johnson, D., Hughes, V., Niccum, E., Kadulewa, A., Takikulu, Safet. "Meteorological Data Analysis and Trajectory Modeling of PM10 Episodes during 1993 – 1995 for the San Joaquin Valley State Implementation Plan." California Air Resources Board, Sacramento, CA.