Final Report to the Davis Natural Resources Commission

Aerosol monitoring in Davis, Winter, 2009-2010

March 31, 2010

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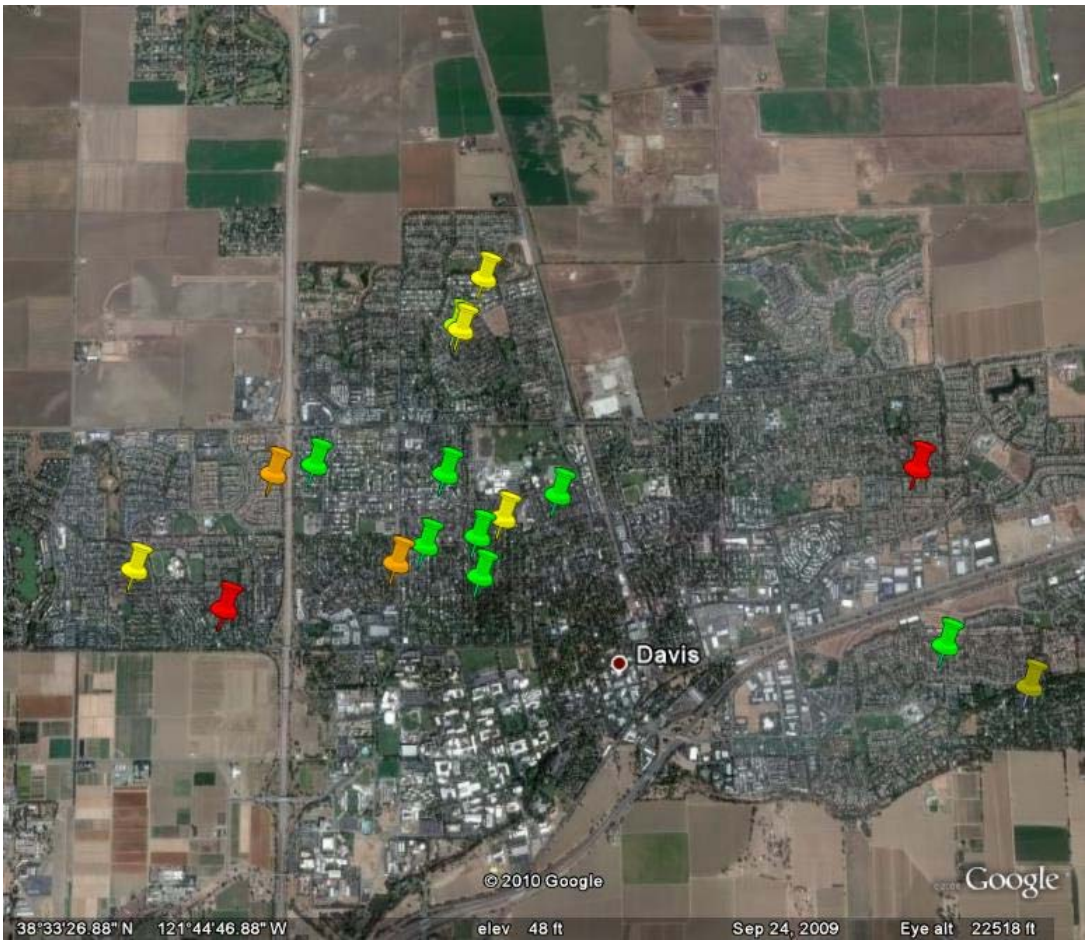
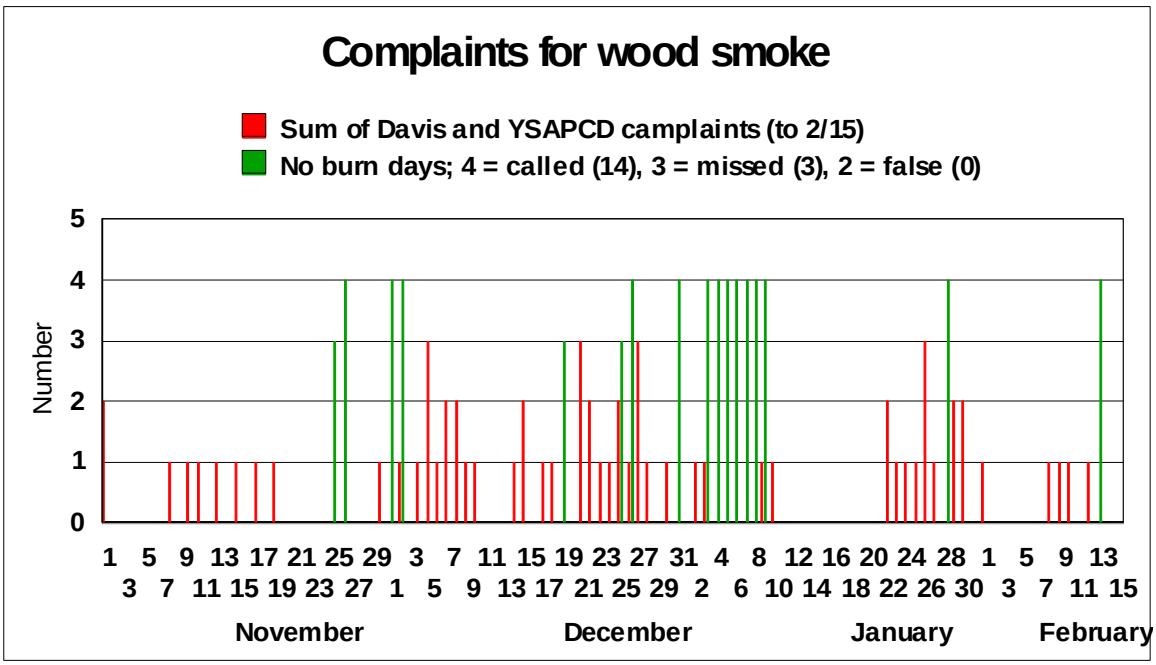
Executive Summary

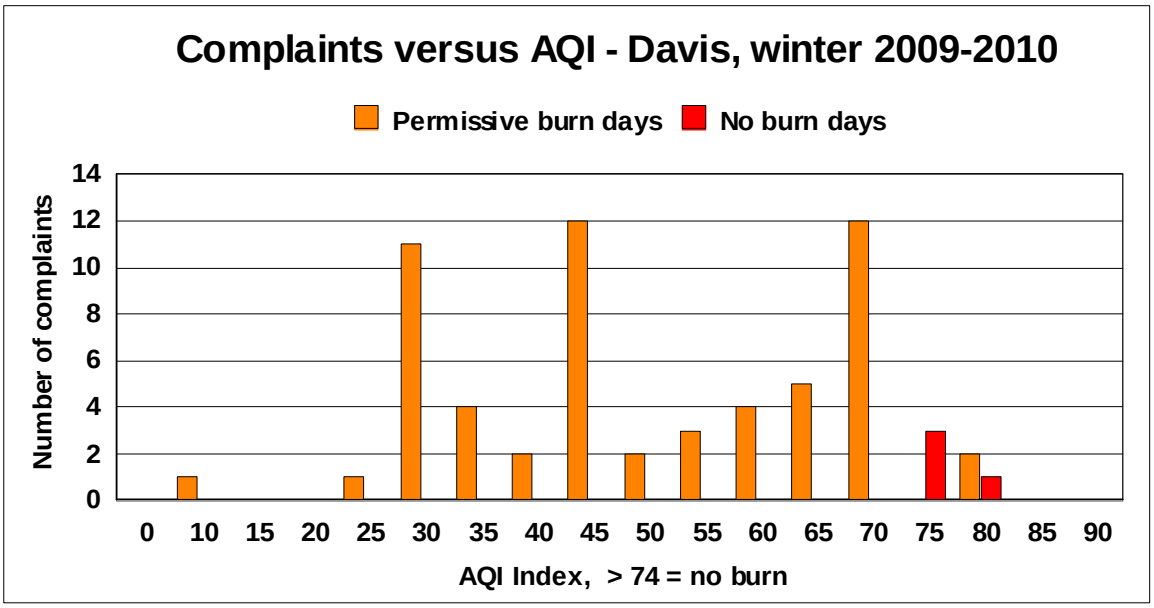
68 complaints of wood smoke were logged by Yolo-Solano AQMD and the City of Davis in the period November 1, 2009 to February 15, 2010 by 19 named and 7 anonymous citizens. Many individuals submitted more than one complaint, with the maximum being 18. When the report detailed the observations, there were more observations of smell (28) than visible smoke (13). 30 complaints identified the source or the area of the source, with one site listing 5 possible sources in its 18 complaints, another 3 possible sources in its 11 complaints.



The locations of the complaints are shown on the map below, with the color of the pin representing the number of complaints from that site: red > 10, orange 4 to 9, yellow or olive, 2 or 3, and green 1.

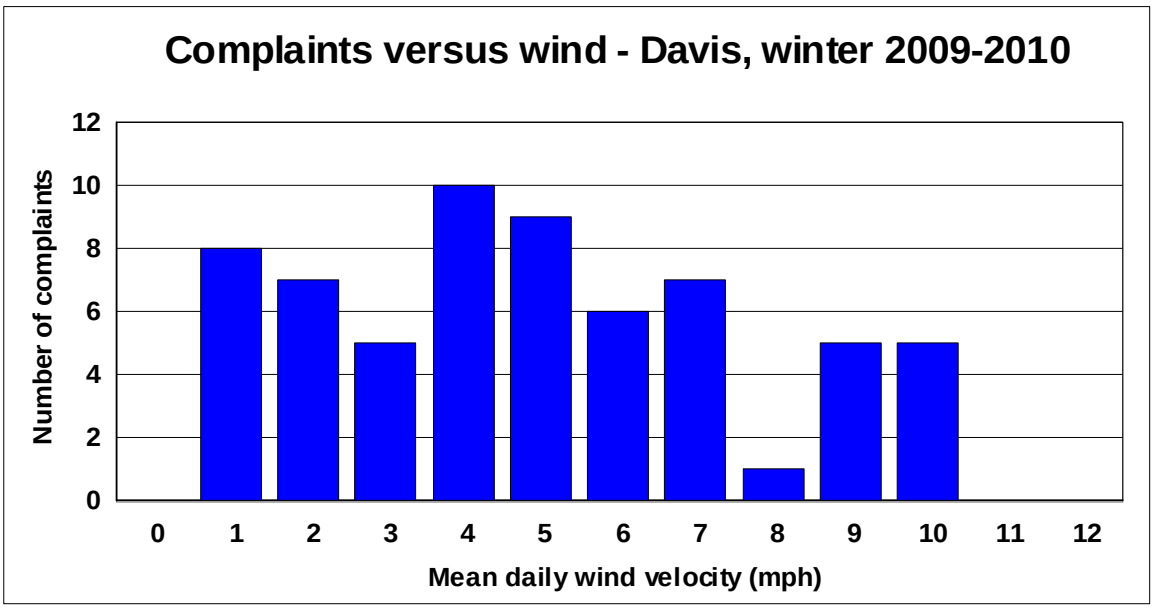


The first point to note is that few complaints (3) were received during the 14 called no-burn days. This is strong evidence that the no burn restrictions are being followed because these are days of the worst ventilation.

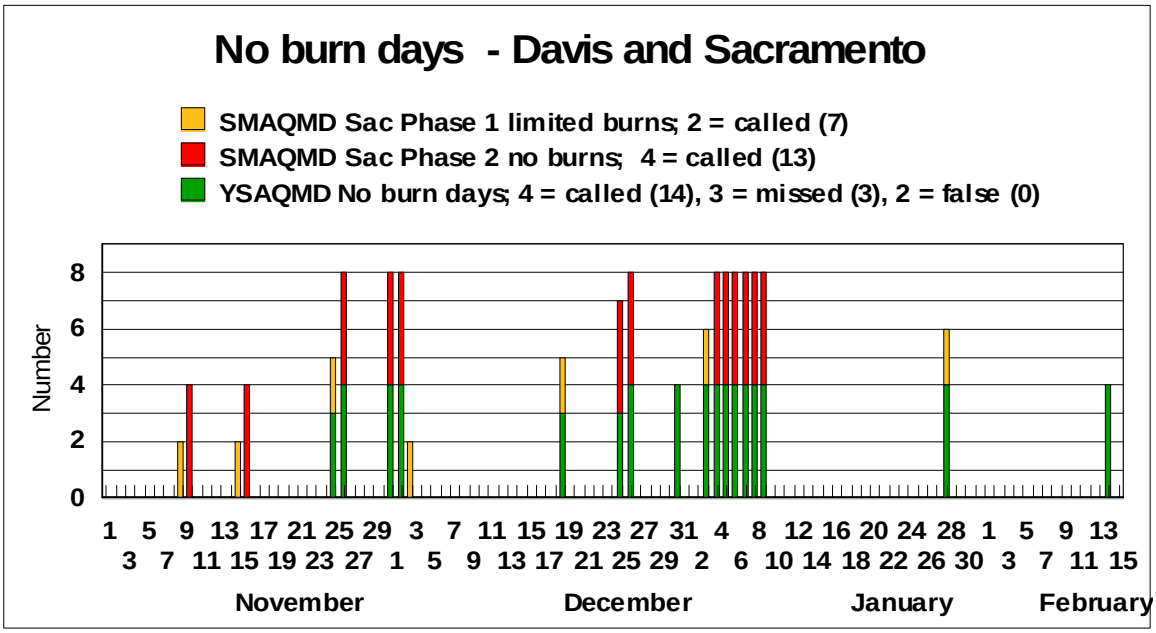


Complaints versus AQI Index. Note that 2 permissive burn events in the 80 to 84 range were actually no burn days missed by the prediction program.

The complaints on permissive burn days were spread across the entire spectrum of AQI values (above) and were not closely associated with mean daily wind velocity. (below). No complaints were received for mean wind velocities 11 mph to 26 mph.



A comparison of Yolo-Solano versus Sacramento burn – no burn days indicated closely associated patterns, again supporting the regional nature of winter smoke aerosols.



Advanced trajectory analyses were employed for the most significant smoke events to identify source regions for the smoke and local impact parameters. The large 6 day no-burn episodes in early January were on slow winds from the north. The Christmas event was on south winds from the San Joaquin Valley.

In all 3 cases where a smoke source was identified in an event when 3 different citizens reported smoke by both visible smoke and smell, the sources were near and to the north of the complaint site.

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1. Introduction

a. Nature of the problem

Complaints have been lodged with the City of Davis concerning wood smoke during winter months. Proposals have been made to identify and alleviate the problem. Other valley air quality agencies have identified reduction of wood smoke important in allowing the region to reach federally mandated standards presently being violated at some sites in the Sacramento, Yolo-Solano, and low elevation portions of Placer and El Dorado counties.

This report is the 3rd in a series specific to Davis wood smoke, and supported by prior and concurrent studies in Sacramento and other sites in the Central Valley.

b. Prior reports

i. **Wood smoke transects in Davis 1994**

Summary: A 24 hr transect across Davis on a hazy winter day 3 days before Christmas showed essentially no enhancement of fine mass or wood smoke in Davis as compared to farm fields west of the city.

Excerpts:

As part of my class work (Atmospheric Science 124), my students and I made a transect across Davis on a cold, hazy day just before Christmas on Friday, Dec 22-23, 1993, a day predicted to have the worst local impact from pre-Christmas shopping and fireplaces on Friday evening. This was included in a report to the City Council on March 15, 1995, **"PM-10 Aerosols in Davis from Traffic Sources", d**ated March 2, 1995, T. A. Cahill, E. A. Gearhart, and K.T. Paw U, from the Air Quality Group and Department of Atmospheric Sciences, UC Davis. This packet also included a reviewer list and an analysis letter on the soundness of the work to the city from the Yolo Solano AQMD.

Site	PM_{10} ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	$PM_{2.5}$ K_{non} (wood smoke)	$PM_{2.5}$ Soot (b_{abs})	$PM_{2.5}$ ammonium sulfate	$PM_{2.5}$ Organic mass	$PM_{2.5}$ soil
West of 113	44.4	39.7	0.11	4.0	2.63	19.86	0.91
UCD west field	50.8	40.7	0.11	4.4	3.17	18.24	1.14
Central Park	46.2	41.5	0.18	5.0	3.26	22.82	1.32
Police 3rd and F St	45.2	40.2	0.11	4.9	3.18	22.06	1.35
Chestnut Park	45.3	40.6	0.04	4.4	3.45	22.95	1.52

Table 1 Transect across Davis, December 22 – 23, 1994 (From Tables 1 and 2, Cahill et al, 1995) **Green** = normally upwind; **Blue** = City of Davis

The first point to note is that the measurements of mass, upon which the state and federal AQI are based, are essentially the same at upwind sites west of town (the average of "West of 113" and "UCD west fields" sites) as in town (average of other three sites). Note that the wind blew from the town to the west sites only 4% of all hours in December.

The smoke tracer (non soil fine potassium, or K_{non}, - Lyons et al 1979; Malm et al 1994) is almost exactly the same in the city as upwind, but much less than what was seen in fall when there was field burning. Soot (black carbon) and organic matter both increase slightly in the city, and these are normally more associated with diesel and smoking car exhaust than with wood smoke. The ammonium sulfate comes largely from Bay Area refineries plus in the city from fuel oil combustion, diesel, and a small amount from natural gas.

In summary, we did not see any significant wood smoke signature above the large regional background at a time local wood smoke was expected to maximize.

ii. Davis to Sacramento transect 2001 – 2002

Summary: As part of a larger transect from Davis (2 sites) across Sacramento, fine mass was measured in West Davis and compared to a site well east of the city at the USFS facility. The results of these 2 sites were virtually identical for 4 weeks in winter, showing little fine mass contributed by the city as compared to rural areas. The values were somewhat less than Sacramento at the same time.

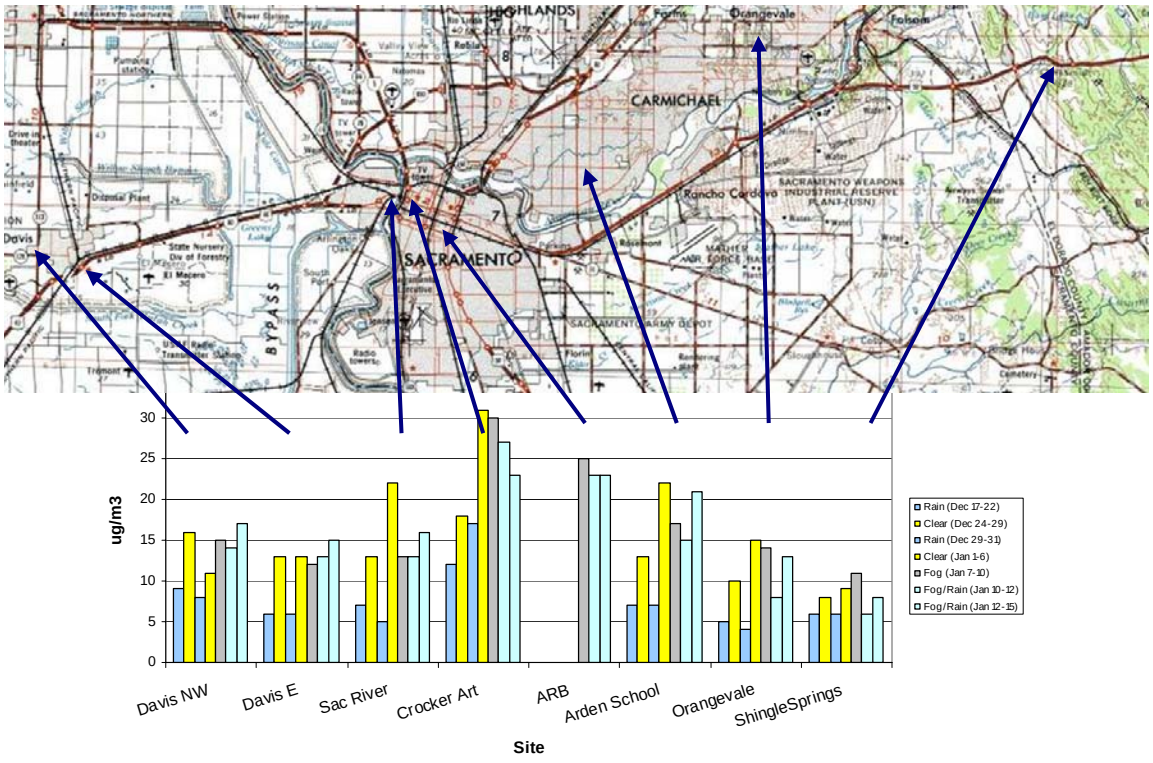


Figure 1 Sacramento transect of fine mass, 2001 – 2002

Excerpt:

In earlier studies, we had shown that there was no measurable increase in aerosol mass or smoke on December 23 1994 (Appendix B, page 27) in a transect across Davis. (above)

In 2002, working with the local American Lung Association (now Breathe California), we did a transect across Sacramento that included 2 Davis sites – one upwind (Amador at Buchanan) and one downwind (USFS Tree plantation south of I-80.) We have aggregated the data for mean multi-day averages of $PM_{2.5}$ mass for five periods**:** (color codes matched to map)

Dec 17 – 21 rain;
Dec 24 – 29 clear;
Dec 29 – 31 rain;
Jan 1 – 6 clear;
Jan 7-10 fog;
Jan 10-12, fog/light rain;
Jan 12-16 fog, some drizzle.

In 2001 – 2002, we had 2 sites as part of the Breathe California/Sacramento Emigrant Trails Valley Transect. The two sites, one in the city and ringed by houses with (presumably active) chimneys and one east of the city but near I-80, were very similar over a period 32 days.

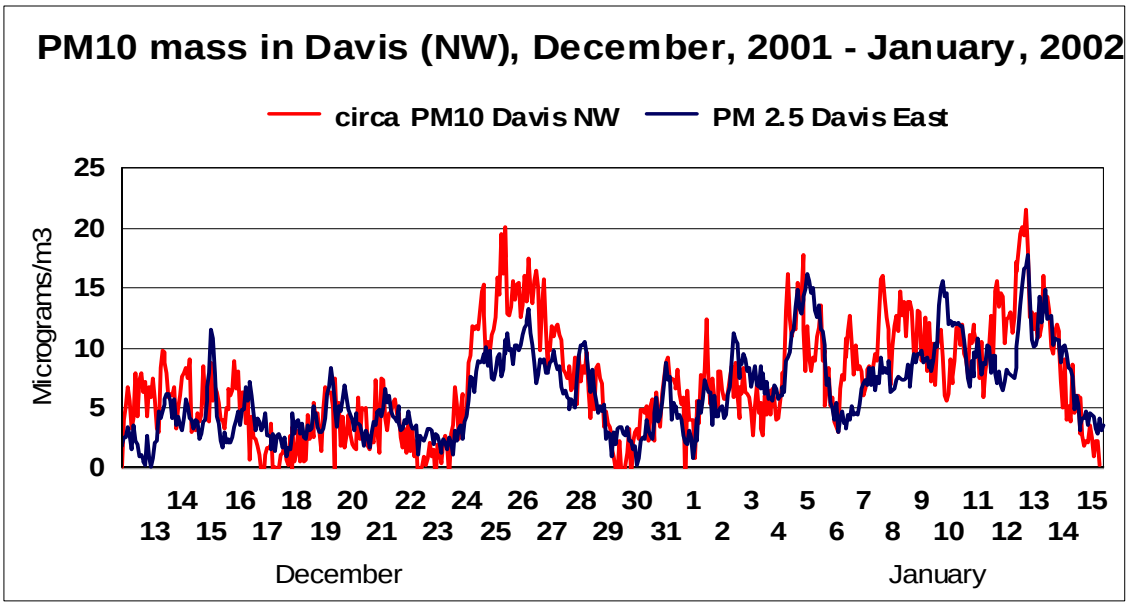


Figure 2 West Davis versus east of Davis, winter 2001 - 2002

The northwest NW site was in a backyard in Westwood, just west of Highway 113 and 2 blocks north of Russell Blvd. Essentially all homes in this neighborhood were built with open hearth fireplaces. The Davis East site was circa 150 ft south of I-80 on the east portion of the USFS land east of Davis. The site was at roughly 2 m above ground in

a rather open grove of Eucalyptus trees with cleat vision to I-80 and Chiles road. There were no visible fireplace chimneys within several hundred meters of the site in any direction.

Note that the Davis NW data should in fact be slightly larger than the Davis East site since the NW site includes aerosols between 10 and 2.5 μm, although these are a relatively small component tin winter (see above for Sacramento).

iii. **Aerosol monitoring in Davis, Winter, 2008-2009 (see Appendix B)**

Summary: Mass measurements were made at City Hall for 4 weeks in winter and compared to downtown Sacramento, confirming the regional nature of winter aerosols in the Sacramento Valley. Data were gathered on the neighborhood scale impacts "nearest neighbor" indicating a nuisance problem even though regional fine mass values did not violate federal mass standards.

Excerpt:

Aerosols measured at City Hall in Davis were well below federal aerosol standards (PM_{10} = 150 μg/m^3, $PM_{2.5}$ = 35 μg/m^3) over the entire winter. However, note that in winter, we show that almost all the PM_{10} aerosol was composed of $PM_{2.5}$ particles.

Aerosols measured in Davis were often equivalent to those measured in downtown Sacramento at the same time, confirming earlier evidence that the aerosols in central Davis are regional in nature, not locally generated.

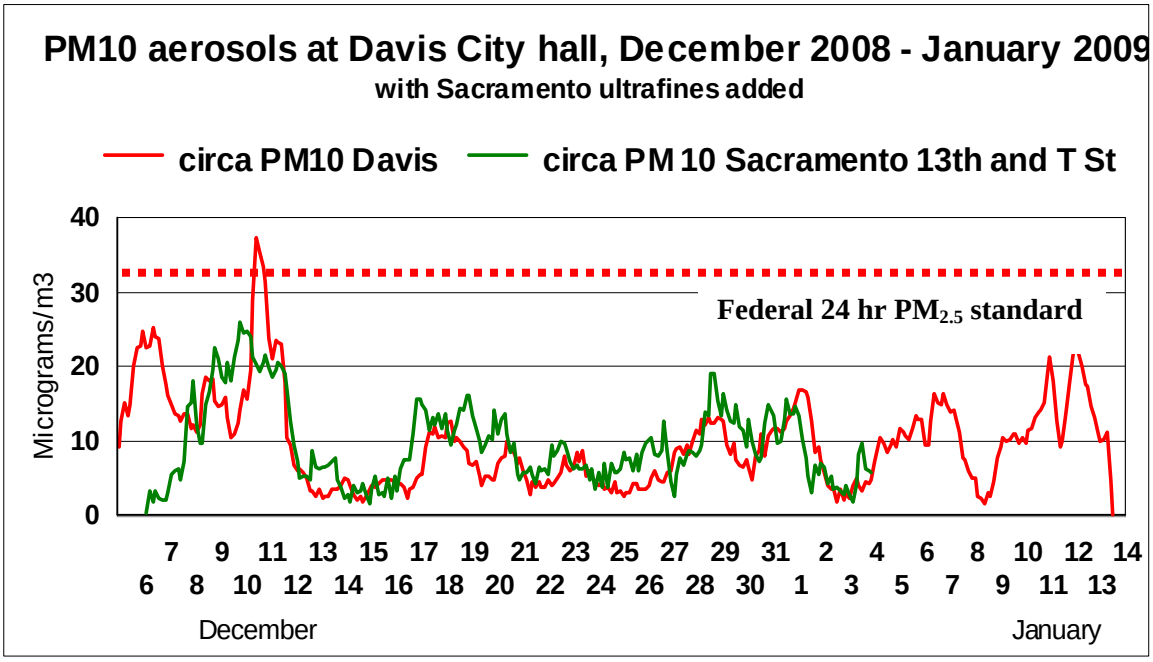


Figure 3 Davis versus Sacramento, winter, 2008-2009

Several episodes of enhanced aerosols were seen, however, when for a number of hours or days aerosol concentrations were elevated in the particle sizes characteristic of wood smoke, nitrates, and sulfates. These occurred usually under conditions of weak winds, strong inversions and hazy conditions, with the winds often coming down slope from the Sierra Nevada, over Sacramento, and into Davis.

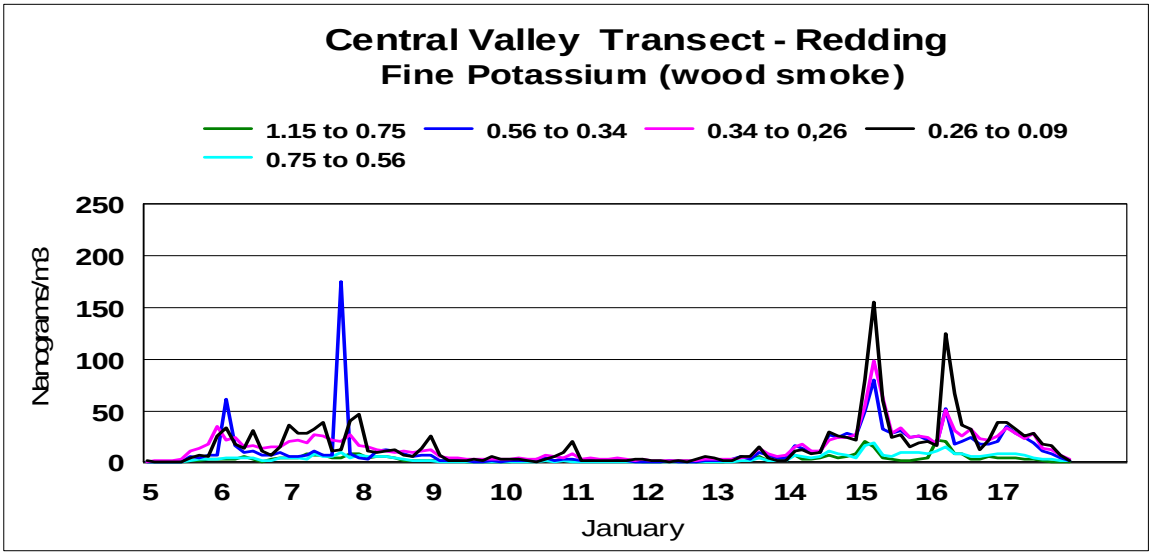
While attempts to use Dusttrack portable samplers failed, a short time (< 1 hr) impact of wood smoke was qualitatively observed on one occasion in nearest-neighbor conditions under low wind conditions.

iv. The Central Valley transect of 2009

Summary: Large amounts of wood smoke were observed in the northern Sacramento valley under conditions that brings smoke south out of the northern foothills and down the valley towards Sacramento and Davis. We identified the source of the smoke as burning of pine wood, with the consequence of high levels of benzo[a]pyrene, a potent carcinogen. The implication for Davis is that considerable improvements in air quality could be achieved by banning the combustion of pine wood. This work has no appeared in the prestigious peer reviewed journal Environmental Science and Technology.

Excerpt:

As part of a study designed to look at the causes of ischemic heart disease in the Central Valley of California – **"Particulate Air Pollution and the Excess Mortality from Ischemic Heart Disease in the California Central Valley; What are the Causes?"** Final Report to The Resources Legacy Fund, January 26, 2010 – we examined patterns of wood smoke using both levoglucosan and fine potassium.



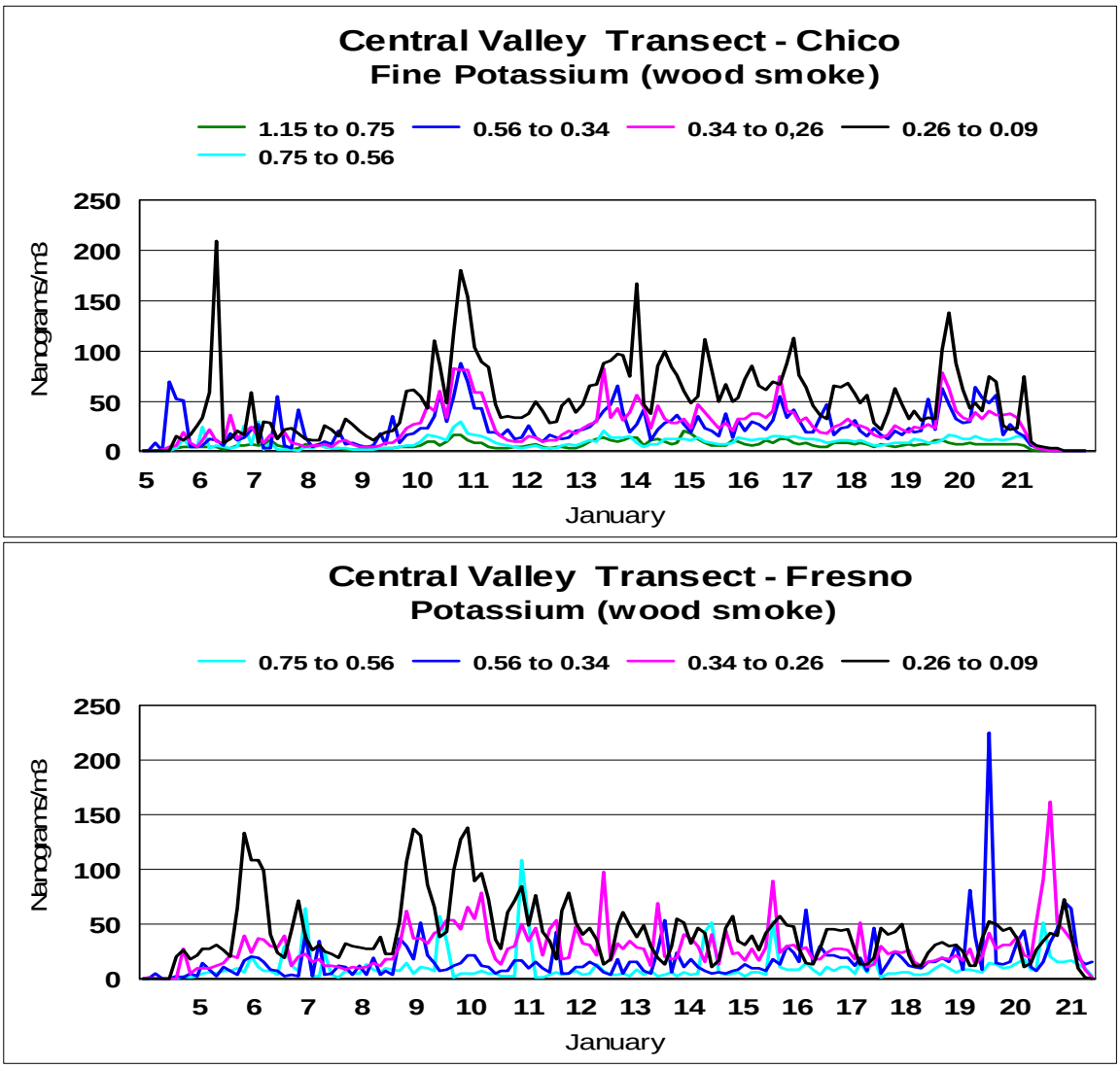


Figure 4 a, b, and c Fine potassium (smoke tracer) in the Central Valley, 2009

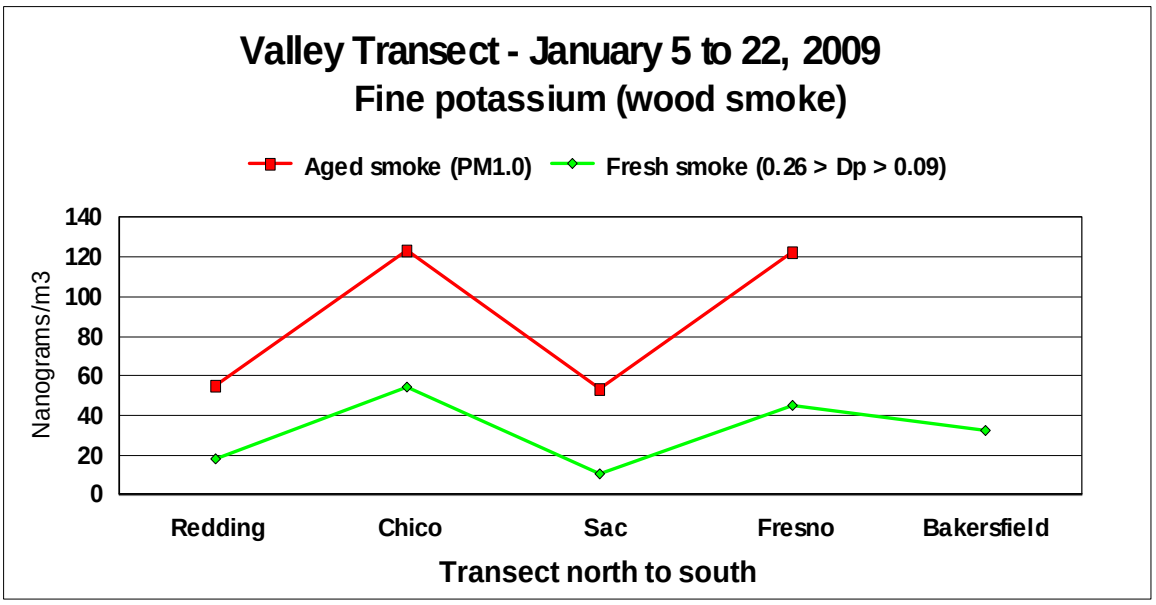


Figure 5 Fresh and aged wood smoke during the Central valley study

From literature values on wood smoke, the initial combustion is in the 0.1 μm size mode, but then it picks up water and grows to roughly 0.5 μm

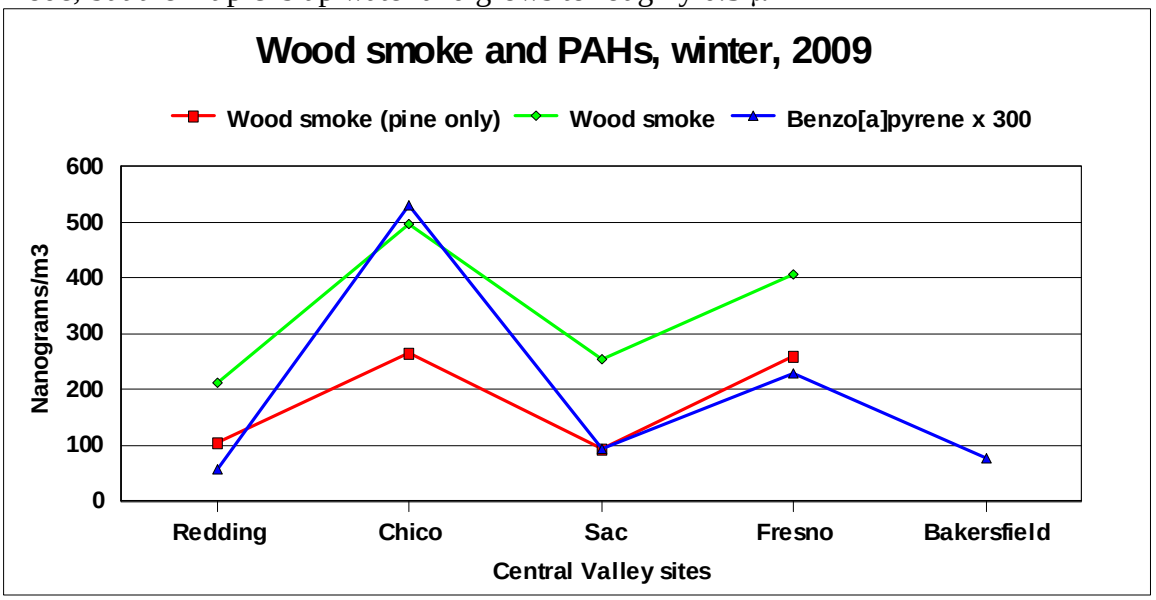


Figure 6 Aged wood smoke from pine and hardwood sources, together with benzo[a]pyrene during the Central Valley study

Thus, we have identified that the high benzo[*a*]pyrene levels in Chico are a result of combustion of primarily pine wood.

c. Concurrent studies

There is a concurrent funded study of wood smoke in Sacramento at the Del Paso Manor site that will become available in late Spring, 2010. This site is the one that is most likely to have violations of the federal $PM_{2.5}$ mass standard and thus throw the whole Sacramento, Yolo-Solano, and low elevation regions of Placer and El Dorado Counties into violations of the Clean Air Act.

2. Current study

a. Valley meteorology

The meteorology of the Central Valley of California in stable, hazy conditions is dominated by subsidence of cold air from the surrounding hills and mountains onto the valley floor, and then slow motion down the valley topography to the lowest point, the Sacramento-San Joaquin delta. (ARB 1994)

Figure 7 Meteorology of the Central Valley

Synoptic weather is superimposed on this base pattern as storms pass through.

b. Wood smoke inventory

The gridded smoke inventory shows Davis (dotted red circle) with 0.023 to 0.043 lbs/day of smoke averaged over 2 mi^2, which is about 1/3 of the value for Woodland and a tiny fraction of Sacramento.

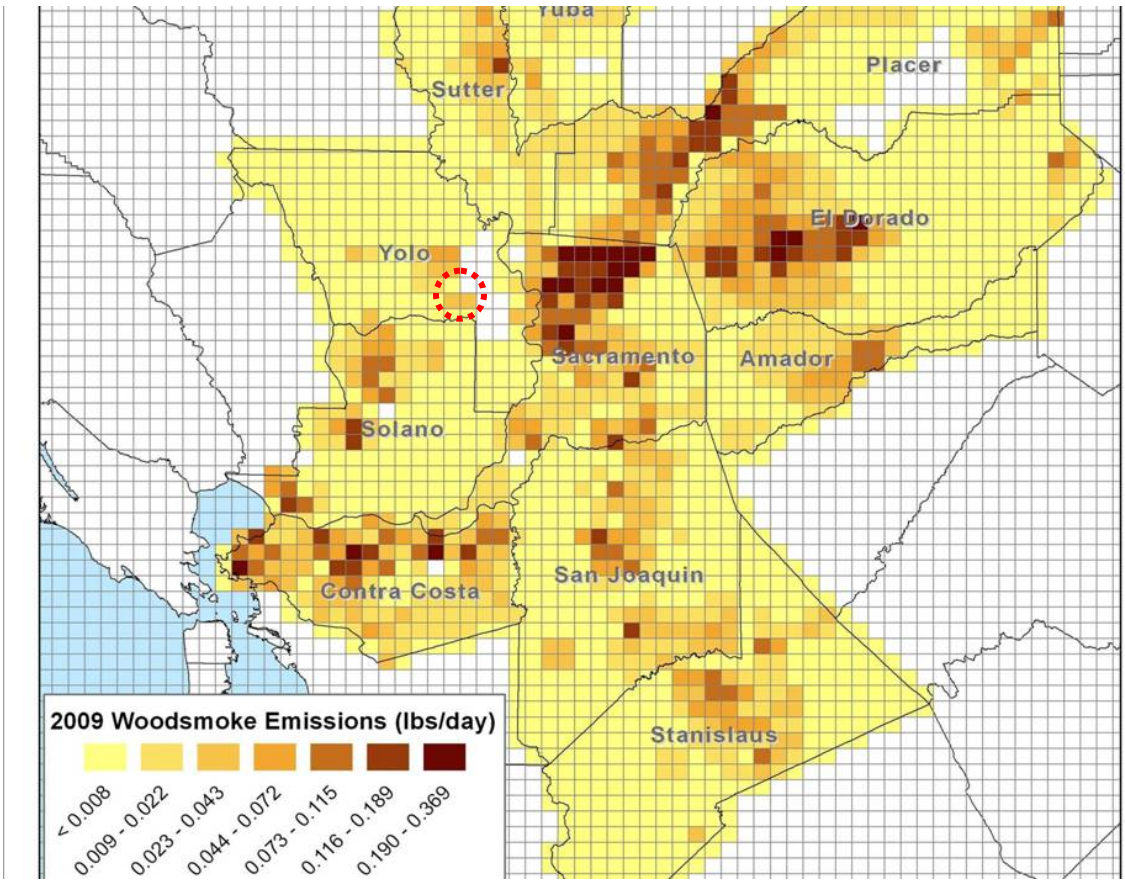


Figure 8 Gridded emission rate of wood smoke

c. Meteorology during the study

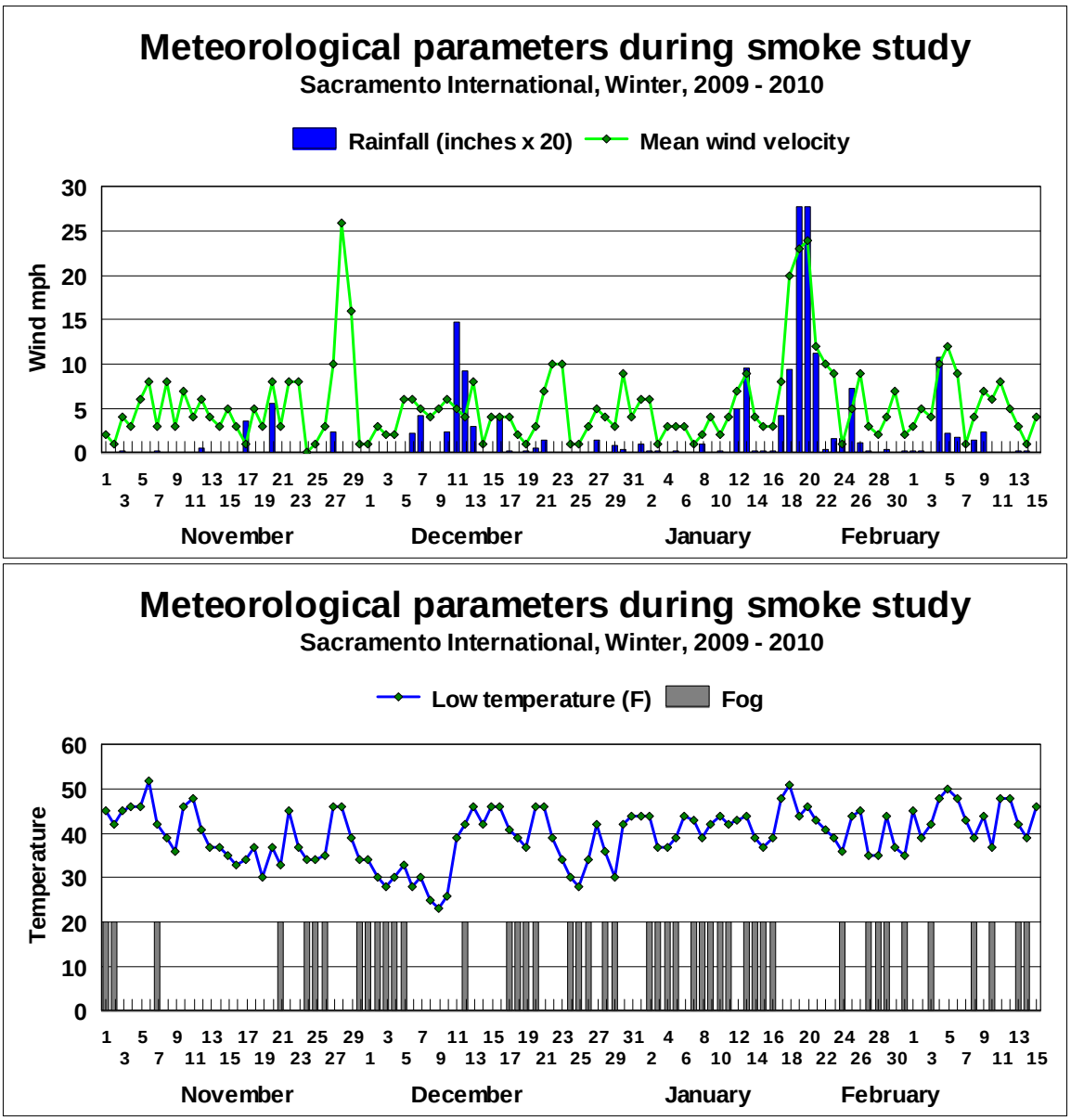


Figure 9 a, b Meteorology of the region during the study

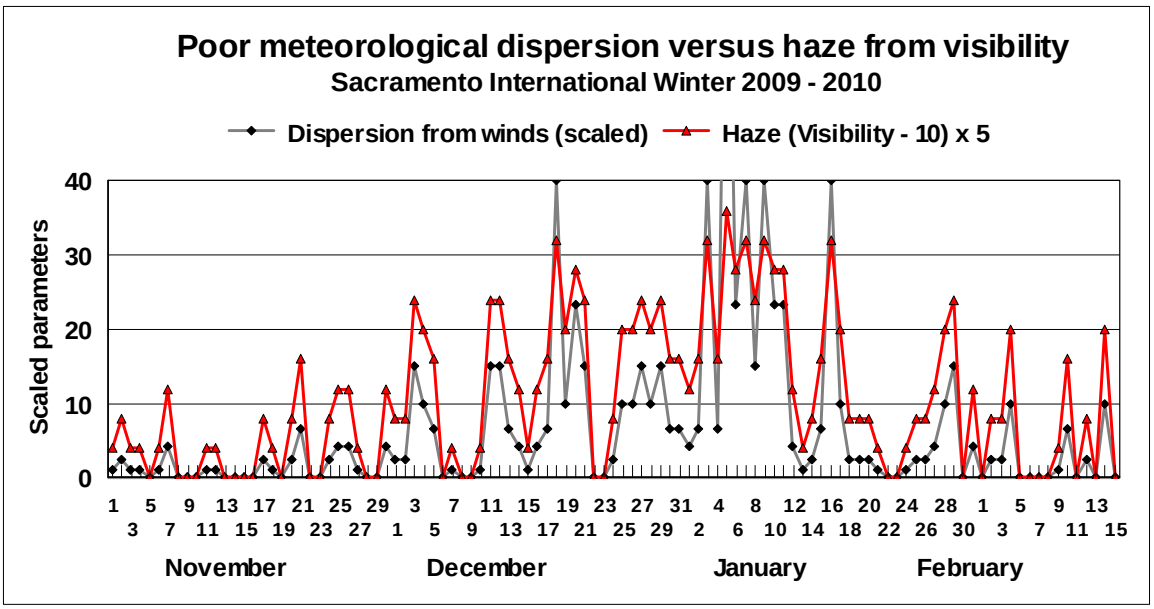


Figure 10 Dispersion versus haze

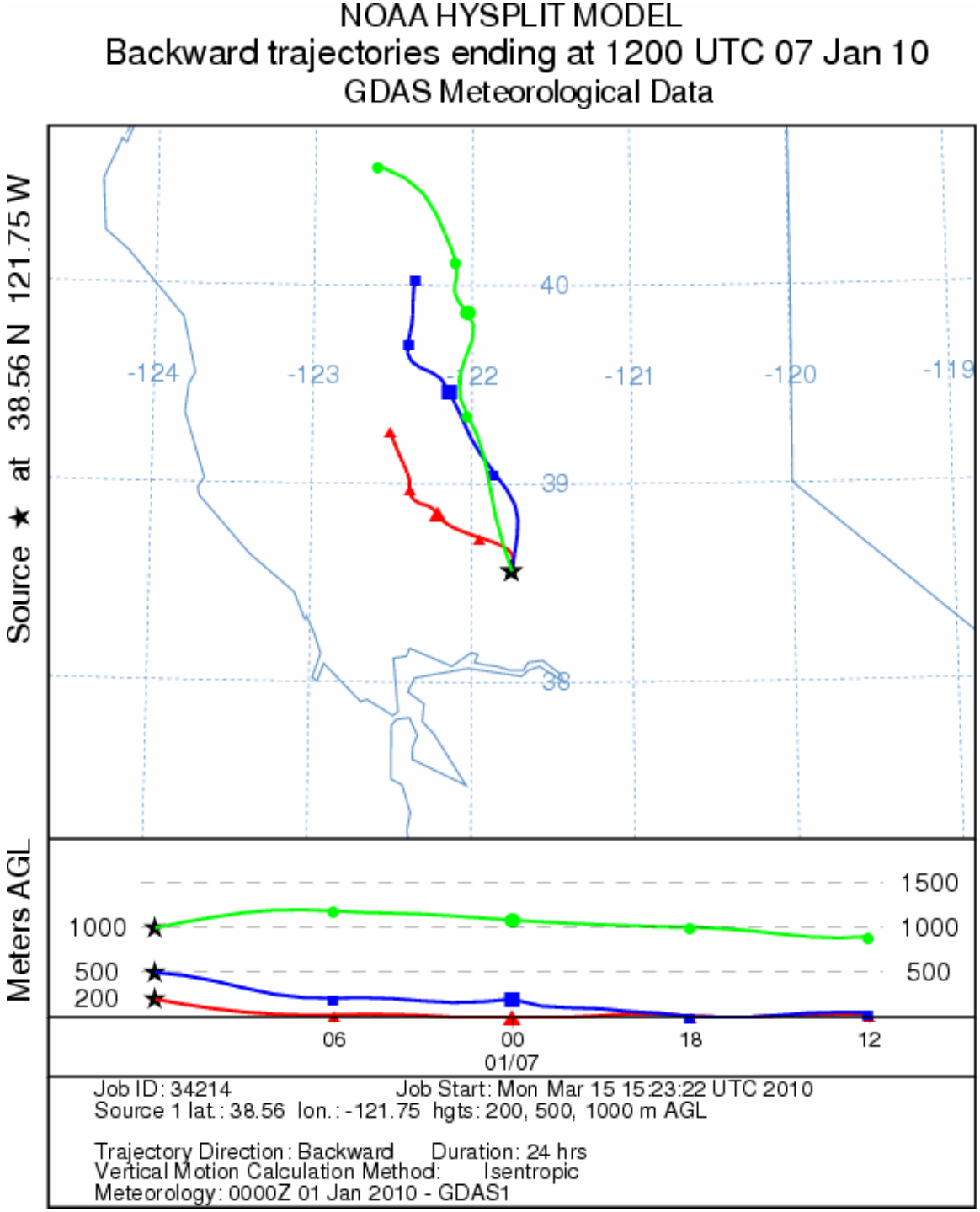


Figure 11 HYSPLIT trajectories during the January 4 through 11 haze event.

d. Mass data

Data on $PM_{2.5}$ mass are routinely predicted as part of the burn–no-burn day analyses, while actual data are generated by the Yolo Solano AQMD. In addition, the DELTA Group measured mass on roof of Walker Hall on the UC Davis campus from November 1, 2009, to February 1, 2010. Specifically, the DELTA Group data included the major wood smoke mode, 1.15 μm to 0.34 μm in diameter.

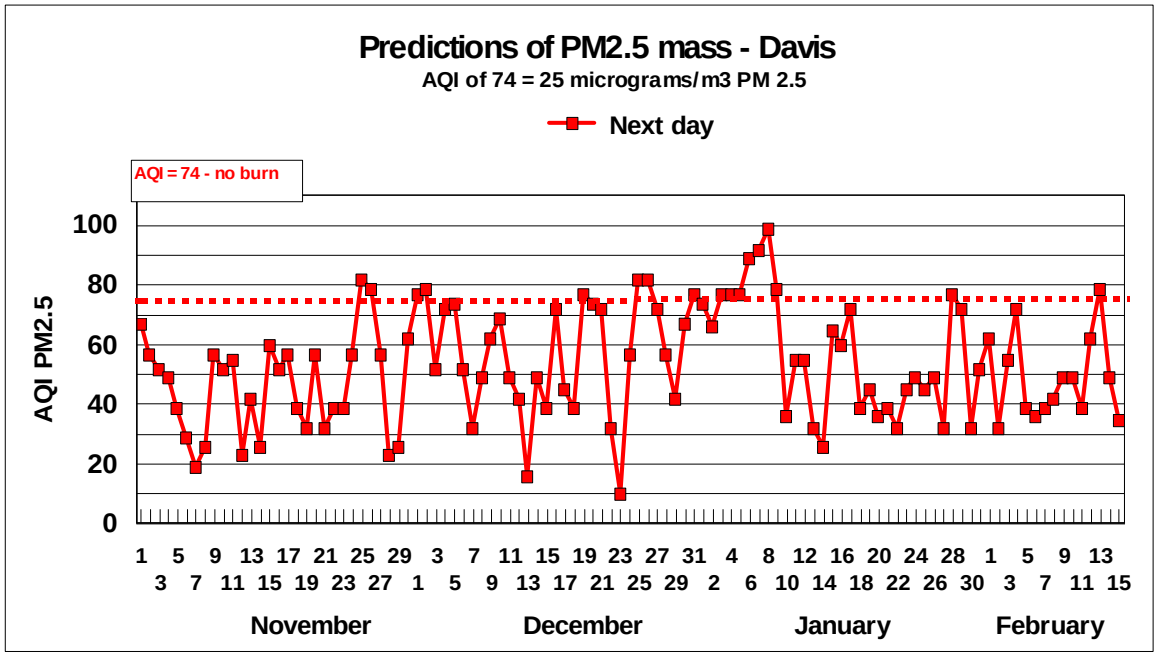


Figure 12 Predictions of AQI for Davis, winter 2009 - 2010

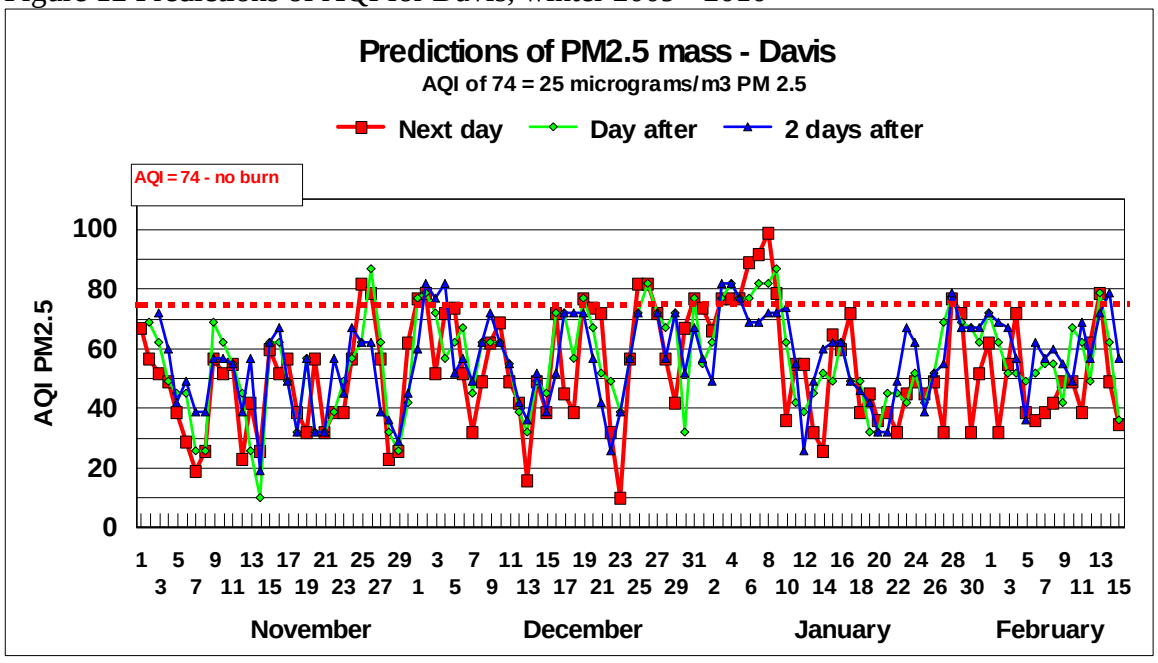


Figure 13 Predictions of AQI index for mass versus delay of prediction

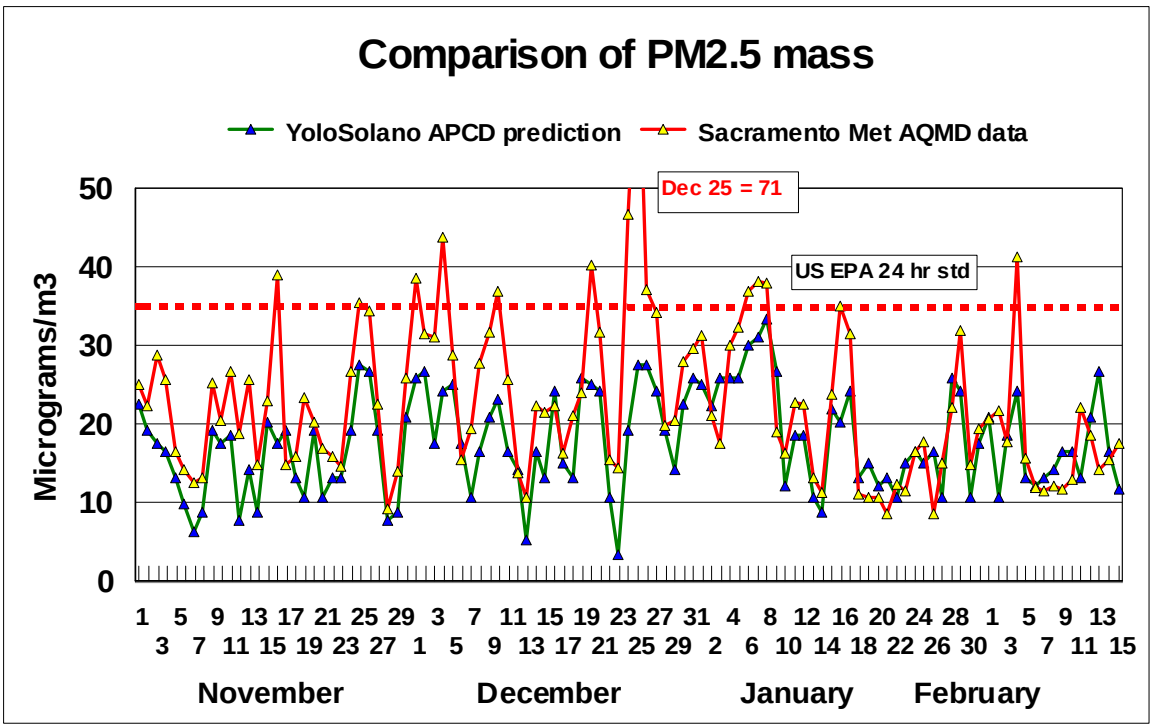


Figure 14 Yolo-Solano predictions versus observed mass, Sacramento, Del Paso Manor

18 25 29 2 6 10 16 20 24 28 1

Figure 15 Actual DRUM strips from December 18 through February 1, with color/darkness standards below. Wood smoke mostly resides in the middle strip, 1.15 to 0.34 μm. Times are approximate.

Figure 16 Mass data for the period December 18 – Feb 14

e. Wood smoke complaints

We are deeply grateful to the citizens that called in complaints, as it has greatly aided our analysis of the nature of the problem.

Complaints for smoke were collected by both the Yolo-Solano APCD and the City of Davis from November 1, 2009, to February 15, 2010, and via a private log on March 13. In all, 68 complaints were lodged by 19 named and 7 anonymous citizens. Most named individuals submitted more than one complaint, with the maximum being 18. When the report detailed the observations, there were more observations of smell (28) than visible smoke (13). 30 complaints identified the source or the area of the source, with one site listing 5 possible sources in its 18 complaints, another 3 possible sources in its 11 complaints.

Observation Date	Observation Time	Location Street	Wind Y-No-Dir	Smoke visible	Smoke smell	AQI
November						
1	6:11pm	Concord Pl	N - NW 3- 5 mph		Y	67
1		South Manor		Y	Y	67
8	6:40pm	Mulberry Lane				26
10	8:44pm	Mulberry Lane			Y	52
11	7:50pm			Y	Y	52
13	6pm	Villanova		Y	Y	42
15	8:44pm	Mulberry Lane			Y	60
17	10:53pm	Mulberry Lane		Y	Y	57
21		Oak Ave 1				32
30	9:54am	Catalina Dr 1				62
December						
2		12th Street		Y	Y	**79**
4	8:45pm	Santa Rosa Dr				72
5	3:00pm	Antioch Dr		Y	Y	**74**
5		Hidalgo Pl				**74**
5	11:15am, 2:20pm	Salamanca Ct				**74**
6	8am, 3pm	Salamanca Ct				52
7	8:30pm	Santa Rosa Dr				32
7	7am	Salamanca Ct				32
8		South davis				49
8		Mulberry Lane				49
9	7:15am	Salamanca Ct				62
10	5:20pm	Salamanca Ct				69
14	10:55PM	Santa Rosa Dr				49
15	6pm	Salamanca Ct				39
15	9pm	Salamanca Ct				39
17		Catalina Dr 2		Y	Y	45
18	9:18PM	N. Campus Way				39
21	2:35pm	Catalina Dr 2		Y	Y	**72**
21		Brown Dr				**72**
21		Concord Pl				**72**

Table 2 Smoke complaint logs from Yolo-Solano AQMD and the City of Davis, along with the AQI Index., November - December

Observation Date	Observation Time	Location street	Wind (Y/N/Dir)	Smoke visible	Smoke smell	AQI
December						
22		Brown Dr				32
22	8:45am	Salamanca Ct				32
23	11:30am, 7:45pm	Salamanca Ct				10
24	10pm	Salamanca Ct				57
25	4:30PM	Santa Rosa St				82
25	9am	Salamanca Ct				82
26	4:30PM	Santa Rosa St				**82**
27	8:45pm	Salamanca Ct				72
27	8:55pm	Salamanca Ct				72
27	9pm	Salamanca Ct				72
28	5:20pm	Salamanca Ct				57
30		unknown				67
January						
2	10:30am	Salamanca Ct				66
3	9am	Salamanca Ct				77
9	11:30am, 1:30pm	Salamanca Ct				**79**
10		Hidalgo Pl				36
22		Village Homes				32
22	PM	Coolidge & Alameda			Y	32
23		Village Homes				45
23	PM	Coolidge & Alameda			Y	45
24	AM	Coolidge & Alameda			Y	49
25	10AM	Coolidge & Alameda			y	45
26	4:12pm	Antioch Dr		Y	Y	49
26	4:38:00pm	near Grande	North @ 3 mph	N	N	49
26	10AM	Coolidge & Alameda			y	49
27		Antioch Dr				32
29	4:48pm	near Lilard	South	Y	Y	72
29		Almond Lane		Y	Y	72
30		Almond Lane		Y	Y	32
?		Hidalgo Pl		Y	Y	?
?		Oak Ave 2			Y	?
?		Catalina Dr 2				?
30	noon	Coolidge & Alameda			y	32
February						
1	late AM	Coolidge & Alameda			y	62
8	noon	Coolidge & Alameda			y	42
9	mid afternoon	Coolidge & Alameda			y	49
10	mid afternoon	Coolidge & Alameda			y	49
12	eve	Coolidge & Alameda			y	62

Table 3 Smoke complaint logs from Yolo-Solano AQMD and the City of Davis, along with the AQI Index. The “Coolidge and Alameda” data were received on an anonymous citizen’s private log on March 13.

The locations of the complaints are shown on the map below, with the color of the pin representing the number of complaints from that site: red > 10, orange 4 to 9, yellow or olive, 2 or 3, and green 1.

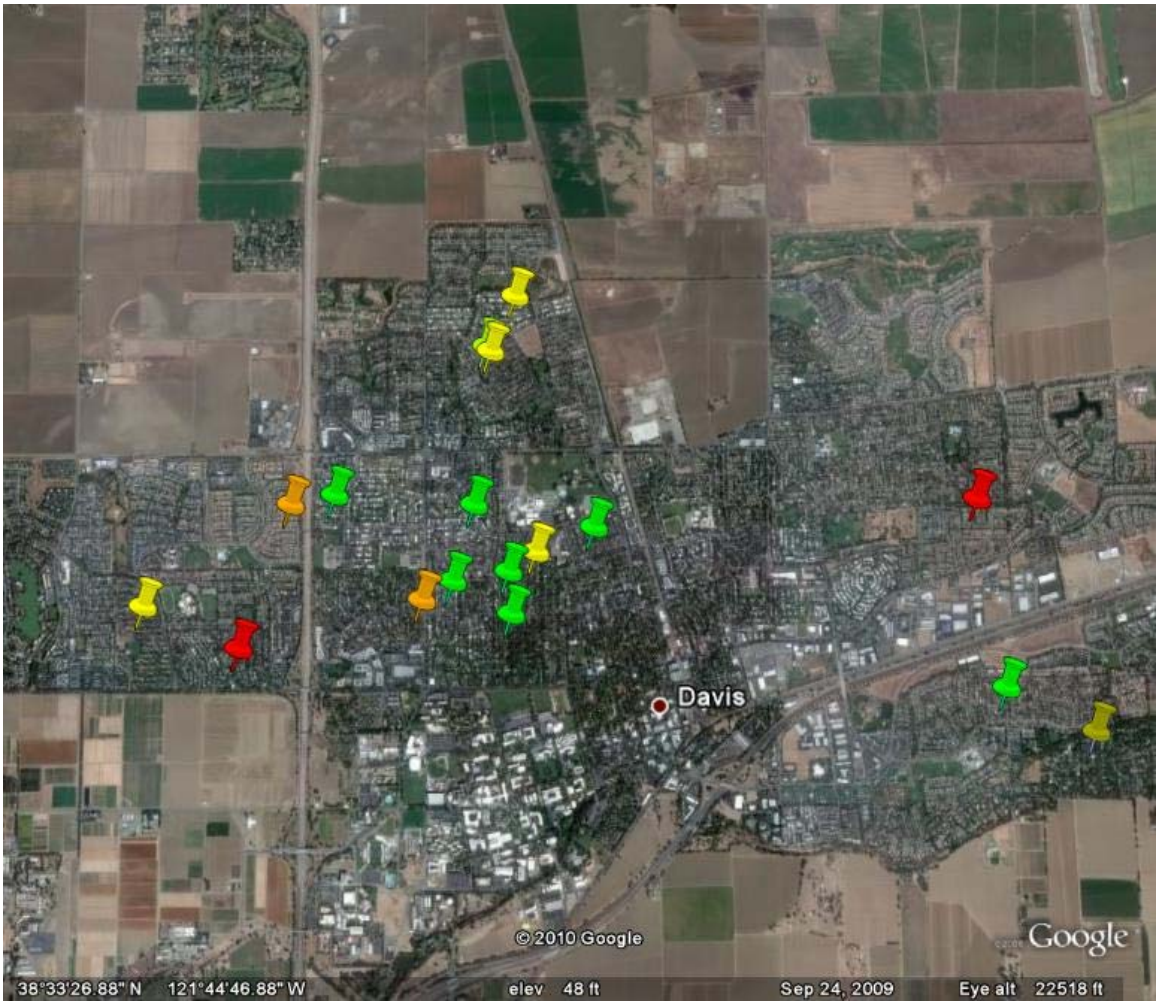


Figure 17 Map of complaints.

In the lower plots, the timing of the complaints is shown. The green bars are no-burn days, with the value = 4 if the no-burn day was called (14), value = 3 if a no burn day was missed (3). Note that there were no called no-burn days (false no-burn days) that did not in fact become a no-burn day. The red bars are the number of complaints on that day. Only 4 complaints were lodged on the 14 called no-burn day, while 2 were lodged on one of the 3 no-burn days that was missed (December 25). The value predicted on December 24 for the December 25 AQI was 72, a permissive burn day, but the actual value was 82, a no-burn day based on the AQI = 74 threshold (25 $\mu g/m^3$ $PM_{2.5}$ mass). Note that December 25 was a called no burn day in Sacramento.

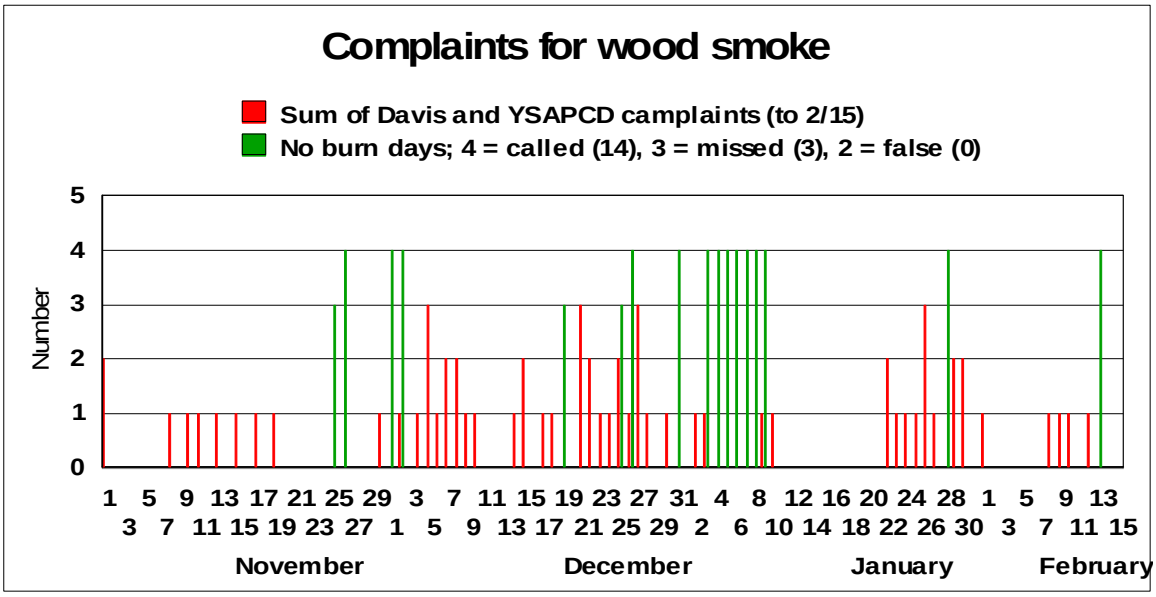


Figure 18 Dates of complaints versus burn – no-burn days

Half of all complaints that identified visible smoke occurred at AQI indices of 67 to 79, close to or above the AQI threshold for a no-burn day.

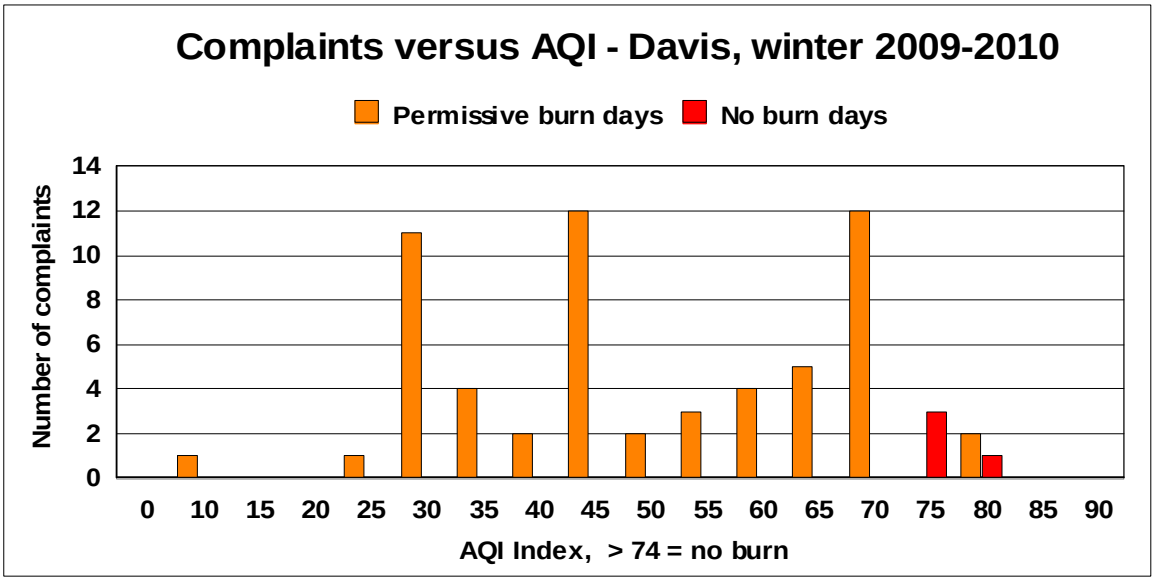


Figure 19 Complaints versus AQI Index. Note that 2 permissive burn events in the 80 to 84 range were actually no burn days missed by the prediction program.

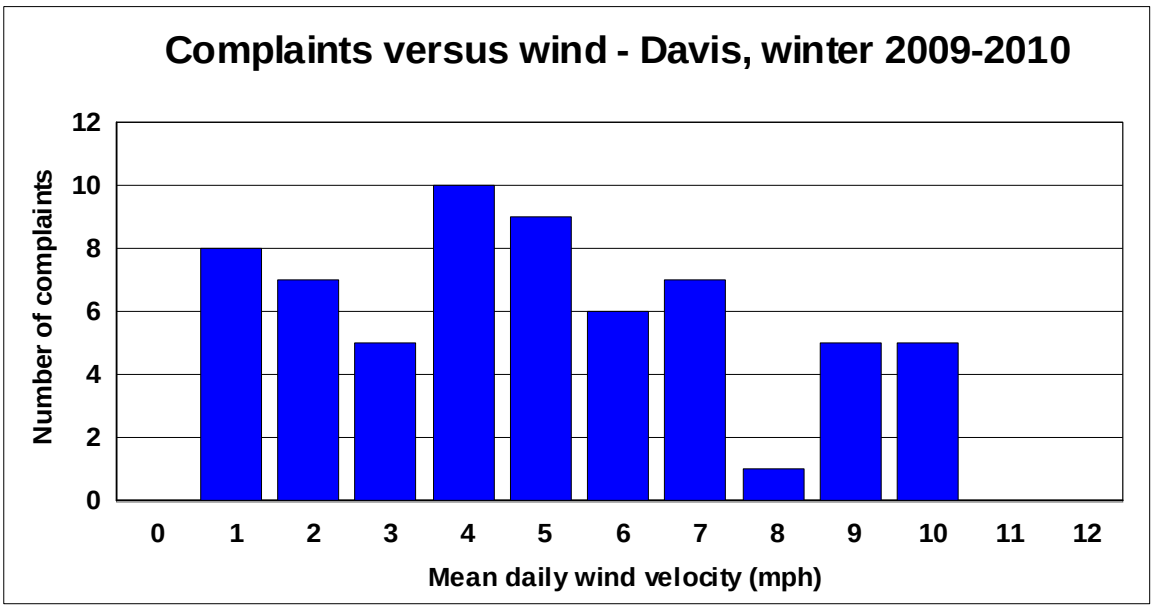


Figure 20 Complaints versus wind velocity

A comparison of the Sacramento SMAQMD no-burn days versus the Yolo-Solano no-burn days is shown below. Note that while there were differences (December 25 notably) there is generally a good agreement, further supporting the observation that the no-burn days are regional in nature. This was shown earlier in the comparison of meteorological dispersion and observed haze at the Sacramento International air port.

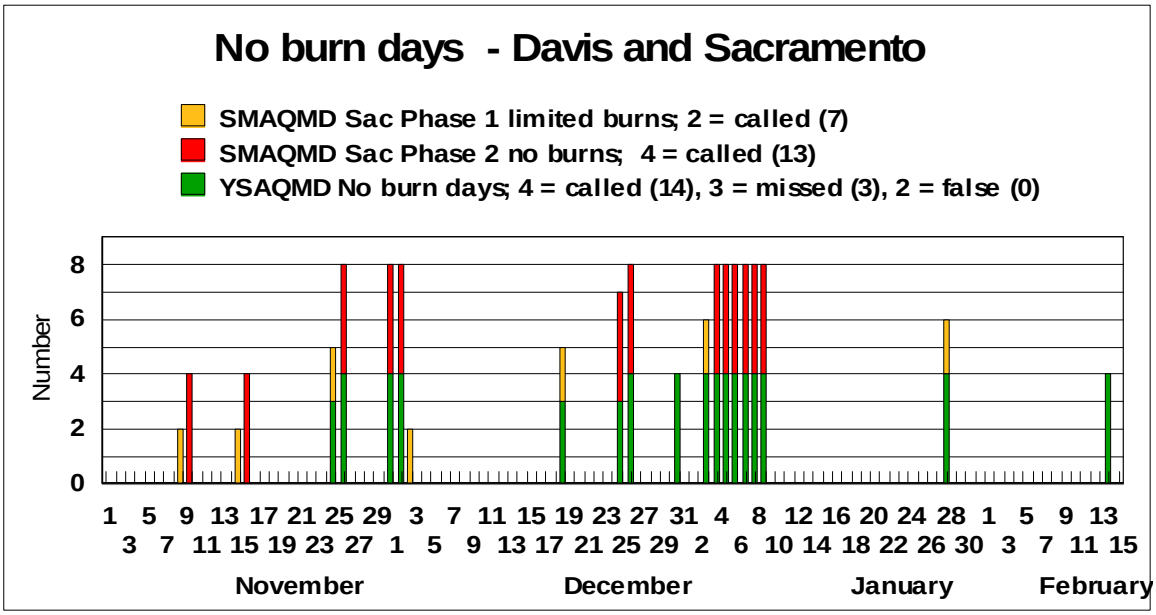


Figure 21 Comparison of Yolo-Solano versus Sacramento burn – no burn days

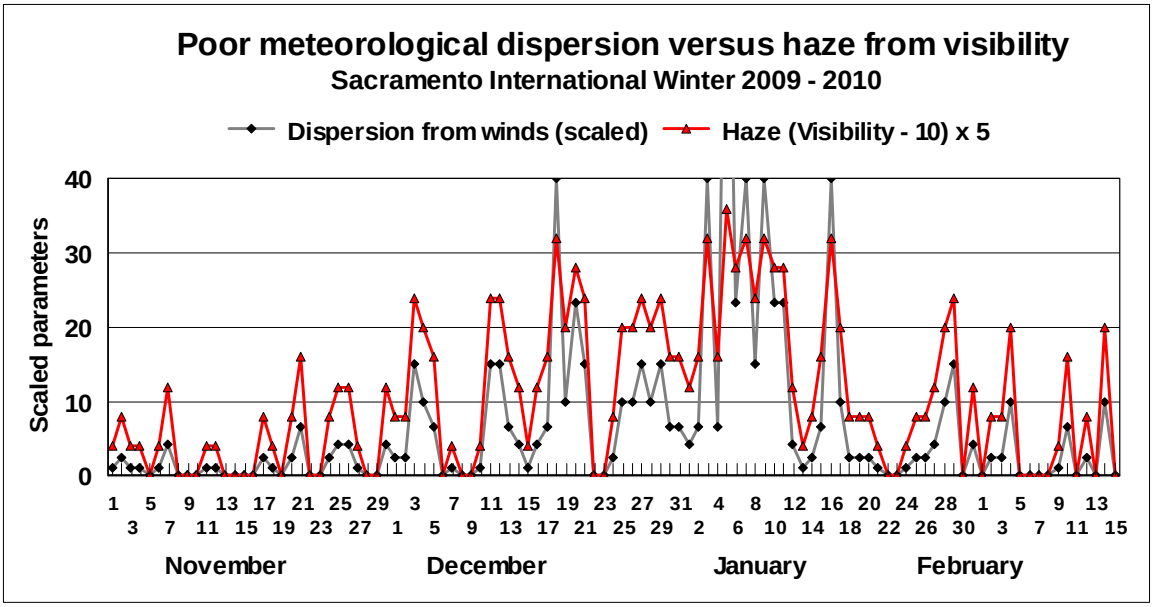


Figure 10 (repeated) Dispersion versus haze

While there is generally good agreement between the haze and dispersion values and no burn days, there are exceptions. The January 16 for example was at the very beginning of several days of intense rainfall, and with winds from the south, haze from the San Joaquin Valley is brought onto the Sacramento area

f. Analysis of specific pollution events

The criteria used for detailed analysis of specific events are:

1. Simultaneous complaints on a single day from three independent observers (an exception is made for Christmas, with 2 complaints),
2. Visible smoke as well as smoke odor.
3. No overlap with no-burn days

In all cases, (notable exception: Christmas), at least one complaint had a potential source named.

i. December 5, 2009

AQI = 74 (at 75, it would have been a no-burn day)
T min = 33 ^{o} F
Wind (mean) 6 mph, NNW
Visibility 6 miles, fog at night

This was a classic stagnation event with a storm approaching, with cold night temperatures and a north wind followed by a storm bringing aerosols into Davis from the south. The most detailed complaint on Dec. 5 identified a house lying directly north as the probable source.

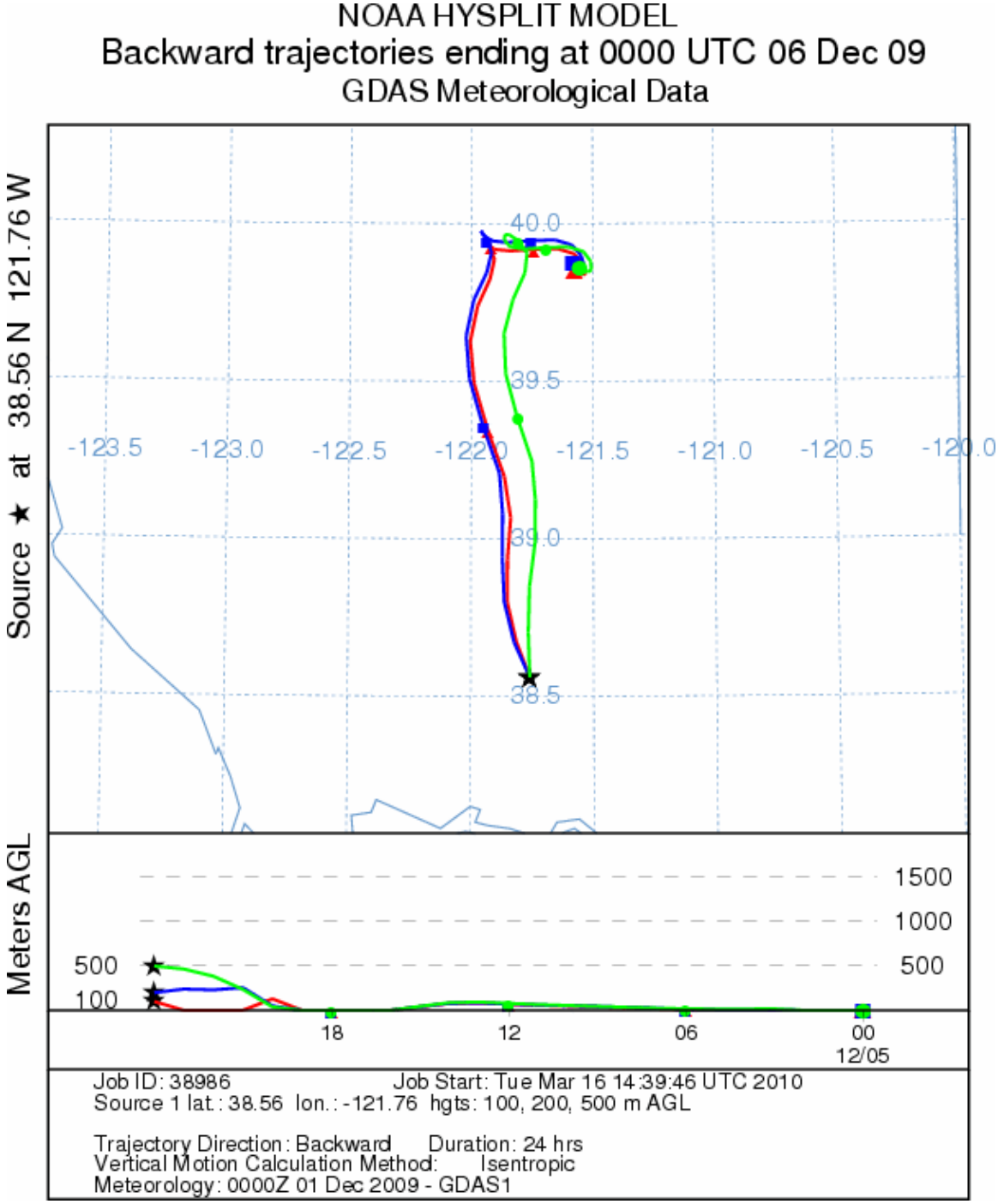


Figure 22 HYSPLIT trajectories for evening, December 5.

ii. December 21, 2009

AQI = 72 (at 75, it would have been a no-burn day)
T min = 46 ^{o} F
Wind (mean) 7 mph, South
Visibility 4 miles, rain

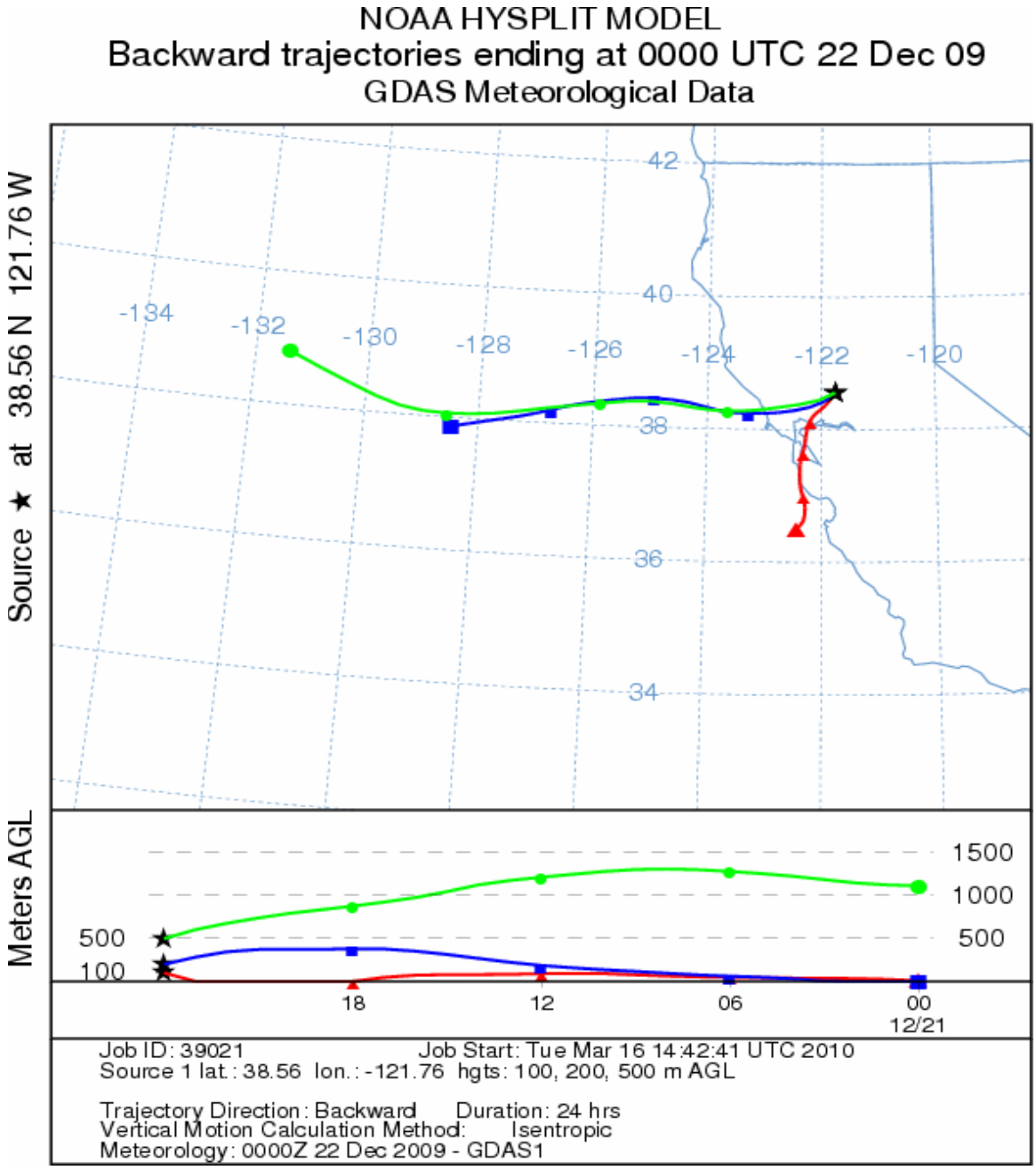


Figure 23 HYSPLIT trajectories for the evening of December 21, 2009.

Another classic almost no-burn day with San Joaquin aerosols. A probable source was identified NNW of one of the complaints.

iii. December 25, 2009

AQI = 82 (not called, but it should have been a no-burn day)
T min = 28 ^{o} F
Wind (mean) 1 mph, SSW
Visibility 5 miles, fog

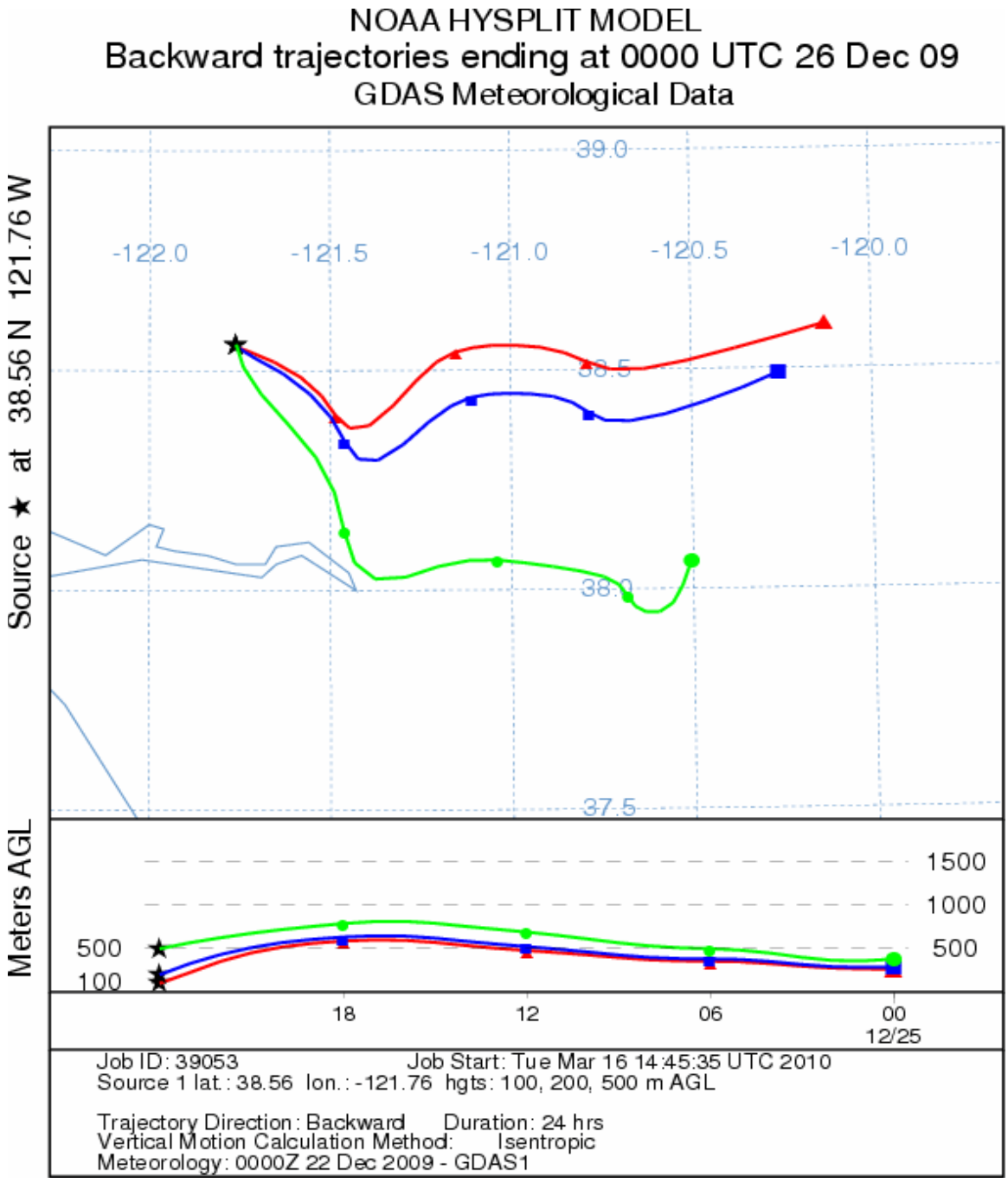


Figure 24 HYSPLIT trajectories for evening of December 25, 2009

Christmas, and a very cold night with very weak winds and fog.

iv. January 26, 2010

AQI = 49
T min = 45 ^{o} F
Wind (mean) 9 mph, NW
Visibility 8 miles, rain

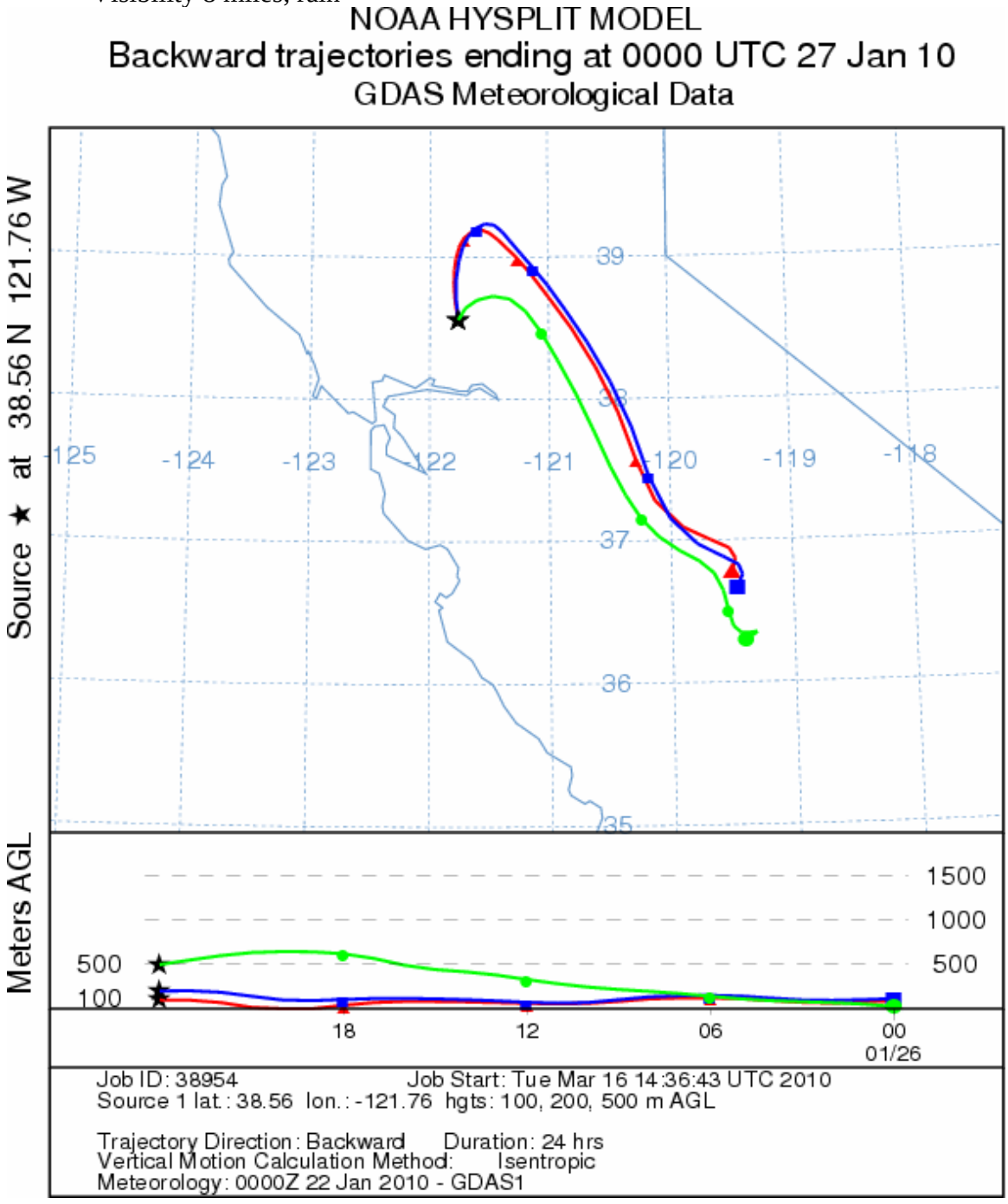


Figure 25 HYSPLIT trajectories for evening, January 26, 2010

This event happened in a low AQI in strong wind and rain. At the time of the impacts, one complaint noted the wind was from the north and 2 probable sources named were also just north of the complaint location.

3. Conclusions

The study has generated valuable data on the nature and extent of smoke impacts in Davis. I recommend that logging complaints continue in 2010-2011. Additional central city mass measurements do not appear needed.

1. The study was effective, including identifying perhaps a dozen credible nearest neighbor problems and the conditions under which they occurred.
2. This study also supported prior work indicating that the lower Sacramento Valley acts regionally in the winter, including
    a. slow drift of smoke south from the north, and
    b. occasionally pulses of bad air from the San Joaquin Valley often preceding storms. There was relatively little contribution to the regional average from Davis itself.
3. There were a relatively limited number of people who filed complaints,
    a. 19 named individuals and
    b. 7 anonymous individuals.
4. Very few complaints were filed on no-burn days despite conditions that would tend to make complaints likely – low winds from the north. This indicates that the no burn restrictions are effective.
    a. Most of the complaints only mentioned the smell of wood smoke, and many occurred in very clean conditions and high wind velocities
5. 6 of the complaints occurred in clusters on days that were at or just below no burn status and 2 occurred under conditions that should have triggered a no burn day. This implies that a slight tightening of the no-burn trigger would be effective.

Acknowledgements

The authors wish to acknowledge first the citizens who took the time to lodge complaints, especially those that included additional information.

The city staff has been responsive and helpful through the entire process.

The UC Davis DELTA Group thanks all out volunteers who performed this study without cost to the city.

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Turn, S.Q., B.M. Jenkins, J.C. Chow, L.C. Pritchett, D. Campbell, T. Cahill, and S. A. Whalen. **Elemental characterization of particulate matter emitted from biomass burning: wind tunnel derived source profiles for herbaceous and wood fuels**. 1997 *Journal of Geophysical Research*, 102, 3683-3699.

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Appendices

Appendix A

DRUM Quality Assurance Protocols ver 1/09 (summary)

DELTA* Group DRUM samplers
Original Version 8/02. (DQAP 8/02)
Current version January, 2009 (DQAP 1/09)

Tom Cahill and DELTA* Group staff

Dr. Steve S. Cliff, Prof. Kevin D. Perry (Meteorology, U. Utah), Dr. David E. Barnes, Lee Portnoff (DRUMAir)

*Detection and Evaluation of Long-range Transport of Aerosols

Newest information

Three new studies have enhanced our understanding of continuous sampling by size, time, and composition with DRUM impactors:

1. Final report to the California Air Resources Board, **Comparison of Fine Mass, UC Davis DRUM versus FRM, at the ARB 13th and T Street Site**, Thomas A. Cahill and David E. Barnes, UC Davis DELTA Group, and the Breathe California of Sacramento/Emigrant Trails Health Effects Task Force, April 25, 2009

2. Final Report, **Drum Sampler Demonstration of PM Mass and XRF Elements** Final Report to the US EPA ORD, , March 14, 2009, Thomas A. Cahill, David E. Barnes and Jonathan Lawton, University of California, Davis, with Thomas M. Cahill, Arizona State University, May, 2009,

and a third that emphasized the size resolved DRUM organics (including ultrafine) with comparison to DRUM S-XRF and mass (including ultrafine),

3. **Organic and Elemental Aerosols near Watt Avenue, Late Winter – Spring, 2007,** Draft prepared for The Health Effects Task Force, Breathe California of Sacramento-Emigrants Trails and the Sacramento Metropolitan Air Quality Management District, June 26, 2009.

The first two are available electronically from BC/SET and the UC Davis DELTA Group.

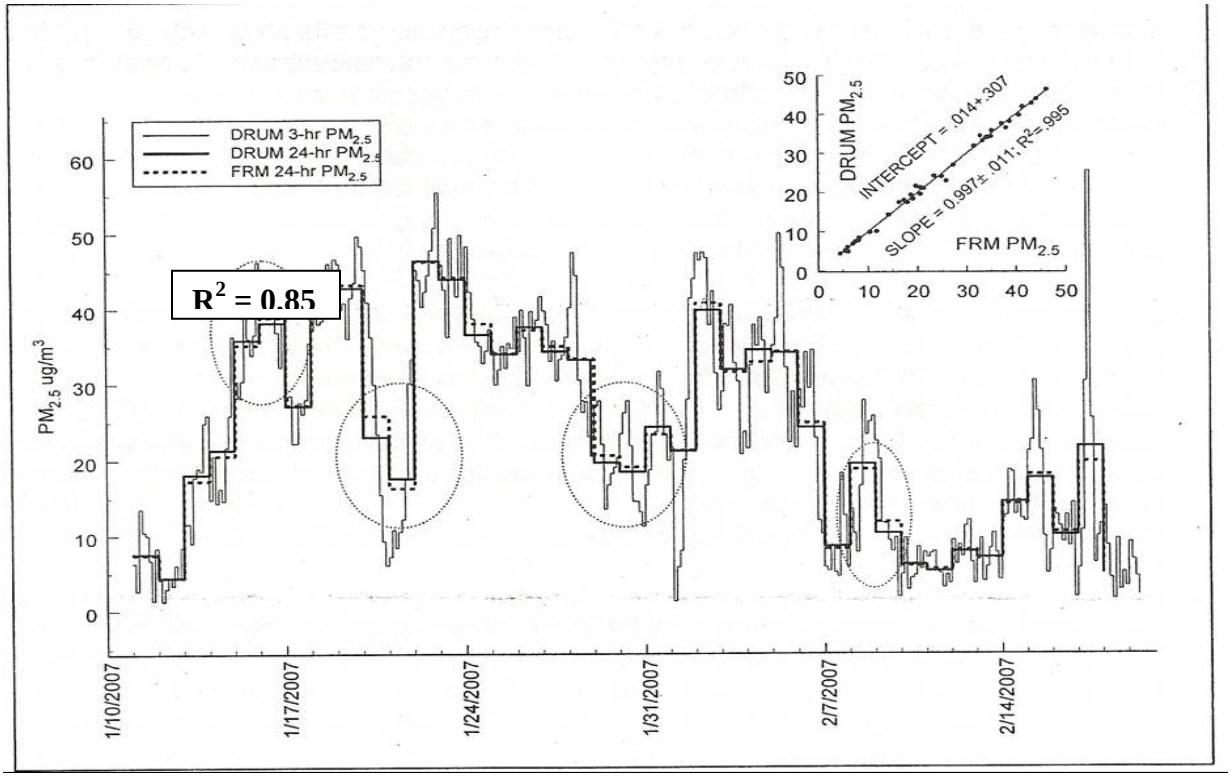
1 New data on DRUM to FRM mass comparisons from the ARB comparisons.

A side by side comparison a made between a DELTA Group 8 DRUM with integrating afterfilter and ARB FRM $PM_{2.5}$ 24 hr filters for 6 months in 2007. The mass was measured by soft beta ray transmission, so the test involved both the accuracy and precision of the DRUM sampler and soft beta ray mass analysis.

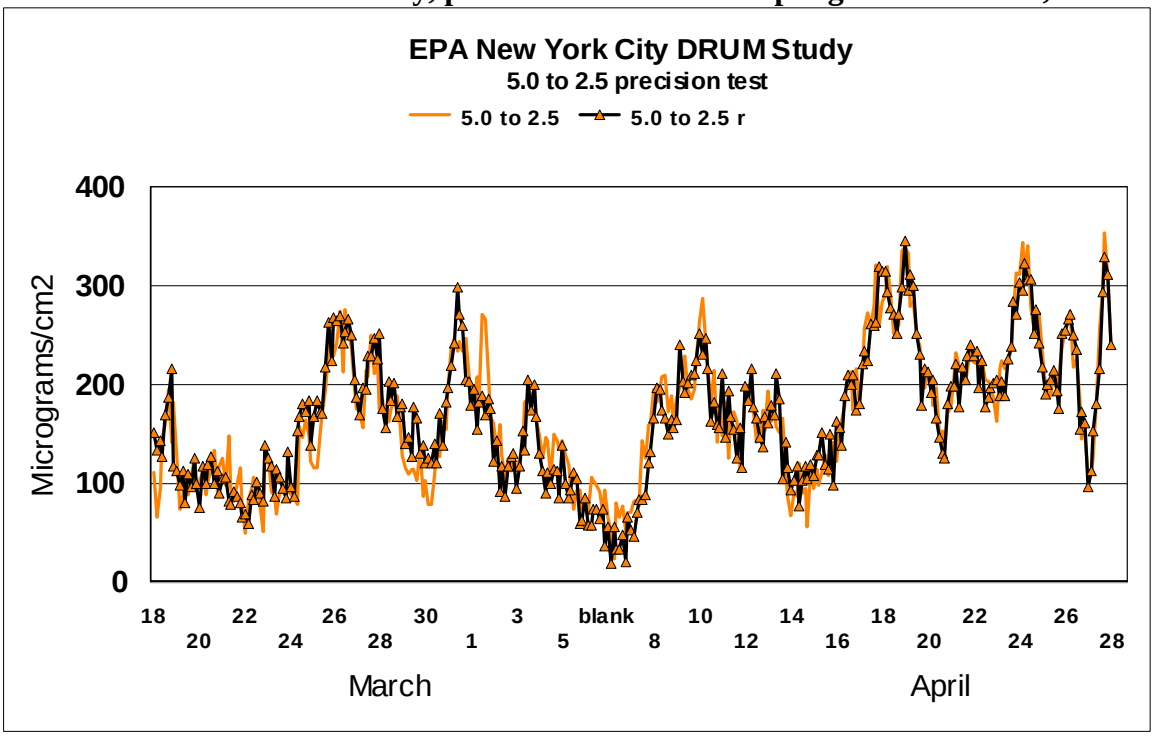
In summary, for Period I, January 12 – February 20, 2007, good agreement between ARB 24 hr filters and the sum of 49 individual DRUM stages and ultra fine after filter, 23.2 ± 1.0 $\mu g/m^3$ DRUM, 22.1 $\mu g/m^3$ ARB. For the entire 6 months, the ratio, DRUM/FRM, was 1.01 ± 0.21, with the uncertainty dominated by the need to take 49 individual DRUM mass measurements to equal one 24 hr filter.

The data were transmitted to the SRB and SRB staff, aided by their access to short-time aerosol data unavailable to UC Davis, re-did the analysis making a slight (3 hr) adjustment in the DELTA Group's start time. The results were sharply better agreement with the FRM (below) with slope = 0.99 and $r^2 = 0.99$.

Based upon these efforts, a high time resolution Dust Trak nephelometer ids now added at the start of every field campaign, guaranteeing an accurate start time.



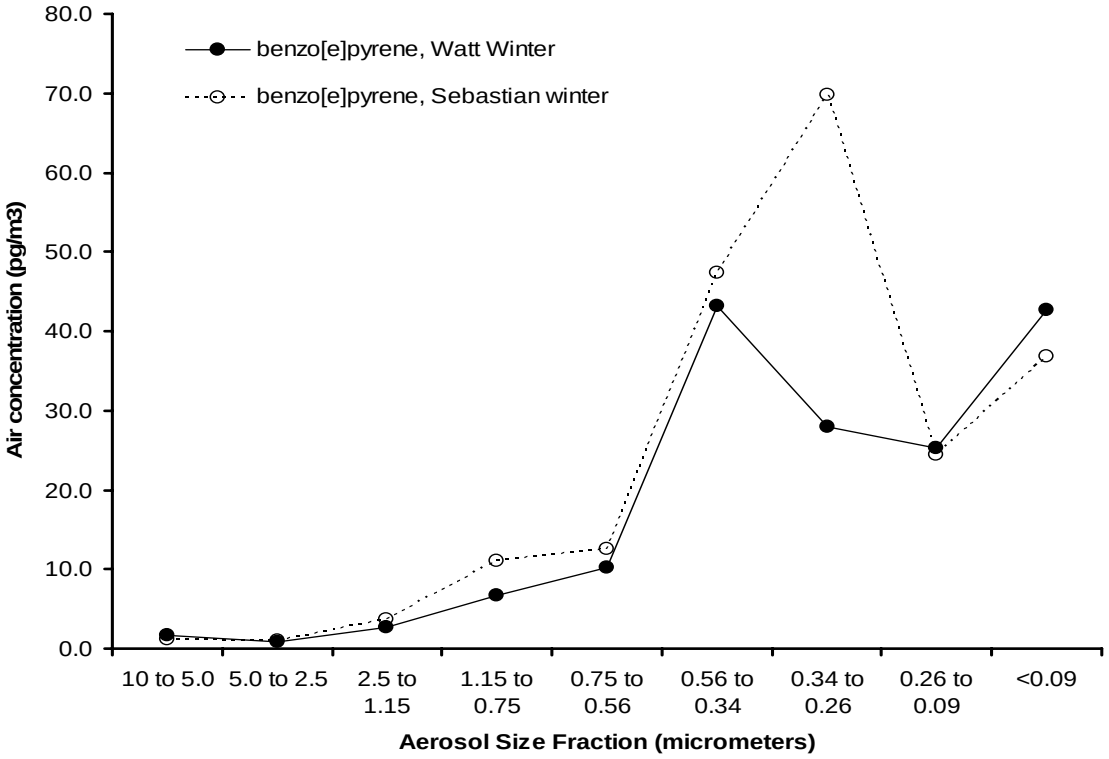
2. From the US EPA study, precision of DRUM sampling was examined,



This work also showed mass balance on the ultra fine filters, the "Gold Standard" for QA.

Major components	ug/m3	ug/m3		Minor components	ng/m3	ug/m3
	filter	cont.			filter	cont.
Mass (gravimetric)	2.04	2.9		Phosphorus	2.4	0.7
Mass (reconstructed)	2.15	na		Vanadium	0.15	0.3
				Chromium	0.45	< 0.1
Organic	1.72	na		Nickel	3.5	0.2
Diesel PM (est.)	na	1.3		Copper	8.3	0.2
Ammonium Sulfates	0.34	0.03		Zinc	11.5	0.7
Salt	0.04	0.01		Arsenic	0.6	0.1
Soil	0.048	0.06		Selenium	0.3	0.2
K non	0.053	0.04		Bromine	3.7	5.7
Metals	0.035	0.011		Lead	4	1.1

3. From the Watt Avenue studies, the precision and accuracy of the organic data are shown by the agreement at 2 sites 500 m apart.



4. Summary comparison, all DELTA S-XRF double blind experiments

Below we summarize all DELTA Group S-XRF inter-comparisons in the past 5 years. Note that there were problems with the ARB RAAS analyses since the two internal ARB X-RF to ARB RAAS comparisons agreed only at the level 1.29 ± 0.63 for all co-measured elements. (DQAP v. 8.02, pg 32) We also give averages below without the ARB RAAS data. A comparison was also done with IMPROVE in the Yosemite study

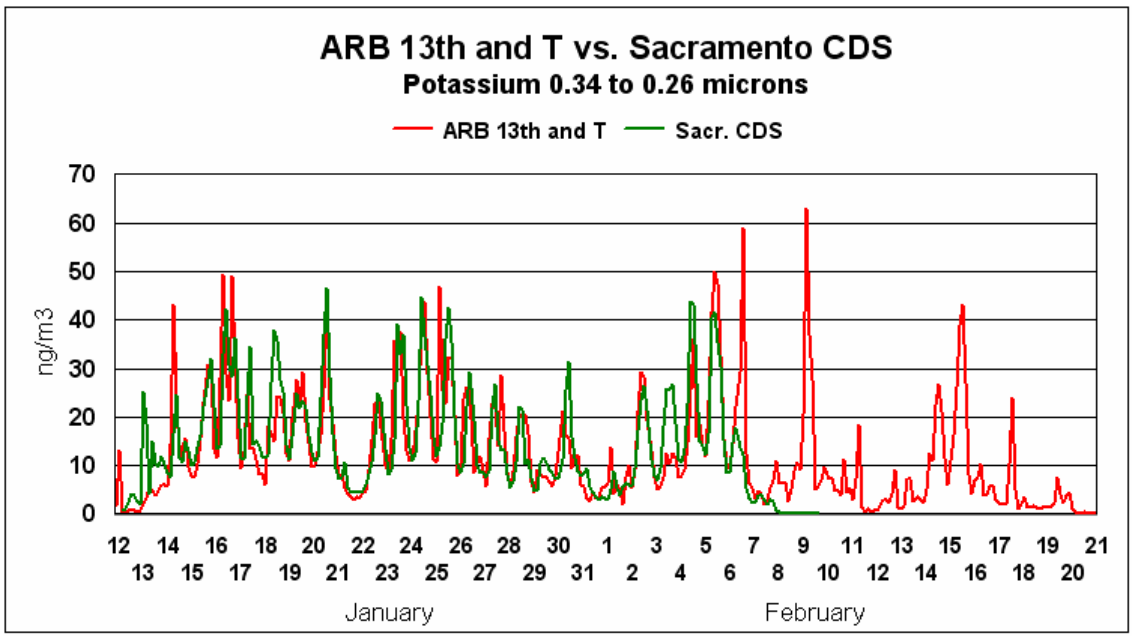
(2002) but this comparison is not included since IMPROVE has also since identified serious deficiencies in data from that period (White et al, AAAR 2004)

Study and date	Methods	**Average ratio, Al to Fe**	Std. dev.	**Average ratio, Cu to Pb**	Std. dev.
BRAVO, 1999	PIXE vs S-XRF	**0.99**	0.04		
BRAVO, 1999	CNL XRF vs S-XRF			**1.24**	0.14
FACES, 2001	ARB XRF vs S-XRF	**0.93**	0.21	**1.02**	0.08
FACES, 2001	ARB (alt) vs S-XRF	**(0.98)**	0.27	**(0.74)**	0.23
ARB LTAD 2005	DRI XRF vs S-XRF	**1.037**	0.085	**0.907**	0.009
All prior studies	**Average** (wo ARB alt)	**0.984**	**0.15**	**0.977**	**0.115**

A. DRUM to DRUM comparison, 0.26 to 0.09 potassium data, BC/SET HETF ARB study

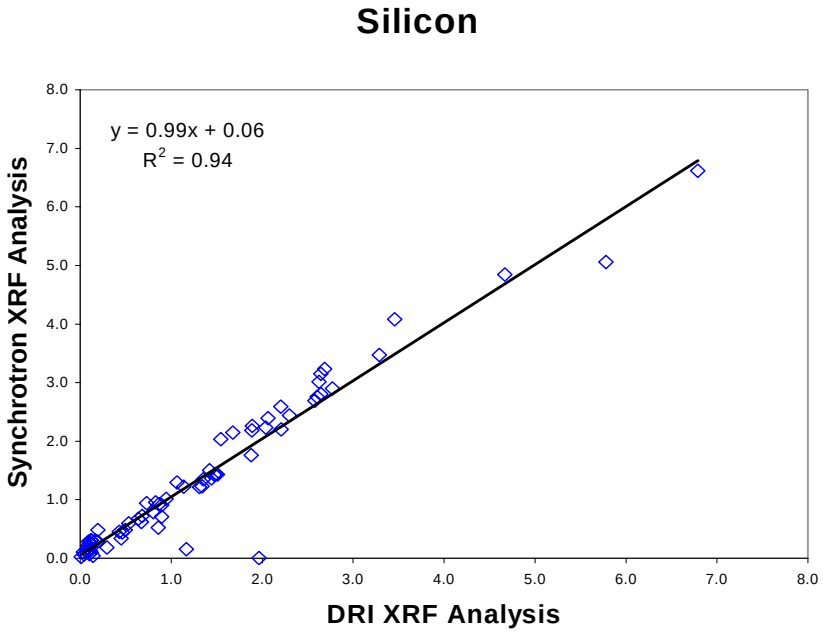
The comparisons of DRUM to DRUM including all aspects of air flow, particle sizing, and S-XRF analyses can result in a serious propagation of error uncertainties Nevertheless, below we show two DRUM samplers, one of the older design running at 16.7 L/min, one of the newest design running at 10 L/min. The sites were roughly 8 km apart in Sacramento.

Very fine potassium shows remarkable agreement week after week as the inversion caps the entire city.



B. DELTA Group S-XRF versus DRI XRF, ARB Lake Tahoe Atmospheric Deposition (LTAD) study, (2005)

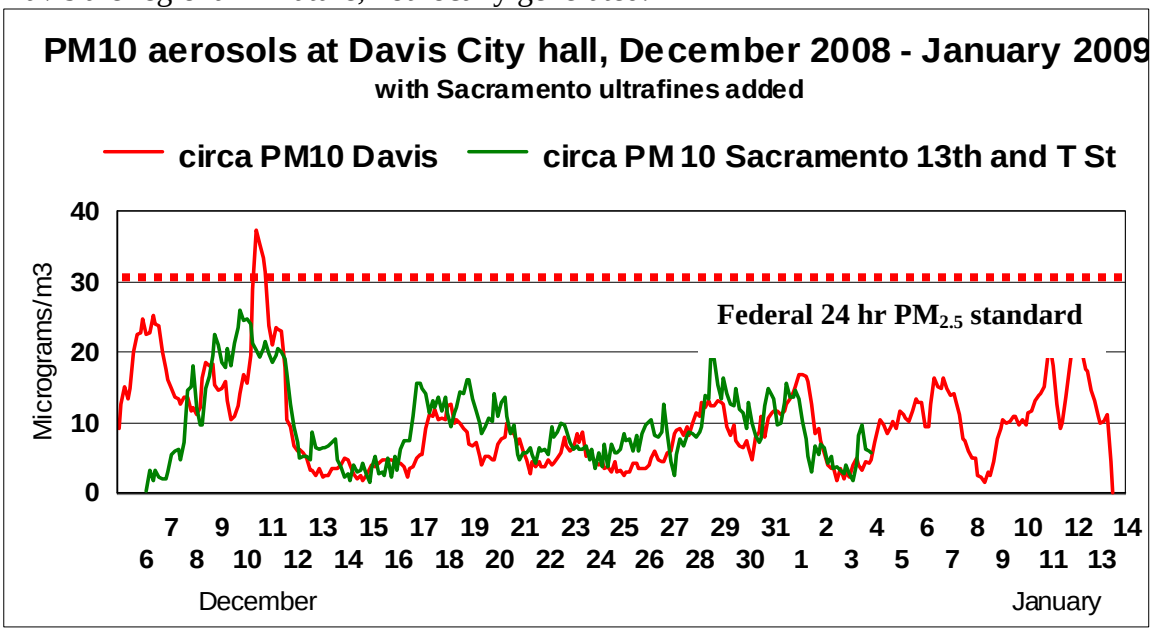
This comparison for silicon in very lightly loaded samples (a few μg/m^3), was typical of major elements. For many minor elements, S-XRF had much higher sensitivities and MDL limitations with the DRI data made comparisons impossible. Specifically, the very important element for lake clarity, phosphorus, was seen above MDL in only about 1% of analyses by DRI, while phosphorus was seen in over 80% of DELTA Group S-XRF analyses. All these data are in the comparison table (above)



Appendix B
Aerosol monitoring in Davis, Winter, 2008-2009

Executive summary

Aerosols measured at City Hall in Davis were well below federal aerosol standards (PM_{10} = 150 μg/m^3, $PM_{2.5}$ = 35 μg/m^3) over the entire winter. However, note that in winter, we show that almost all the PM_{10} aerosol was composed of $PM_{2.5}$ particles. Aerosols measured in Davis were often equivalent to those measured in downtown Sacramento at the same time, confirming earlier evidence that the aerosols in central Davis are regional in nature, not locally generated.



Several episodes of enhanced aerosols were seen, however, when for a number of hours or days aerosol concentrations were elevated in the particle sizes characteristic of wood smoke, nitrates, and sulfates. These occurred usually under conditions of weak winds, strong inversions and hazy conditions, with the winds often coming down slope from the Sierra Nevada, over Sacramento, and into Davis.

While attempts to use Dusttrack portable samplers failed, a short time (< 1 hr) impact of wood smoke was qualitatively observed on one occasion in nearest-neighbor conditions under low wind conditions.

Table of Contents

1. **Introduction**

In order to better establish aerosol levels in the City of Davis in winter, including times of wood burning, the UC Davis DELTA Group volunteered to obtain data on aerosol mass in Davis from December, 2008, to March, 2009.

1. Operations
    a. Aerosol monitoring with the 3 DRUM

Sampling site	DRUM Sampler	Period ID	Start time	Stop time	Days
Davis City Hall Period 1	3D – 13	384	12/5/2008 11:30	1/14/2009 11:11	40.0
Davis City Hall Period 2	3D - 13	401	1/14/2009 11:15	2/21/2009 9:15	37.9
Del Campo site Period 3	3D - 16	400	1/28/2009 10:38	3/4/2009 14:15	35.2

    b. Measuring with the Dusttrak

2. DRUM Quality Assurance

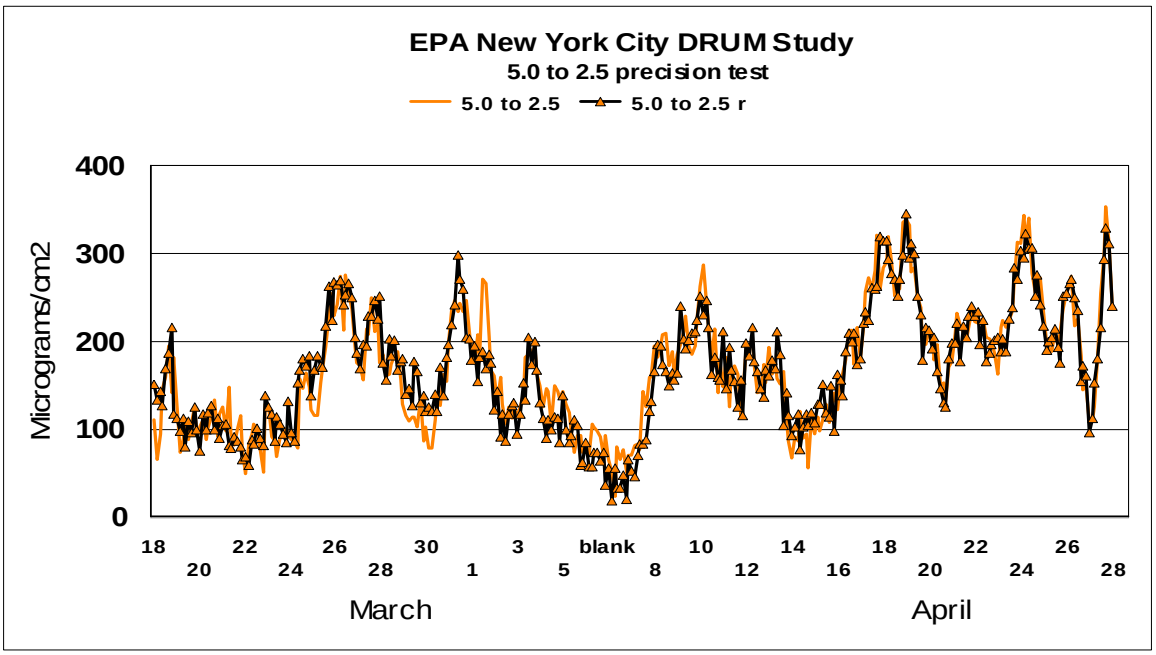
Quality assurance of the DRUM samplers are given in detail in DRUM Quality Assurance Protocols, ver 1/09 (DQAP v 1/09) at the DELTA Group web site, http://delta.ucdavis.edu. Recent additional examples have been generated in the current US EPA study of DRUM samplers in New York City and Sacramento and a side by side test in Sacramento versus the California Air Resources Board at 13th and T Street.

a. Air volume

The volume of air was calibrated via a filed audit orifice and Magnehelic meter which is tied to a Collins integrating spirometer at the DELTA Group. Flows measured before and after sampling must be within 5%, or a complicated algorithm can assist if the difference are between 5% and 15%. Above 15%, the data are rejected. Thus never occurred in this study.

b. Precision – mass analysis by soft beta ray

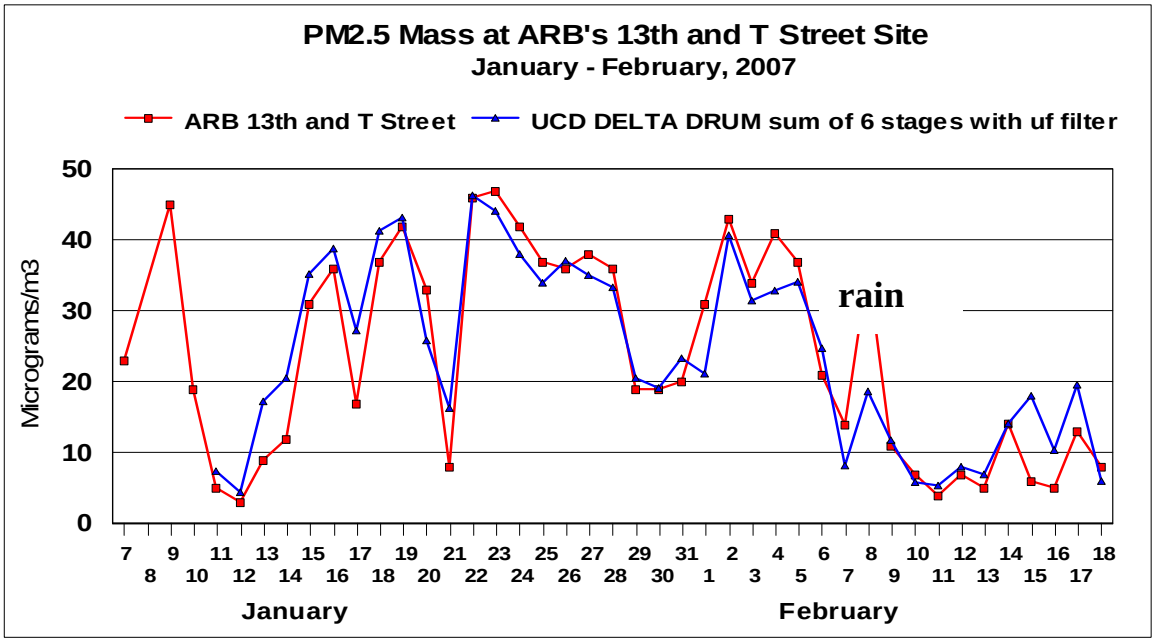
Samples are routinely re-analyzed to compare with the original analysis. An example is shown below for particles between 5.0 and 2.5 μm in the US EPA New York study, spring, 2008. Note that this is a more severe test than for filters because of the rapid time response.

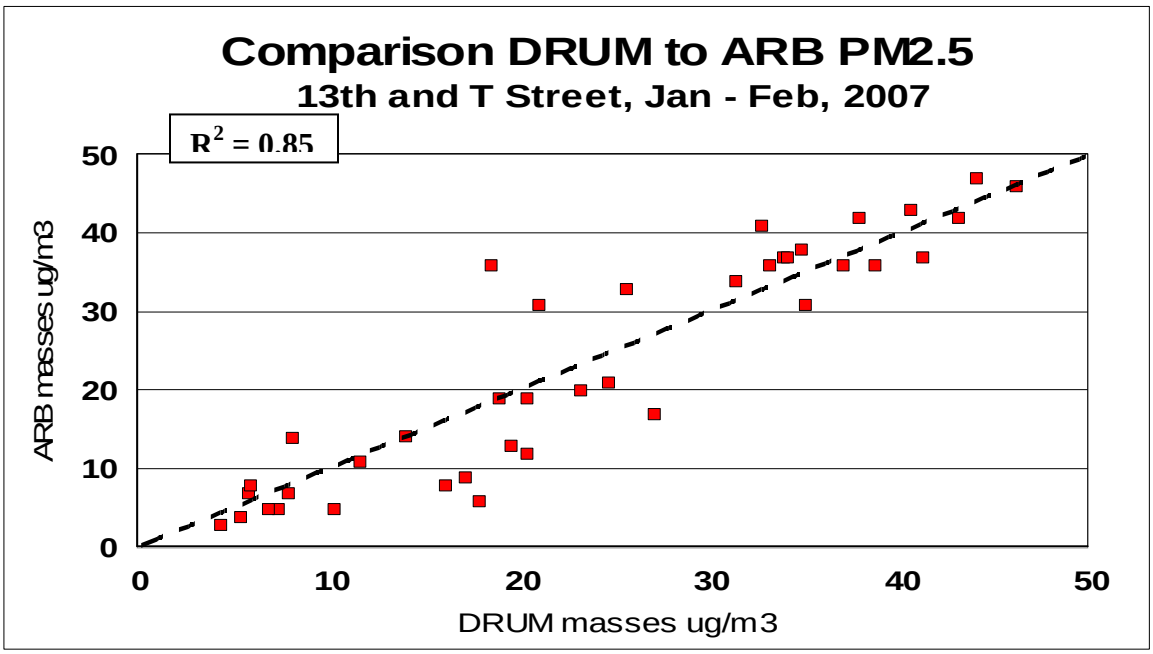


c. Accuracy

Mass values are calibrated by Type S standards on a Cahn 31 Microbalance with 0.1 µg MDL. The protocols used are those we developed for the IMPROVE program in 1988 and followed to this day. (Malm et al, 1994)

DRUMs were operated side by side with standard EPA FRM filter samplers at the California Air Resources Board test site at 13th and T Street. An example of one such test is shown below.





In summary, for Period I, January 12 – February 20, 2007, good agreement between ARB 24 hr filters and the sum of 49 individual DRUM stages and ultra fine after filter, 23.2 ± 1.0 μg/m^3 DRUM, 22.1 μg/m^3 ARB.

For all tests, over the entire year, the ratio was 1.01 ± 0.21, with the relatively high uncertainty associated with the need to add 48 separate DRUM mass values to equal one 24 hr filters sampler.

d. HYSPLIT trajectories

HYSPLIT is a NOAA program based on the central US weather computers that allows air mass transport calculations anywhere in the world. Tom Cahill has been a certified and registered user since 2000.

Draxler, R.R. and Rolph, G.D., 2003. HYSPLIT (HYbrid Single-Particle Lagrangian Integrated Trajectory) Model access via NOAA ARL READY Website (http://www.arl.noaa.gov/ready/hysplit4.html). NOAA Air Resources Laboratory, Silver Spring, MD. ; Rolph, G.D., 2003. Real-time Environmental Applications and Display sYstem (READY) Website (http://www.arl.noaa.gov/ready/hysplit4.html). NOAA Air Resources Laboratory, Silver Spring, MD.

e. Elemental analysis

Selected samples were analyzed by synchrotron-induced x-ray fluorescence (S-XRF) at the Advanced Light Source, Lawrence Berkeley NL, on the DELTA Group beam line 10.3.1.

The S-XRF system has been tested in blind inter-comparisons since 1999, and all of these are shown below in Table 1. Typically 32 elements are recorded for each analysis, all of which can be traced back to NIST primary (SRM # 1832, SRM # 1833) or secondary (Micromatter thin film) standards. Over 250,000 S-XRF analyses have been done by the DELTA Group since completion of the system in 1999.

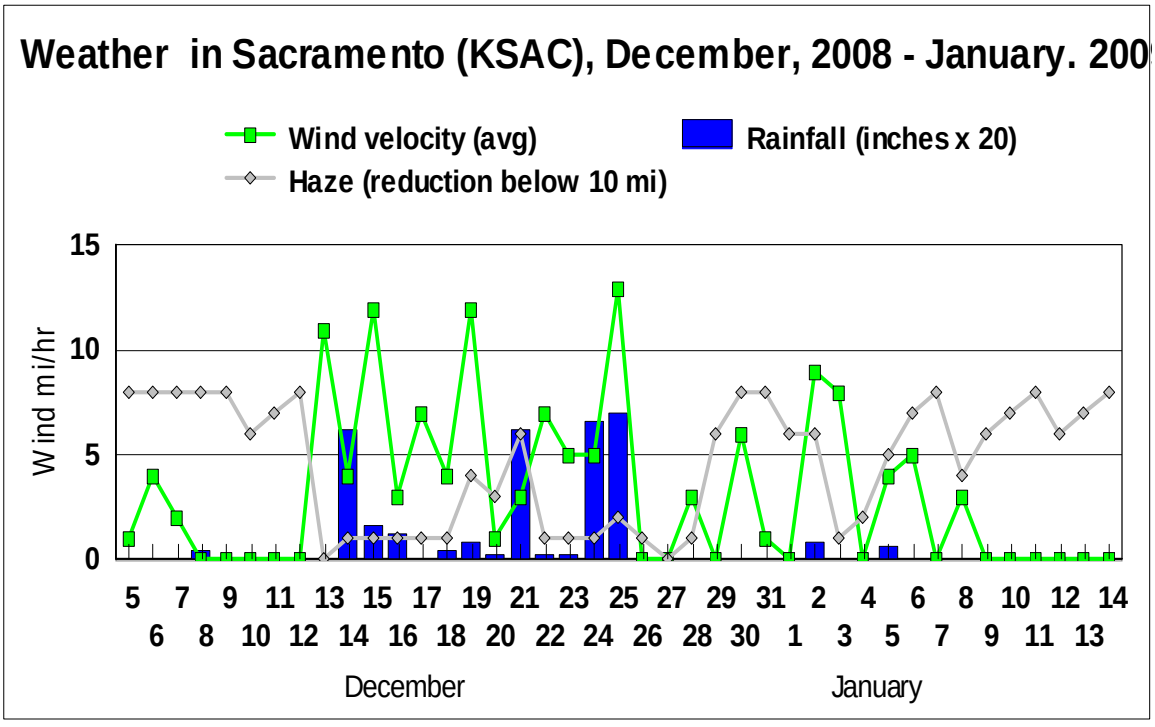
Study and date	Methods	**Average ratio, Al to Fe**	Std. dev.	**Average ratio, Cu to Pb**	Std. dev.
BRAVO, 1999	PIXE vs S-XRF	**0.99**	0.04		
BRAVO, 1999	CNL XRF vs S-XRF			**1.24**	0.14
FACES, 2001	ARB XRF vs S-XRF	**0.93**	0.21	**1.02**	0.08
FACES, 2001	ARB RAAS vs S-XRF	**(0.98)**	0.27	**(0.74)**	0.23
ARB LTAD 2005	DRI XRF vs S-XRF	**1.037**	0.085	**0.907**	0.009
All prior studies	**Average**	**0.984**	**0.15**	**0.977**	**0.115**

Table 1 S-XRF comparison, all blind tests since 1999.

3. Weather

The weather data are taken via http://www.weatherunderground.com for KSMF, the Sacramento International Airport.

The weather data are presented in two batches, designed to match the 2 DRUM sampling programs; Period 1, December 6 – January 14, and Period 2, January 14 – February 23. The first period had extended periods of hazing, low wind conditions, Dec. 6 to 13, Jan 6 to 14, interrupted by rainy conditions and stronger winds (shown below)



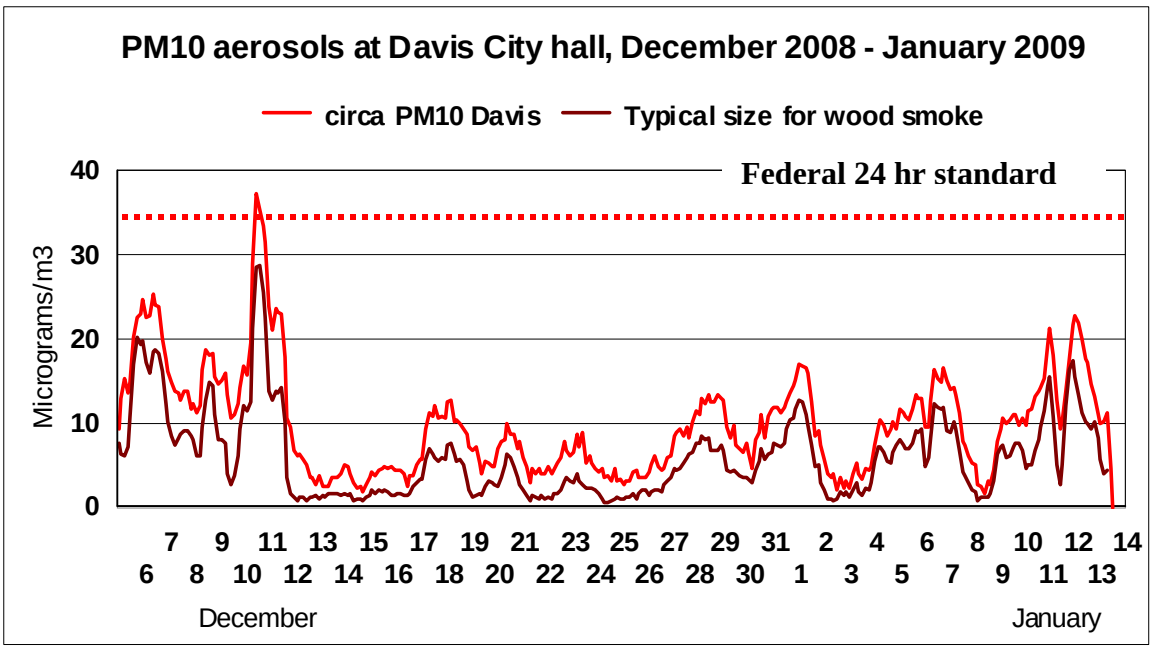
4. Aerosol Data from the DRUM sampler – Period 1

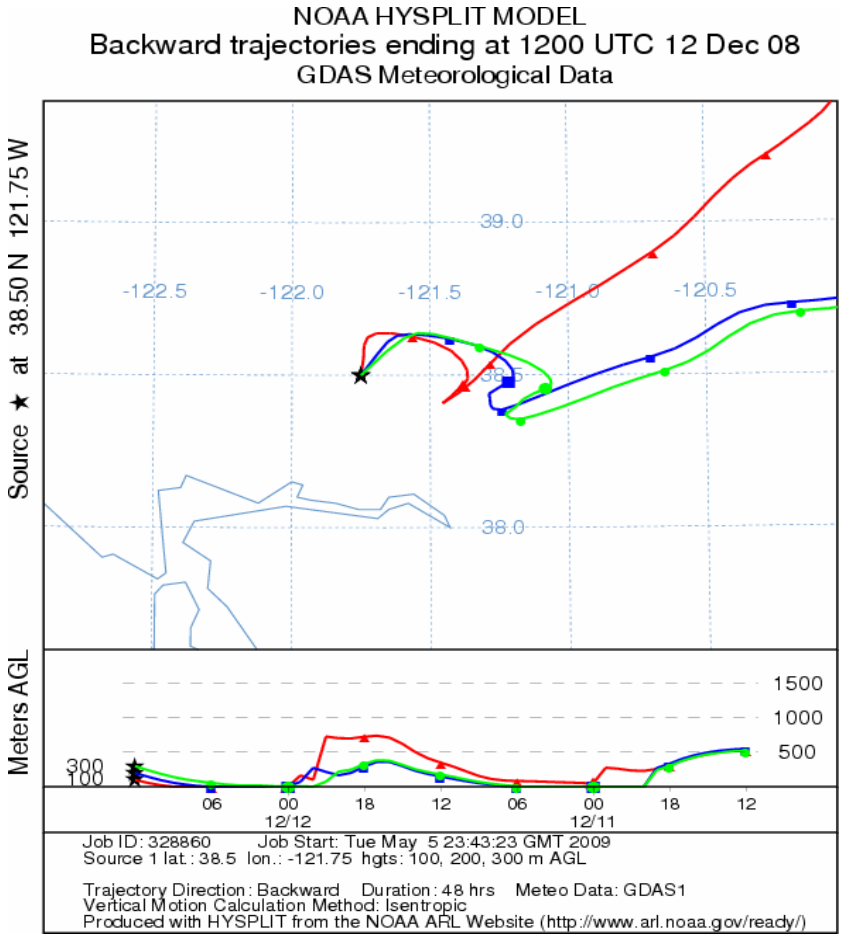
The aerosols from Period 1 are shown below in true color. The top strip is Stage A, circa 10 to 1.15 μm, the second is Stage B, 1.15 to 0.34 μm, and the third Stage C, 0.34 to 0.15 μm aerodynamic diameter.

Below the DRUM strips is a color scale and a gray scale for calibration purposes. Note how dark the samples are in the beginning and the end on Stages B and C.

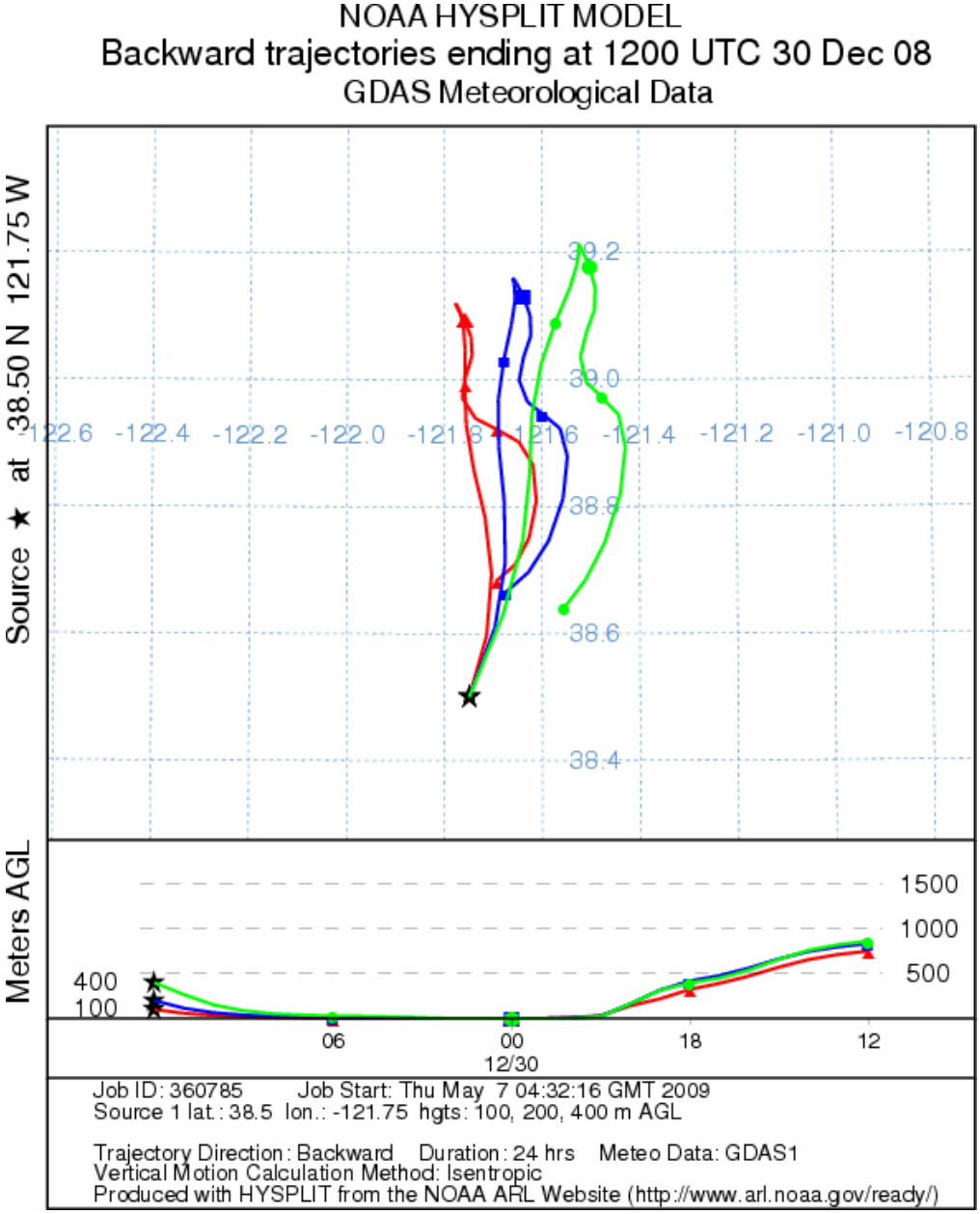
a. Mass data

Below we show the aerosol mass in Davis from December 6 to January 14, both for the sum of all stages (PM_{10}) and for Stage B, 1.15 to 0.34 μm, the size that contains most of the wood smoke mass but also can include accumulation mode aerosols such as nitrates and sulfates.





24 hr HYSPLIT trajectory analyses are shown above for nighttime (4 AM) Jan 12, 2008, with air originating the previous evening on the Sierra foothills.

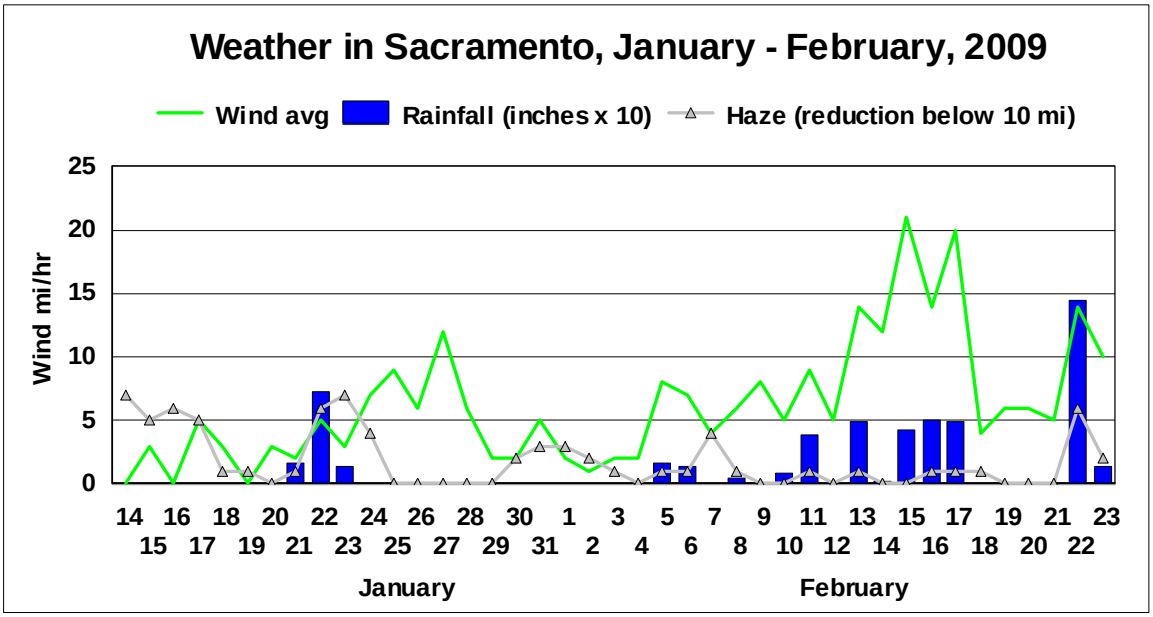


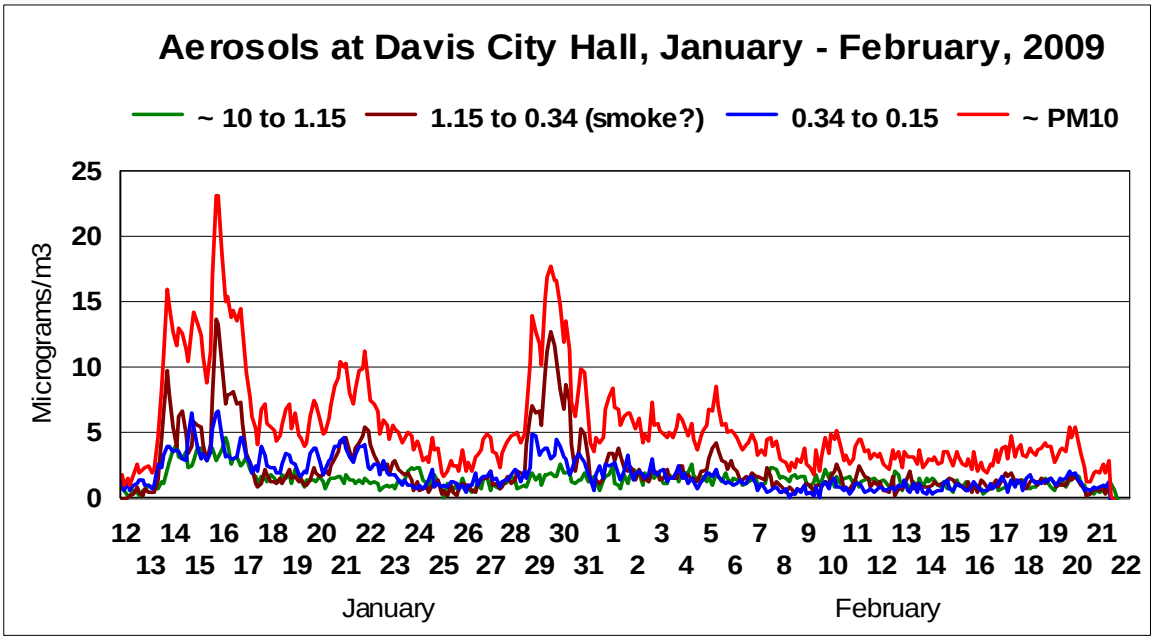
From the HYSPLIT analysis, we can see that the air at Davis on Dec.12, 4 AM, came from the western slopes of the Sierra Nevada, where wood burning is common. The air crossed over Sacramento and finally arrived at Davis. This would explain why the Davis and Sacramento results are so similar – they share the same source. This pattern persisted from Dec. 5 to Dec. 12.

On December 30, a cleaner period, the air came in to Davis from the north valley.

5. Aerosol Data from the DRUM sampler – Period 2:

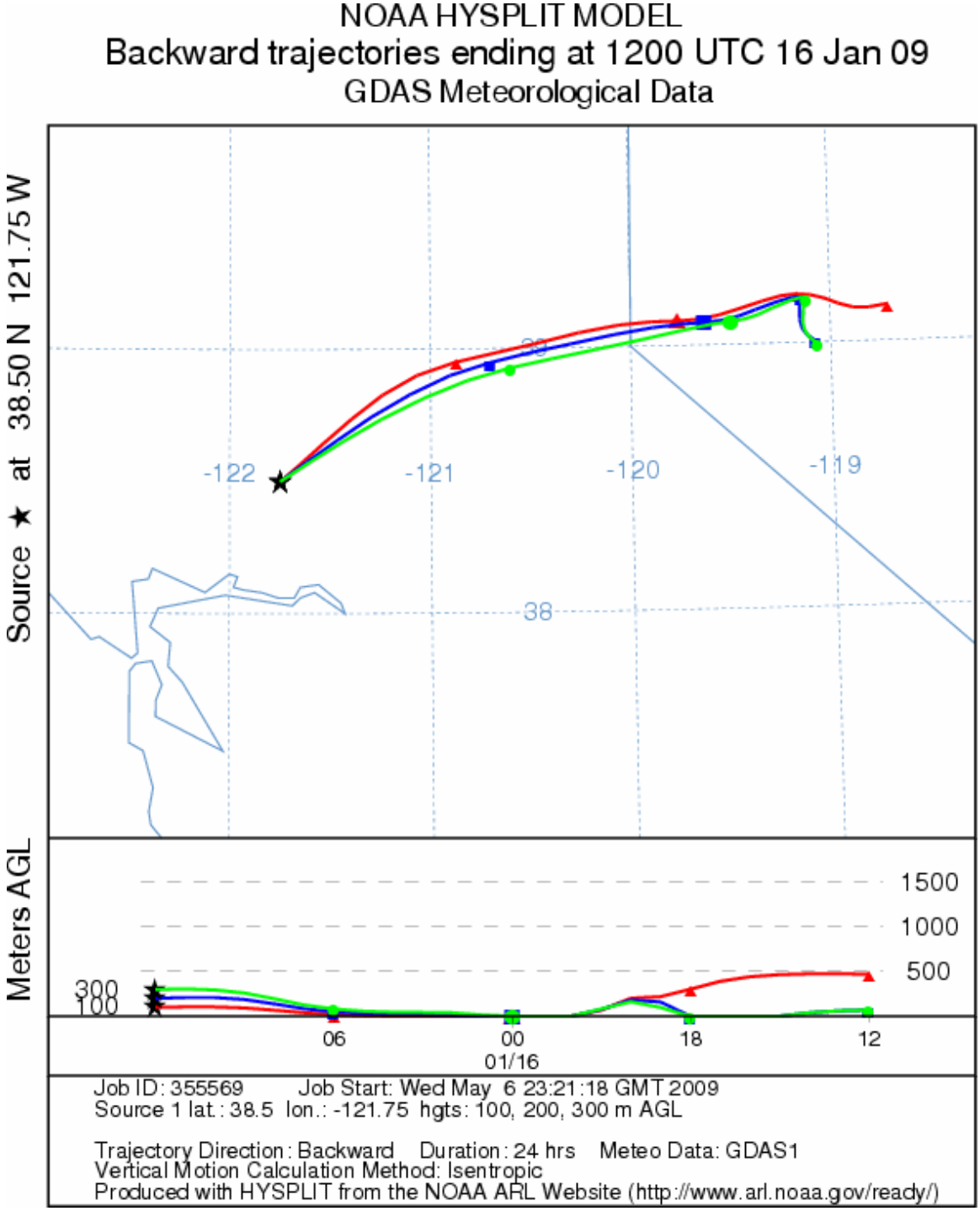
The period from January 14 to February 23 showed an excellent correlation between haze measured at Sacramento (SMF) and mass of fine particles in the range dominated often by wood smoke. The nominal perfect airport visibility is 10 miles, and the reduction below 10 miles is a measure of haze. Clearly, if visibility is zero, the haze parameter is 10. Almost all such days reported fog.

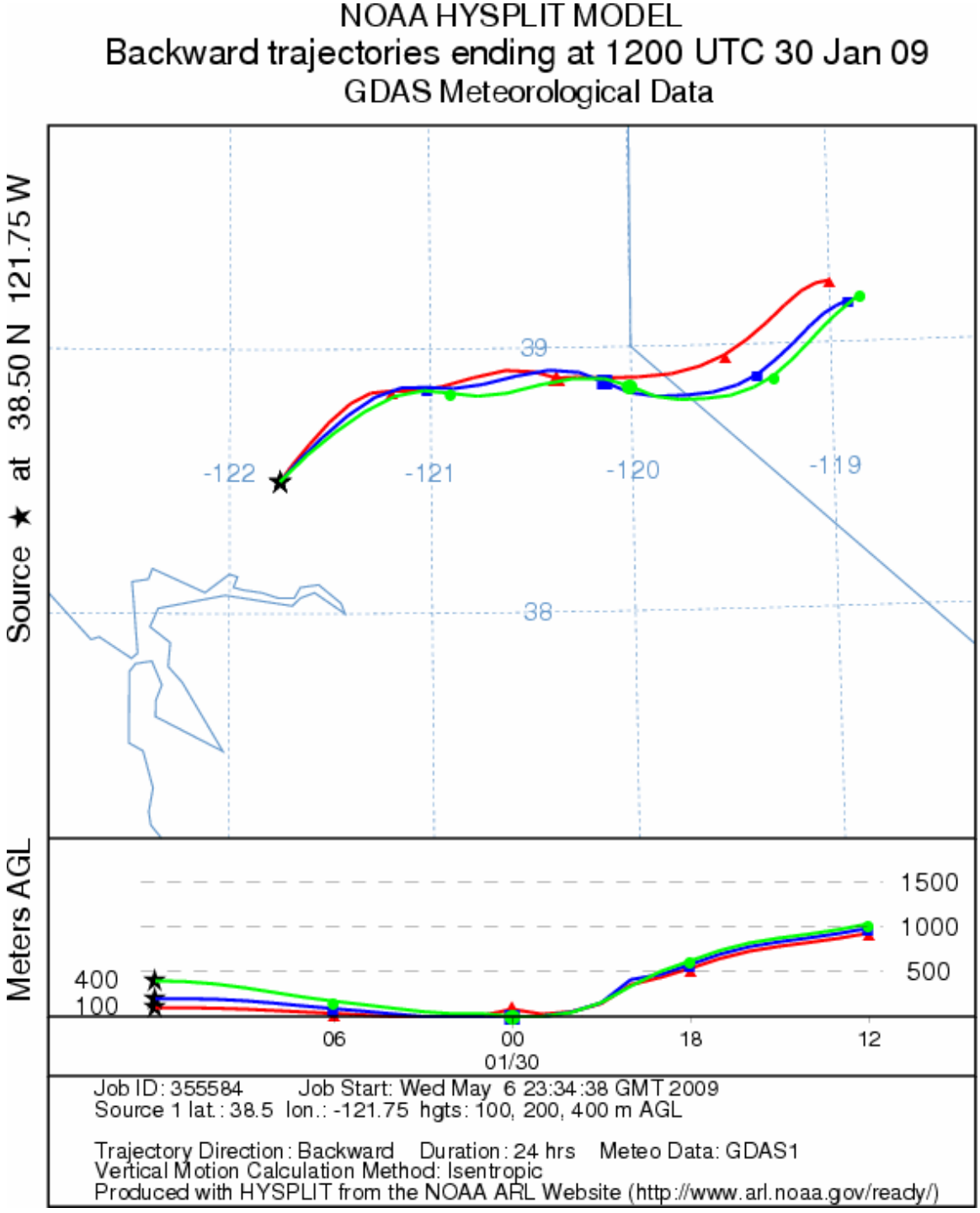




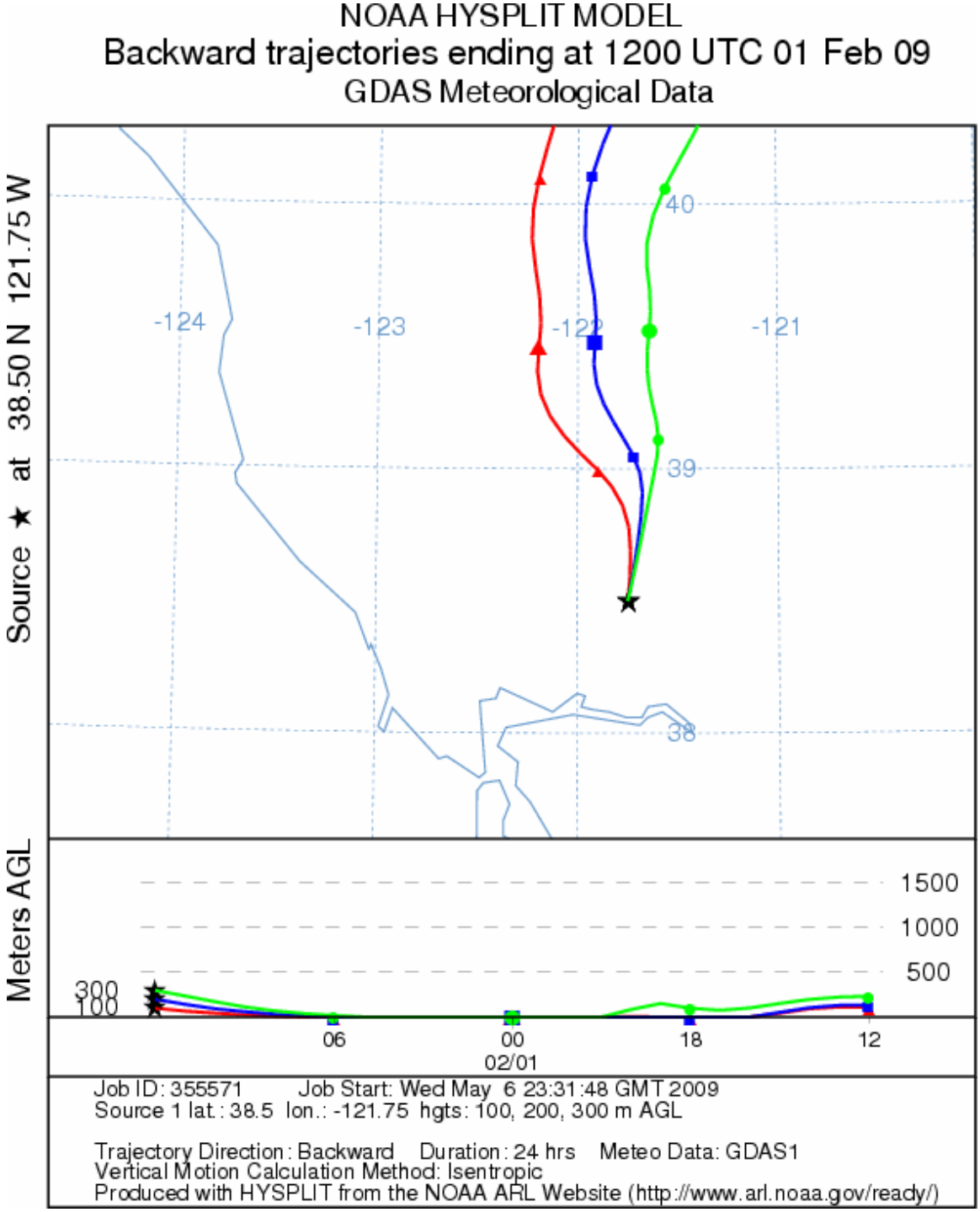
The mean wind velocity for the entire period was 6.3 mi/hr, but during the three aerosol and haze period, Jan 14 – 17, Jan 21 – 22m and Jan 29 – Feb 1, the average was 2.8 mi/hr.

The HYSPLIT trajectories again show transport from the western slope of the Sierra Nevada, across Sacramento, to Davis.





From the HYSPLIT analyses, we can see both the motion of air downslope from the Sierra Nevada and its compression under a strong inversion, since the Sierra downslope air is cold. The combination of transport from wood burning area, travel over Sacramento, and compression under a strong inversion are all complicit in the higher mass levels seen, widespread valley haze, and often fog.

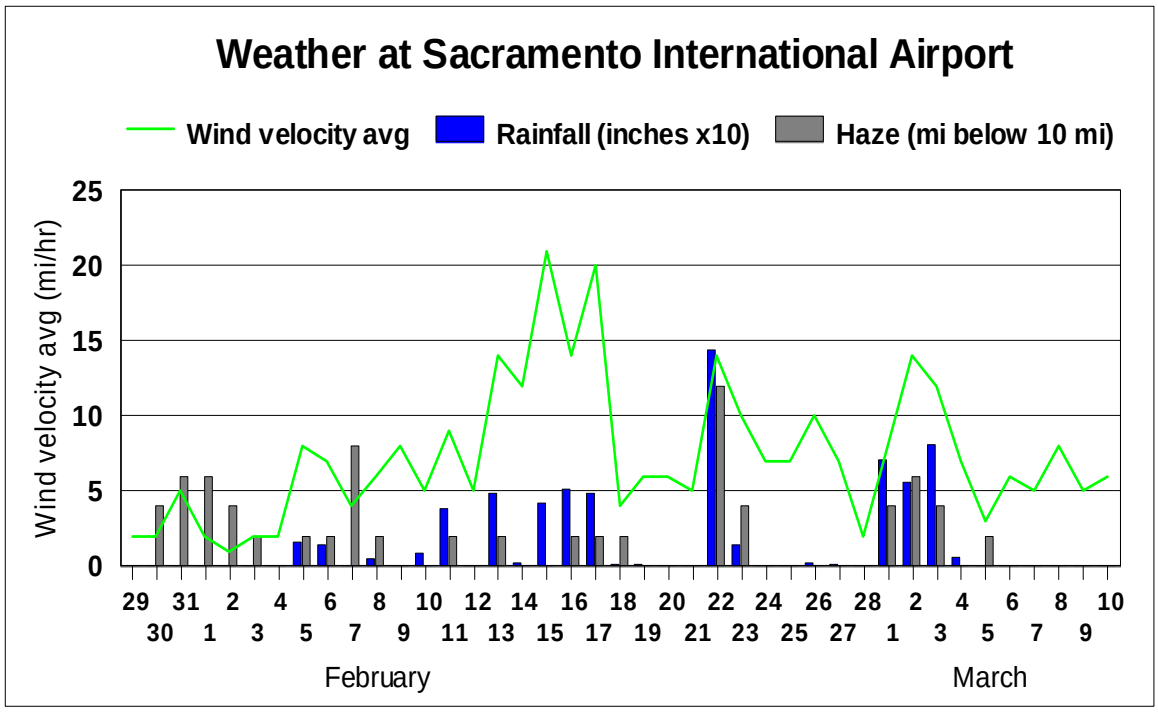


The haze and aerosol episode ended of February 1 as the air returned to a down valley flow from the northern Sacramento Valley.

6. Aerosol Data from the DRUM sampler – Period 3:

The collection of aerosol data, originally scheduled to end in January, was extended to March 4 in order to allow additional aerosols at the Del Campo site in south Davis and additional transects with the Dusttrack nephelometer.

a. Weather



Period 3 had far more rainfall and far less haze than period 1, and higher rainfall. The only times of reduced airport visibility were in a strong rain storm.

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b. Mass data

The mass data from the three stages are still bring processed and under quality assurance protocols. It will be provide separately since we have a deadline to make the May NRC meeting.

7. Dusttrack nephelometers

a. Protocol

December 15, 2008

City of Davis
Aerosol Nuisance Protocol
Draft of Tom Cahill and David Barnes

DELTA Group

1. The DustTrak nephelometer will be checked and calibrated roughly every 2 weeks by DELTA Group staff.
    a. At that time, a 1 day run will be made, taking samples every ½ hour for 24 hours.
2. Upon receipt of a complaint –
    a. Locate the time and place of the complaint as closely as possible.
    b. (One could take a Google Earth picture of the surrounding 3 block area)
    c. Take a 10 minute DustTrak reading at City Hall before leaving for the site
    d. At the site, take a 10 minute reading on all 4 quadrants of the city block within which the complaint is lodged. (At the street – take through an open window of the vehicle with the engine off.).
    e. At these tests, note all qualitative observations such as wind direction and strength, fog or rain, visible smoke, smell of smoke, etc.
    f. Repeat the around the block survey.
    g. (Take unit to most impacted location as referenced in the complaint – do not enter homes or other buildings). Take 3 readings in sequence.)
    h. Return to City Hall. Take a 10 minute reading.
    i. Log all observations.
3. Send record electronically to Tom Cahill and David Barnes for meteorological and regional air quality evaluation.
4. Their report will be prepared within 5 working days, and returned to the city

While the protocol was sound, it was a great disappointment that the Dusttrack nephelometers did not deliver data that met the minimum quality assurance protocols established at the beginning of thus study. The probable cause was a sensitivity to vibration and motion, as the same units had performed well when mounted if static positions. This was true for the City hall site since vibration from the DRUM pump was evident at the Dusttrack.

The criteria violated include:

1. The Dustrack start and stop measurements at Davis City hall did not agree. Typically the value upon return was far greater than the value when they left in conditions that were measured by the DRUM as stable.
2. During these excursions, and in side by side at City Hall, the Dusttrack routinely delivered values an order of magnitude higher than simultaneous Davis (or Sacramento) readings.

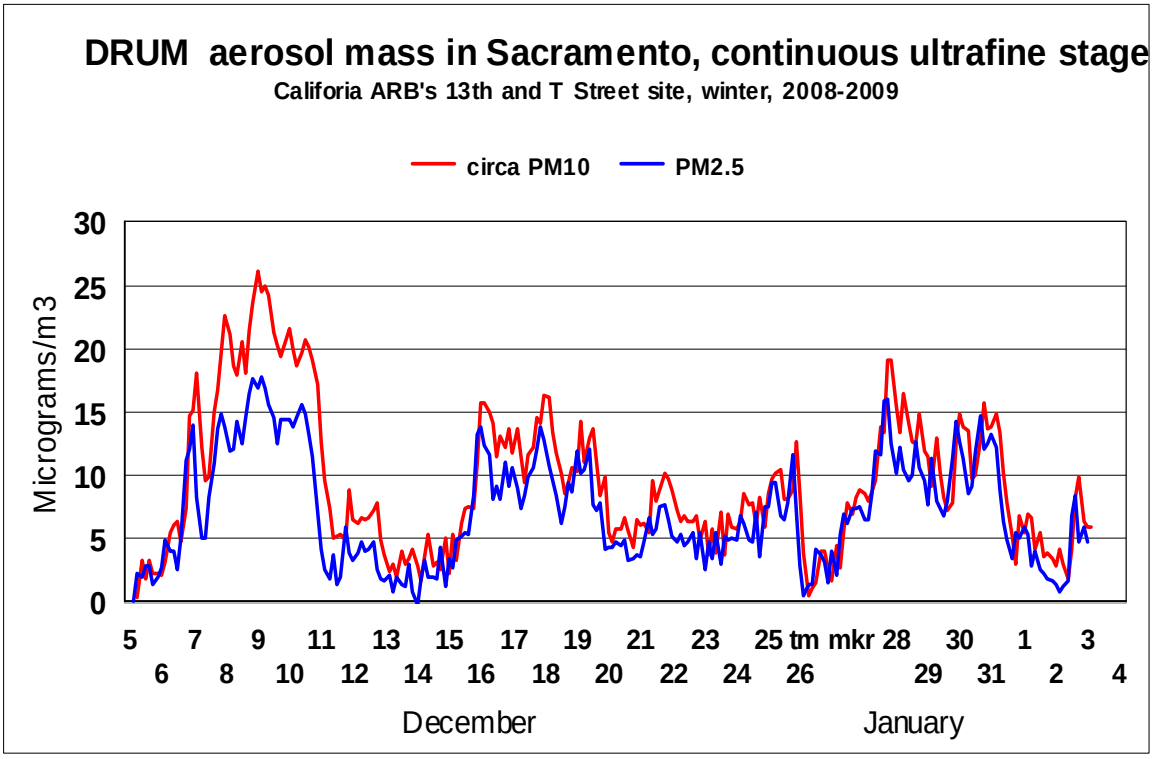
If such readings had been accurate, the visibility in Davis would have been reduced to about 2 km, when in fact often visibilities were many miles. There were a few periods when the Dustrack and DRUM were in rough agreement, but these can not be trusted in light of the other unexplained problems.

8. Qualitative observations

During the study, we observed on one occasion a heavy local impact of smoke from a neighborhood (< 50 m) wood stove/fire place. Pictures were taken of the visibility reduction, indicating a rough visible range in the order of 200 m to 300 m. The conditions were unstable air, just after rain storm, and the smoke was forced to ground level. Winds were light but variable during the episode. In roughly 30 minutes, the smoke dissipated. From the visibility, we can make an estimate of the smoke mass. From studies of dispersed forest fire smoke, we obtain from several sources the relationship that 3.0 ± 1.8 km is equal to 150 μg/m^3 (Cahill and Cliff, 2000) On that basis, we estimate that the smoke was at a level of very roughly 1,500 μg/m^3 for that 30 minutes, clearly a level that could cause distress. However, it was not observed again. Using a typical fine mass of 10 μg/m^3 for the other 23 ½ hours, that episode would have raised the average for that day and site to 41 μg/m^3.

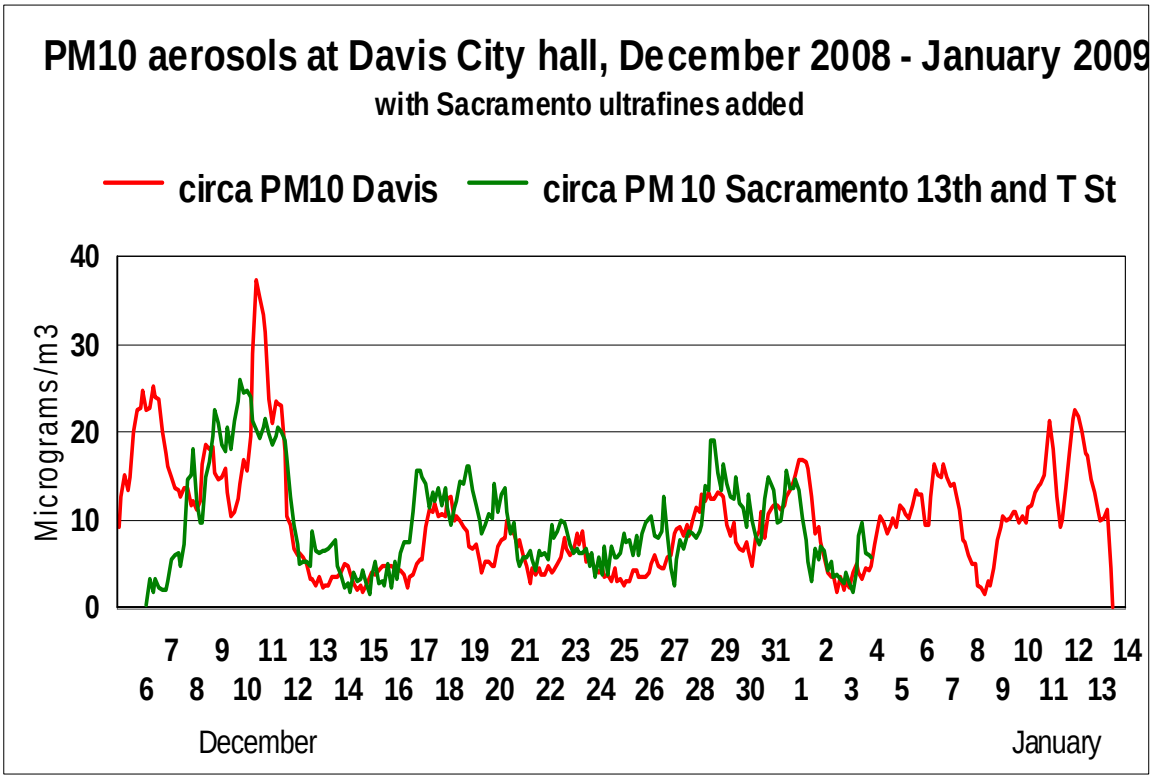
9. Comparison to Sacramento

Aerosols were being measured at the ARB 13th and T Street site by DELTA Group DRUM samplers at the same time as Davis



The first point to note that the more complex DRUM sampler in Sacramento had an EPA validated 10 μm inlet while the one in Davis was only approximate. Second, the Sacramento DRUM had a certified $PM_{2.5}$ cut point. Thus, the Sacramento data confirms that almost all the mass seen in the December 5 – January 3 was $PM_{2.5}$.

In the figure below, we can compare Davis and Sacramento aerosol mass, that although it is presented as PM_{10}, in both cases it is overwhelmingly $PM_{2.5}$, fine particles that are more likely to have lung penetration and capture than coarser particles.

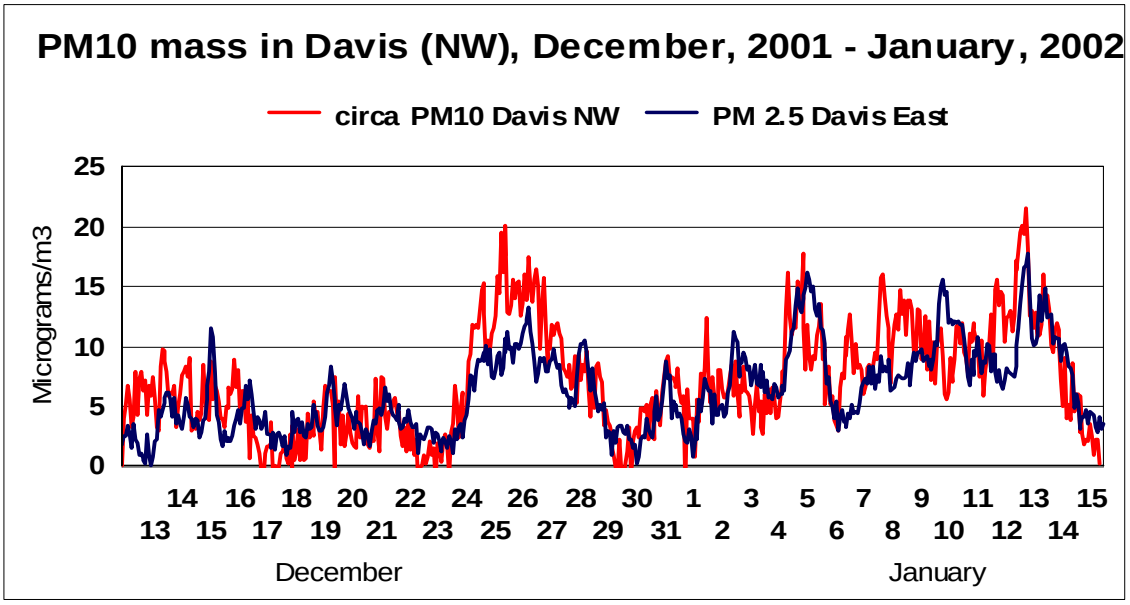


Nevertheless, the plot below is still startling in it implications. The aerosol mass in downtown Sacramento at 13th and T Streets, with freeways carrying over 1,000,000 vehicles/day in all directions, has aerosol data similar in pattern and magnitude to Davis. However, it is also supported by the fact that aerosols moved over Sacramento and then on to Davis in a few hours, driven by the downslope winds at night.

As will be seen below, this results confirms earlier data showing that the winter aerosols are regional in nature.

10. Prior data

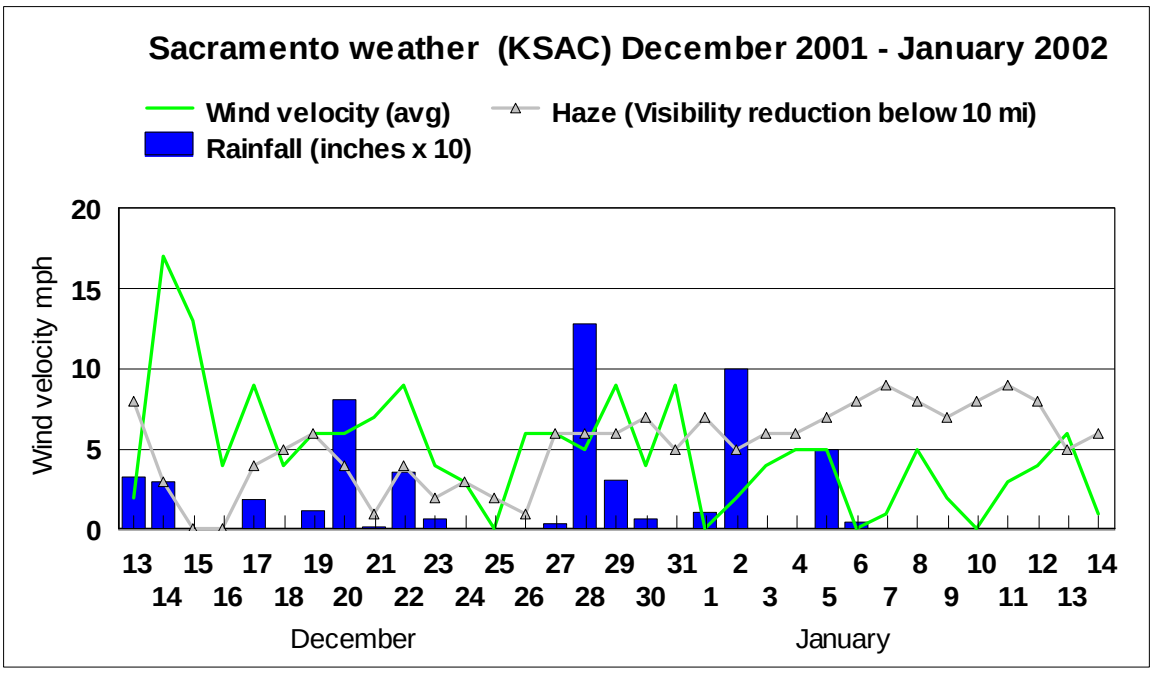
In earlier studies, (see NRC Davis profile) we had shown that there was no measurable increase in aerosol mass or smoke on December 23 1994 (Appendix B, page 27). In 2001 – 2002, we had 2 sites as part of the Breathe California/Sacramento Emigrant Trails Valle Transect. The two sites, one in the city and ringed by houses with (presumably active) chimneys and one east of the city but near I-80, were very similar over a period 32 days.

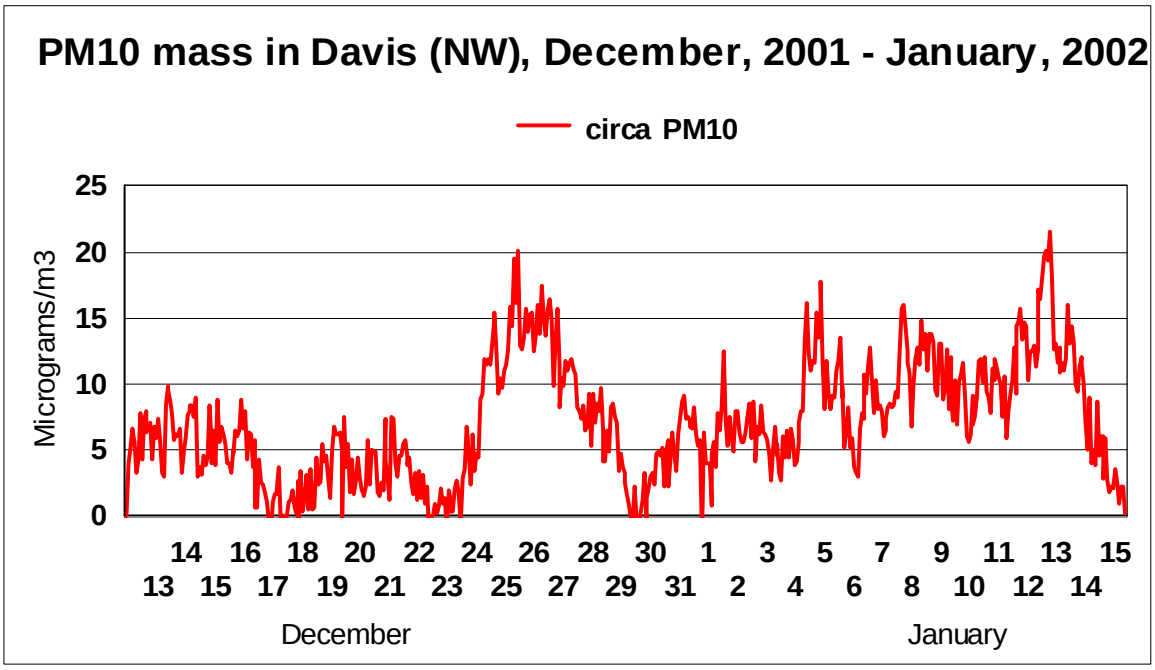


The northwest NW site was in a backyard in Westwood, just west of Highway 113 and 2 blocks north of Russell Blvd. Essentially all homes in this neighborhood were built with open hearth fireplaces. The Davis East site was circa 150 ft south of I-80 on the east portion of the USFS land east of Davis. The site was at roughly 2 m above ground in a rather open grove of Eucalyptus trees with cleat vision to I-80 and Chiles road. There were no visible fireplace chimneys within several hundred meters of the site in any direction.

Note that the Davis NW data should in fact be slightly larger than the Davis East site since the NW site includes aerosols between 10 and 2.5 μm, although these are a relatively small component tin winter (see above for Sacramento).

The similarity of these data is evidence that the city itself, and particularly open hearth fireplaces, are not a major factor in the aerosol seen or otherwise the Davis NW site would be much higher than the Davis east site. Note that winds very rarely flow in the direction from the NW site to the East site.





The average PM10 mass (almost all PM2.5) was 7.1 μg/m^3 in 2001 – 2002, versus 9.0 μg/m^3 Davis, 8.8 μg/m^3 Sacramento 13th and T in 2008 - 2009. All comparisons are done without an ultra fine component (0.78 μg/m^3) since such data were not available in 2001.

However, 2001 to 2002 was far rainier than 2008 to 2009 for the same period, 5.6 inches versus 1.6 inches, and 15 days with rain versus 8 days with rain > 0.02 inches. Thus, one would expect the 2001 – 2002 period to have significantly less aerosol mass.

A similar analysis can be done for wind. Again, we must use the Sacramento Executive airport winds, as the record at Davis does not go back before 2007. Average wind velocity was 4.9 mph in 2001 – 2002, versus 3.2 mph in 2008 – 2009, for a ratio of masses, 1.26 mass, versus 1.5 wind.

11. Sacramento burn-no burn regulations

The burn/no burn regulations of the SMAQMD are based on calculations done by Sonoma Technology Inc. The regulations, widely promulgated by electronic media, have three categories: Permissive burn, clean burn only, and no wood burning.

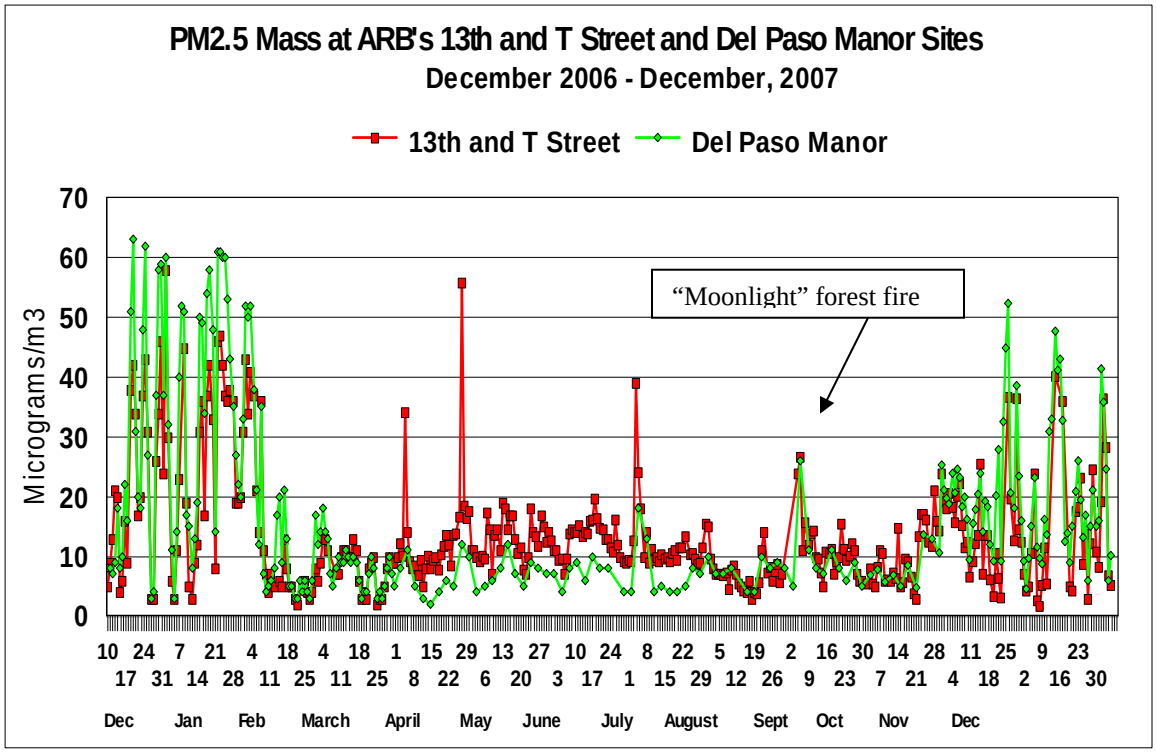
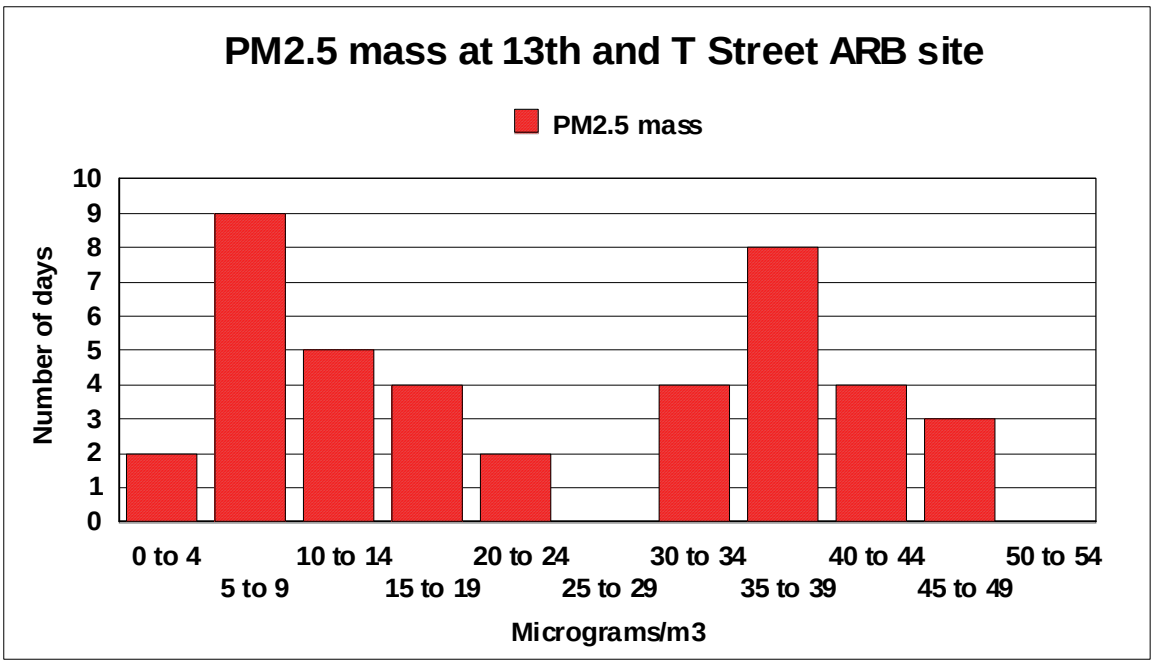


Figure 2 24 hr $PM_{2.5,}$ 13th and T Street and Del Paso Manor, annual, 2007

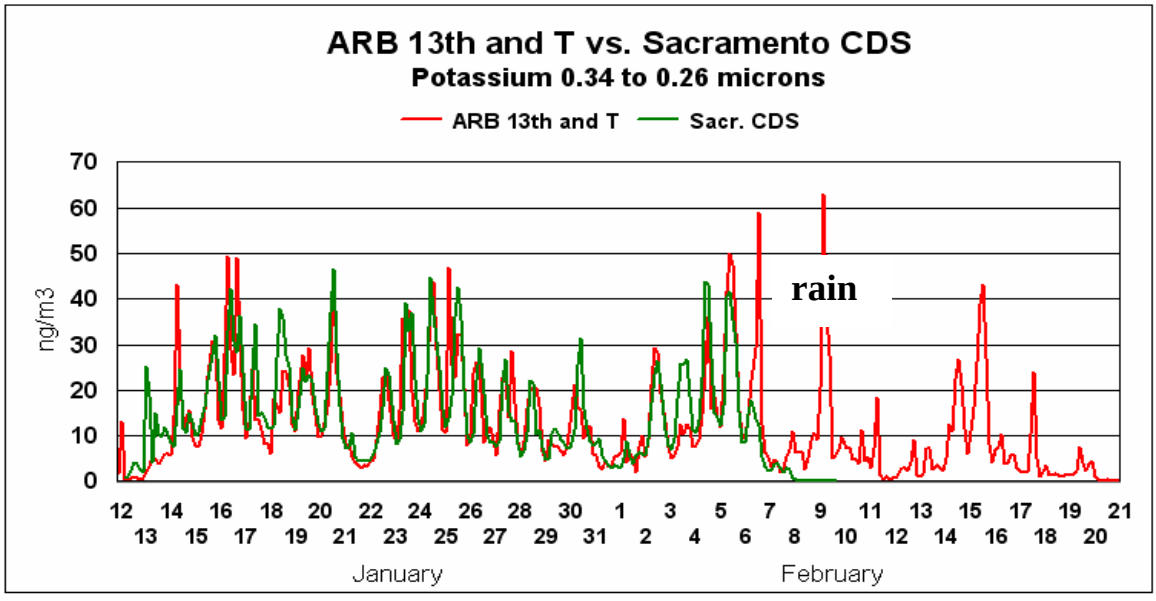
These data illustrate a mass profile that was strongly bimodal in winter, 2007. The air quality was either quite good (median 8 $\mu g/m^3$) or quite bad (median 36 $\mu g/m^3$), with little overlap of the distributions.

Trajectories indicate downslope Sierra Nevada winds at night and stagnation in the valley during daylight hours. Correlation with wind speed was poor.



Frequency distribution of mass, ARB 13th and T Street site, winter, 2007

The wind was weak, with nighttime calms and downslope winds. The peak potassium values at nighttime convert to about 3 μg/m^3 of $PM_{2.5}$ mass (Turn et al, 1997) and thus below the circa 10 μg/m^3 $PM_{2.5}$ mass differences 13th and T versus Del Paso Manor.



Above we show potassium in the very fine mode, a marker of fresh wood smoke combustion. The freshly generated smoke values are about the same at both sites, indicating transport probably on the nighttime eastern (downslope) winds from the foothills and the Sierra Nevada.

12. Conclusions

The study was designed to give Davis additional information upon which to base policy on control of smoke.

First, aerosols measured at City Hall in Davis were well below state and federal aerosol standards over the entire winter.

Second, the results confirm prior work and extend the discussion to establish that most of the $PM_{2.5}$ mass in Davis is regional in nature, not caused by local Davis sources, and included a significant component of downslope air from the western slopes of the Sierra Nevada, an area with heavy local wood combustion, via downtown Sacramento.

The most dramatic evidence of this is in

a. the equivalence between the ARB's data at 13th and T Street in downtown Sacramento with Davis City Hall, and
b. The aerosols profiles taken across Davis in winter, 1994. and
c. The HYSPLIT trajectories tagging episodes of increased aerosol mass in Davis to downslope winds from the Sierra and strong inversions.

Local impacts were hard to ascertain, with only one documented heavy smoke impact of a short duration from an extremely nearby source.

Acknowledgment

The authors acknowledge the support of City of Davis staff in siting and operating the samplers.

The authors gratefully acknowledge the NOAA Air Resources Laboratory (ARL) for the provision of the HYSPLIT transport and dispersion model and/or READY website (http://www.arl.noaa.gov/ready.html) used in this publication

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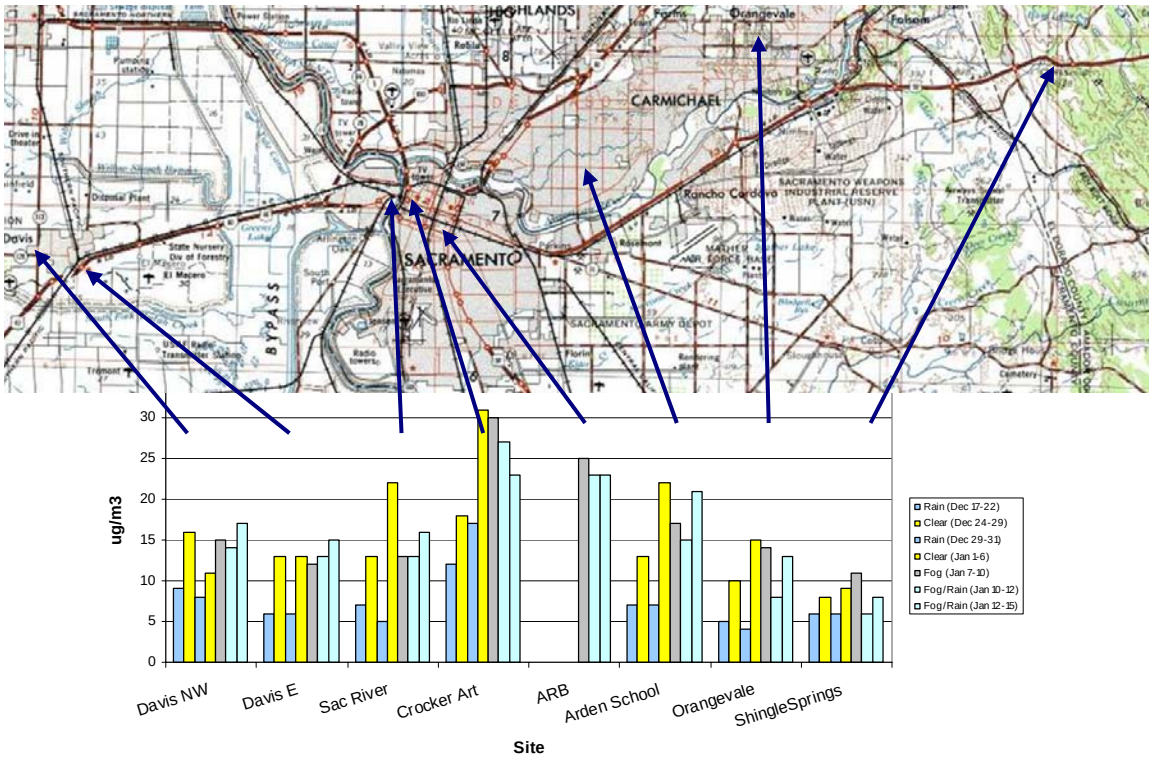
1. **Other information**

In 2002, working with the local American Lung Association (now Breathe California), we did a transect across Sacramento that included 2 Davis sites – one upwind (Amador at Buchanan) and one downwind (USFS Tree plantation south of I-80.) We have aggregated the data for mean multi-day averages of $PM_{2.5}$ mass for five periods**:** **Dec 17 – 21 rain; Dec 24 – 29 clear; Dec 29 – 31 rain; Jan 1 – 6 clear; Jan 7-10 fog; Jan 10-12, fog/light rain; Jan 12-16 fog, some drizzle.**



Note the fact that Davis is about ½ of Sacramento, and a lack of city enhancement.

Proposal

From the transect above, we can see the $PM_{2.5}$ in Davis is about ½ that of Sacramento. Thus, if Davis adopted mandatory no burn days of the Sacramento Metropolitan AQMD, we would in effect be triggering no burn conditions in Davis at a pollution level about a factor of 2 cleaner air than Sacramento, or about ½ the federal standards. In my opinion, this would give Davis a guarantee that we would not enhance the regretfully large regionally concentrations.

In permissive burn days (strong winds and/or rain storms) even Sacramento was little elevated over the valley wide background.

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Turn, S.Q., B.M. Jenkins, J.C. Chow, L.C. Pritchett, D. Campbell, T. Cahill, and S. A. Whalen. **Elemental characterization of particulate matter emitted from biomass burning: wind tunnel derived source profiles for herbaceous and wood fuels**. 1997 *Journal of Geophysical Research*, 102, 3683-3699.

Appendix C
The value of chemical analysis of Davis samples for wood smoke

Tom Cahill Dec. 5, 2008

Note to City of Davis
Natural Resources Commission

The Health Effects Task Force of the American Lung Association, now Breathe California of Sacramento-Emigrant Trails, and the Sacramento Metropolitan AQMD, working through the UC David DELKTA Group http://delta.ucdavis.edu, have performed studies of local aerosol pollution in the Sacramento region since 1994. On two occasions, these studies included data from in and near Davis (examples appended).

Currently, we are in the midst of two studies that address fro Sacramento the problem of the role of wood smoke in local winter aerosol pollution, a one year study (2007) with the California Air Resources Board at their downtown site at 13th and T Street and a suburban sites at Sacramento Country Day and Del Paso manor AQMD sites, with recent US EPA Research Division study recently added, and an intensive study of the impact of Watt Avenue on Arden Middle School, which is near the two suburban sites. The ARB study involves over 4,500 size and compositionally segregated aerosol samples, and the latter 2,500 size and compositionally segregated aerosol samples. The Final Report on the ARB/EPA study is due late January, 2009, and the Watt Avenue study May, 2009.

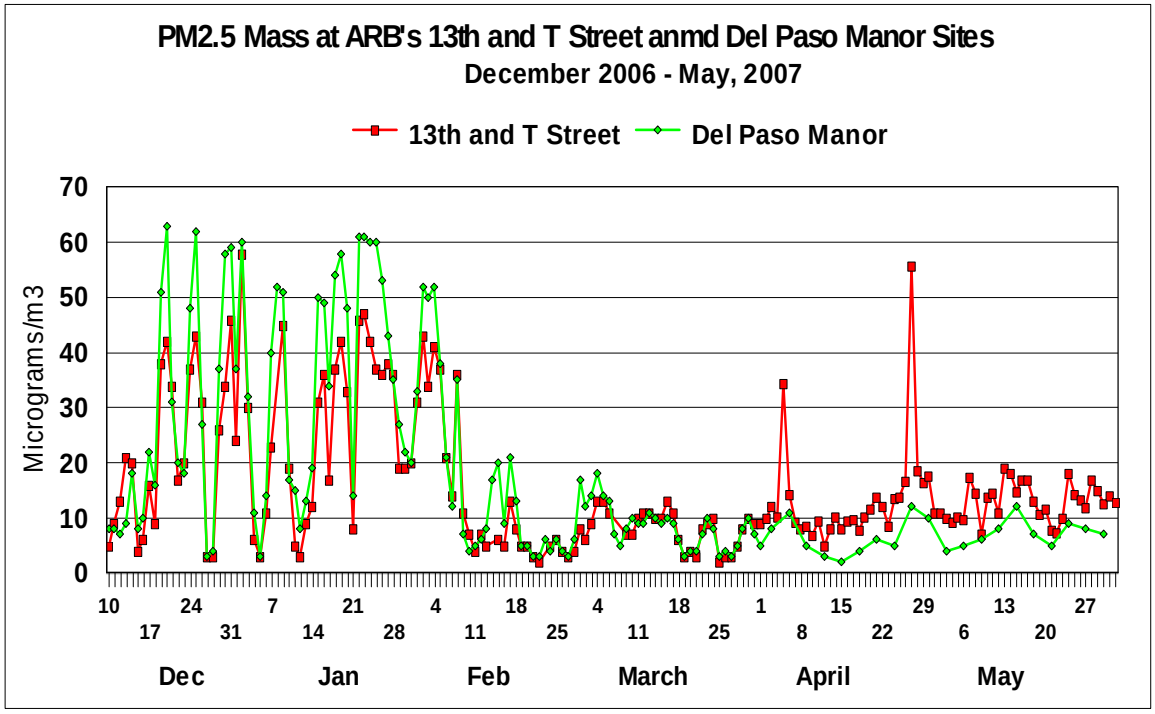
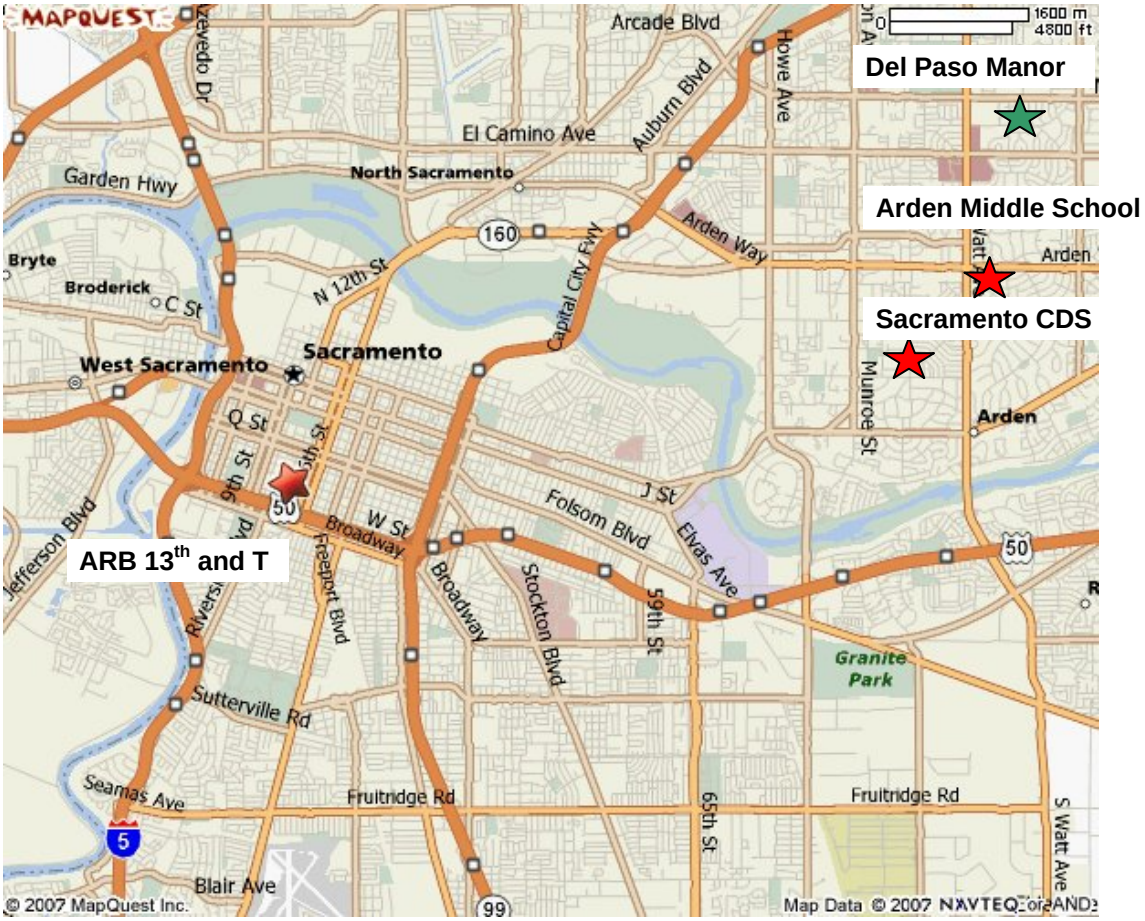


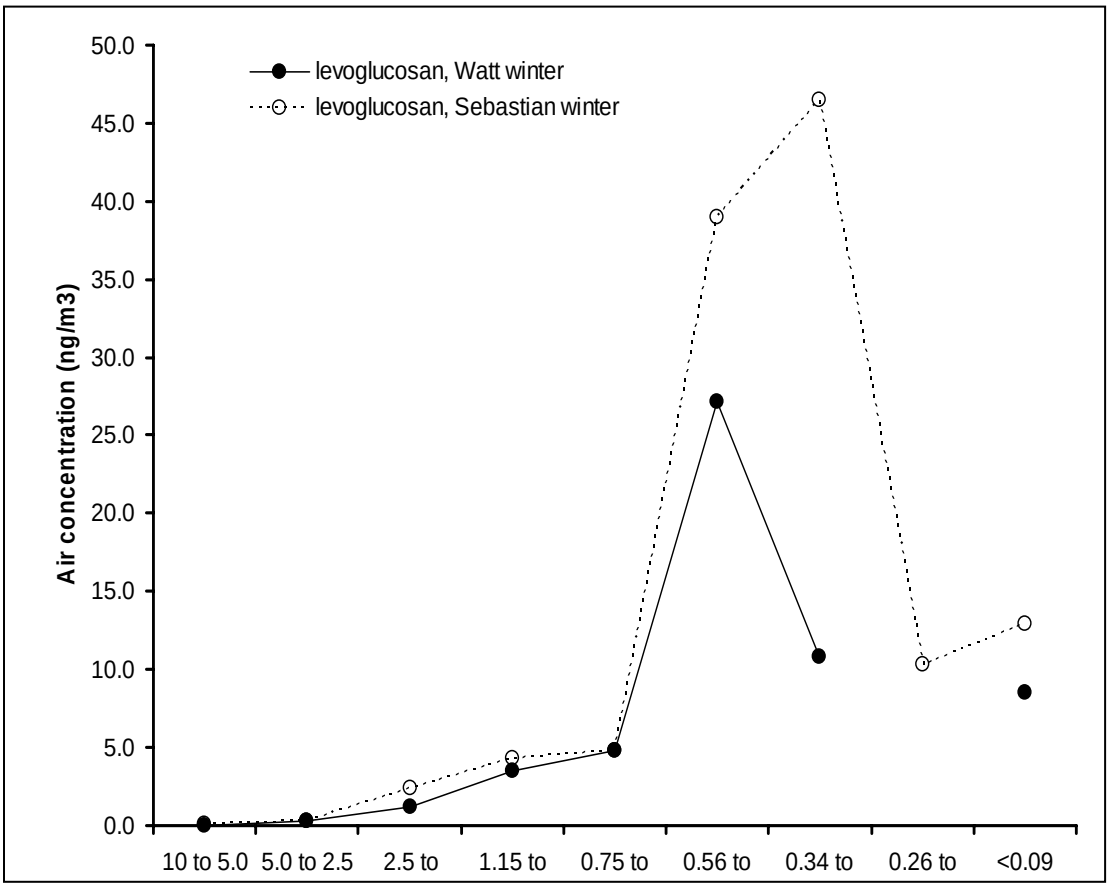
Figure 9 24 hr $PM_{2.5,}$ 13th and T Street and Del Paso Manor, winter – spring, 2007

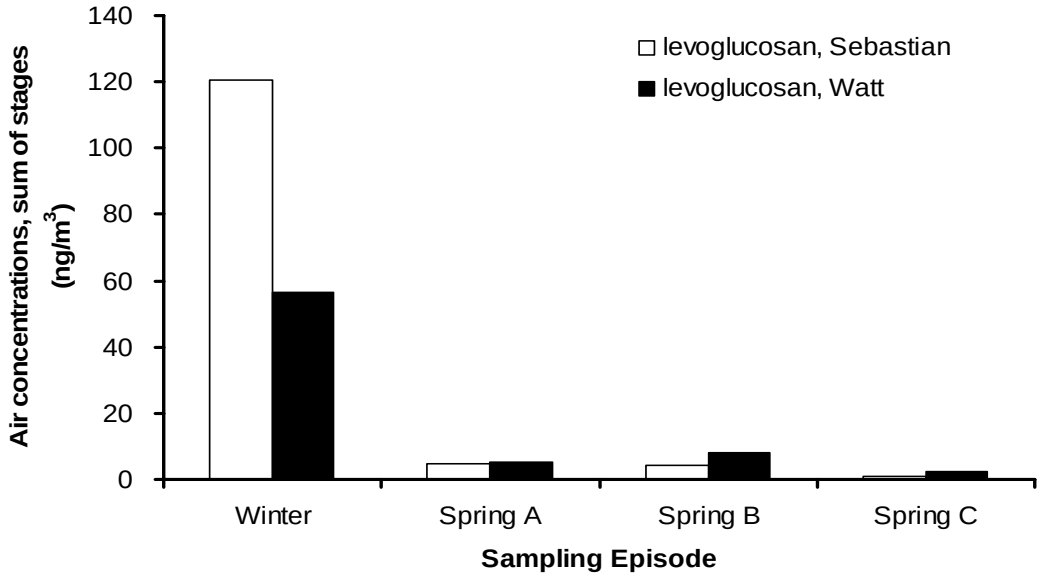
While these studies have many goals, including validation of DRUM sampling technology versus standard ARB/EPA monitoring, one is an analysis of the present wood smoke control measures of the SMAQMD. As part of the DELTA Group offer to Davis, we will provide the mass and elemental data to the city without cost, an estimated contribution of about $6,000, but the definitive size segregated chemical analysis specific to wood smoke is done at Arizona State University (by my son) and requires real costs DELTA can not absorb.



The value of the latter analysis, at present unique to Tom's work, is that it allows identification of locally generated wood smoke from regionally generated wood smoke, and is the focus of a publication soon to be submitted the premier journal Environmental Science and Technology.

Below I show Tom's result from two sites near Watt Avenue in February, 2007, towards the end of the wood burning period of Sacramento, at two sites; Arden Middle School, which is buffered by sports fields and shopping centers and thus is about 200 m away from the nearest house that could burn wood, and Sebastian Way, 400 m in a generally upwind direction in an established older neighborhood in which essentially every house has a fireplace (the nearest one is 30 m from the sampling site).





Figures 2 and 3 Levoglucosan tracer of wood smoke near Watt Avenue.

The analysis is for levoglucosan, the major chemical signature or burning cellulose. As you can see, the coarse, 10 to 0.56 μm particles, and the very fine/ultra fine particles < 0.09 μm, are essentially equal at both sites, indicating regional sources.

The Watt Avenue data at Arden Middle School peaks at the 0.34 to 0.56 μm size mode, which is essentially universally seen in aged wood smoke from many other studies, but the Sebastian Way site smoke peaks in a finer mode, 0.26 to 0.34 μm. This size mode will according to models pick up water and move to larger sizes as the smoke ages, but its presence indicates a nearby wood burning source.

The impact of this on Sacramento is seen below, now using the elemental data from synchrotron-induced x-ray fluorescence (S-XRF). We are now using very fine potassium, derived from the wood sap, showing fresh wood smoke over much of Sacramento.

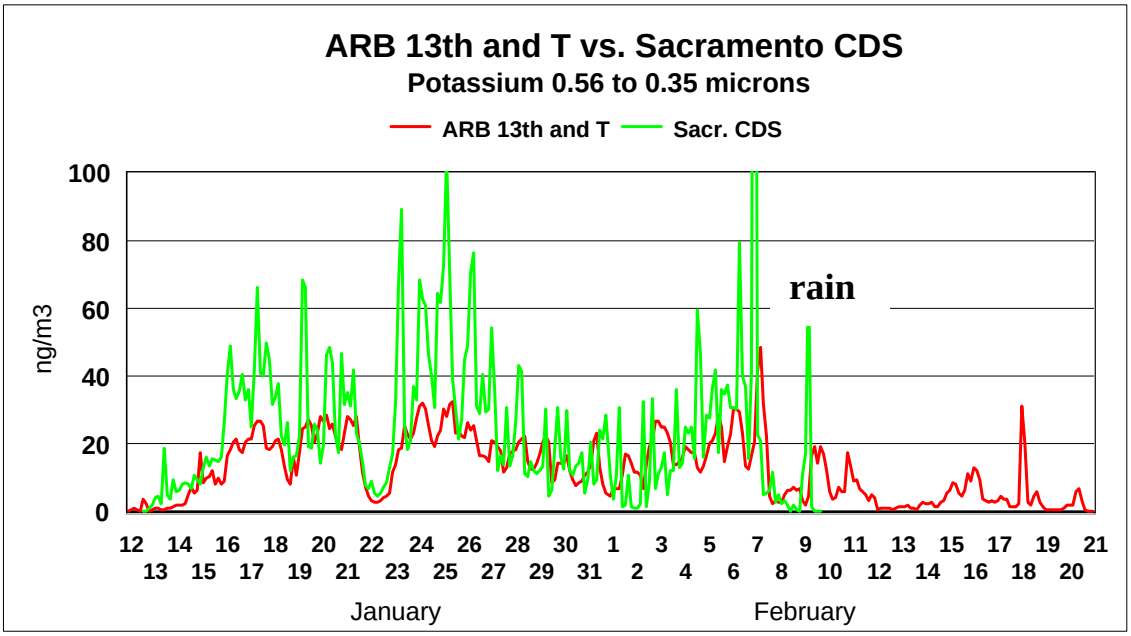


Figure 4 Potassium in the accumulation mode, generally the size mode of most wood smoke.

In this plot, more wood smoke is seen in suburban sites than in downtown Sacramento. This kind of data will be provided to Davis as part of our contribution, but because it lacks the specificity of the chemical levoglocosan to cellulose, it is not as unique to fresh wood smoke.

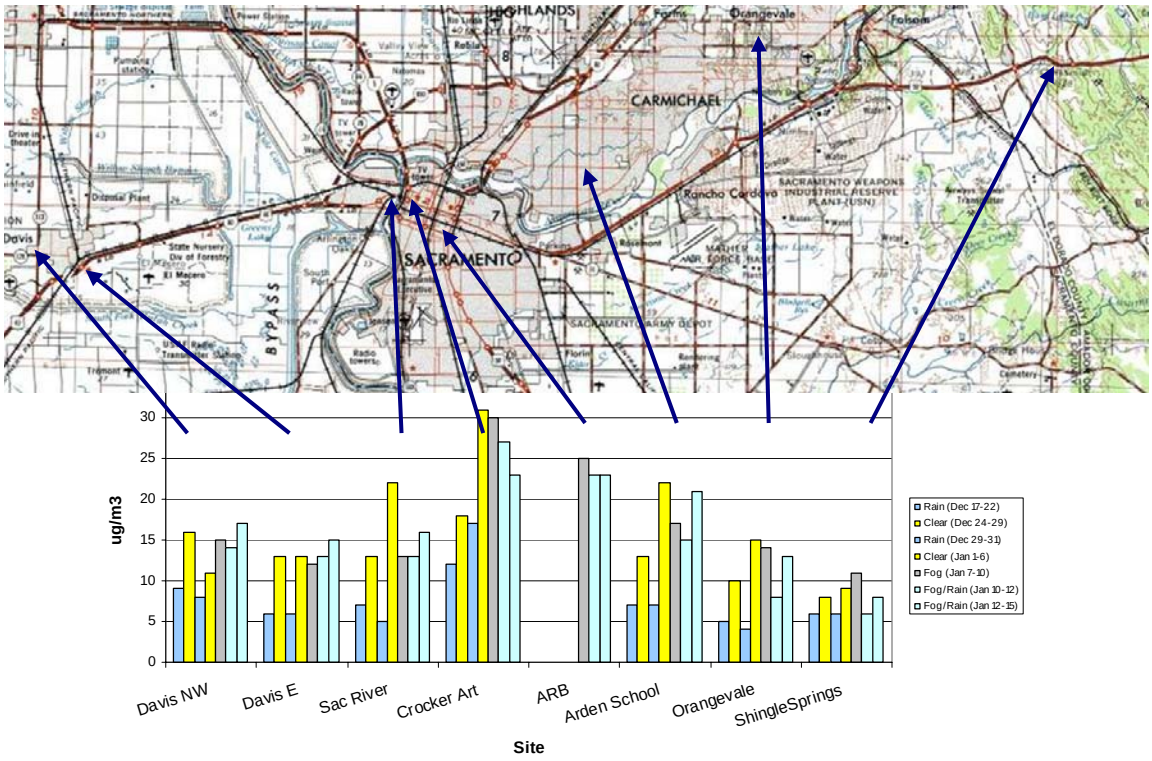
Below I append data from the winter, 2002 study. The full report is available electronically from Breath California of Sacramento-Emigrant Trails (916) 444 5900.

Results – Sacramento - Interstate 5 transect data

Mass

$PM_{2.5}$ mass data from DRUM samplers and soft beta ray attenuation analysis are presented below coordinated to our site map. We have aggregated the data for mean multi-day averages of $PM_{2.5}$ mass for five periods: Dec 17 – 21 rain; Dec 24 – 29 clear; Dec 29 – 31 rain; Jan 1 – 6 clear; Jan 7-10 fog; Jan 10-12, fog/light rain; Jan 12-16 fog, some drizzle. Note that ultra-fine particles < 0.09 μm were not sampled by any of the DRUM samplers.

Figure 5 Site Map and $PM_{2.5}$ aggregated data



The pattern is extremely revealing. First, during periods of rain, PM2.5 at all the sites except The Crocker Art site are essentially identical, even Shingle Springs. We return to this later as we discuss the inability of rain to remove diesel particles. Note that Davis East (next to I 80) and Orangevale (residential) are almost identical in amount and time behavior of $PM_{2.5}$ aerosols, showing a regional pattern. We found a major enhancement of particles near I-5 that, while not a violation of the federal 65 μg/m^3 24 hr standard, is clearly far greater than our more remote sites. On one occasion, we found very fine (< 0.34 μm) particles in concentrations previously seen in Fresno (Bench et al, Aerosols Science and Technology, 2002), but whereas Fresno had 8 such peaks in 3 weeks, we saw just one in the 3 weeks of January (non-rainy) sampling. It is interesting that the period was hazy with very low wind velocities but did not appear to be a saturated fog at Sac Executive