Draft Final Report to the Davis Natural Resources Commission

Aerosol monitoring in Davis, Winter, 2008-2009

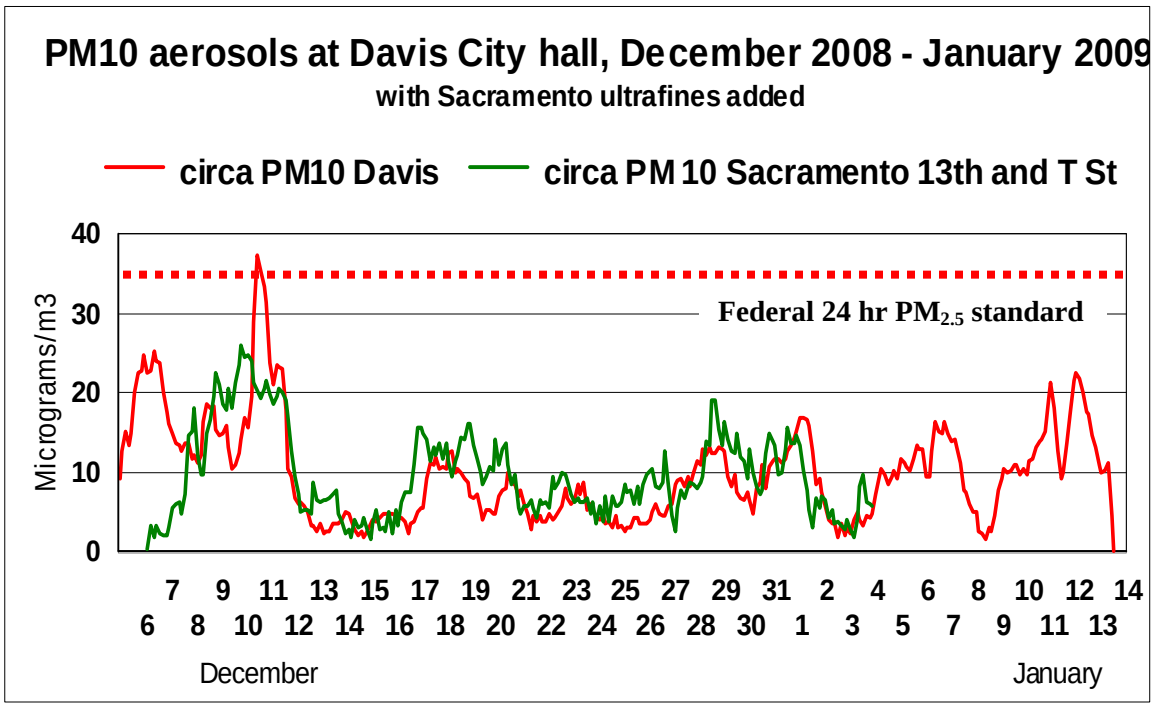
May 7, 2009

DELTA Group, UC Davis,
Dr. David Barnes, Project Manager,
Thomas A. Cahill, Senior Scientist, Bernie Lee, Staff

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 DustTrak 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
El 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

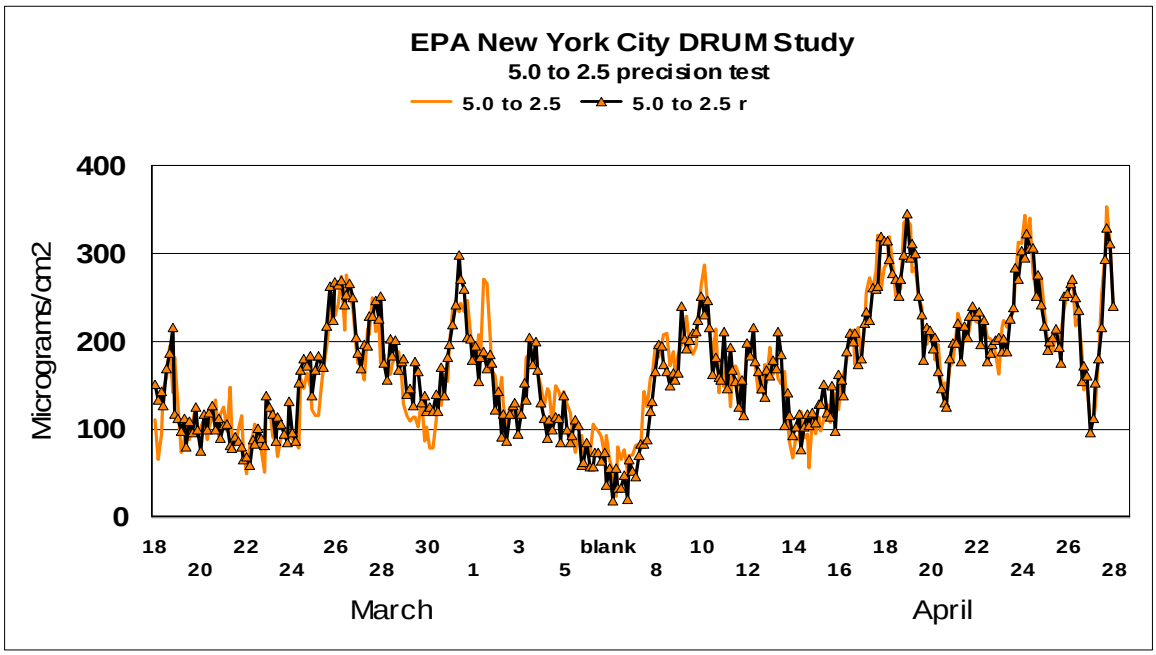
Quality assurance of the DRUM samplers are given in detail in DRUM Quality Assurance Protocols, ver 1/09 (DQAP v 1/09) at the DELTA Group web site, http://delta.ucdavis.edu. Recent additional examples have been generated in the current US EPA study of DRUM samplers in New York City and Sacramento and 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. This never occurred in this study.

b. Precision – mass analysis by soft beta ray

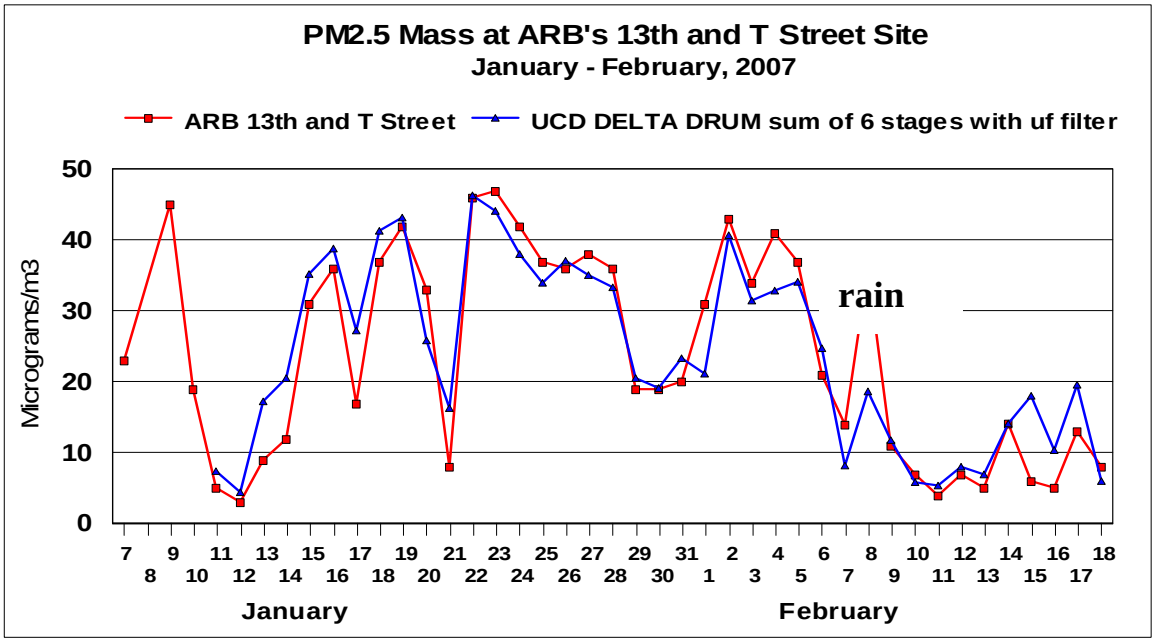
Samples are routinely re-analyzed to compare with the original analysis. An example is shown below for particles between 5.0 and 2.5 μm in the US EPA New York study, spring, 2008. Note that this is a more severe test than for filters because of the rapid time response.

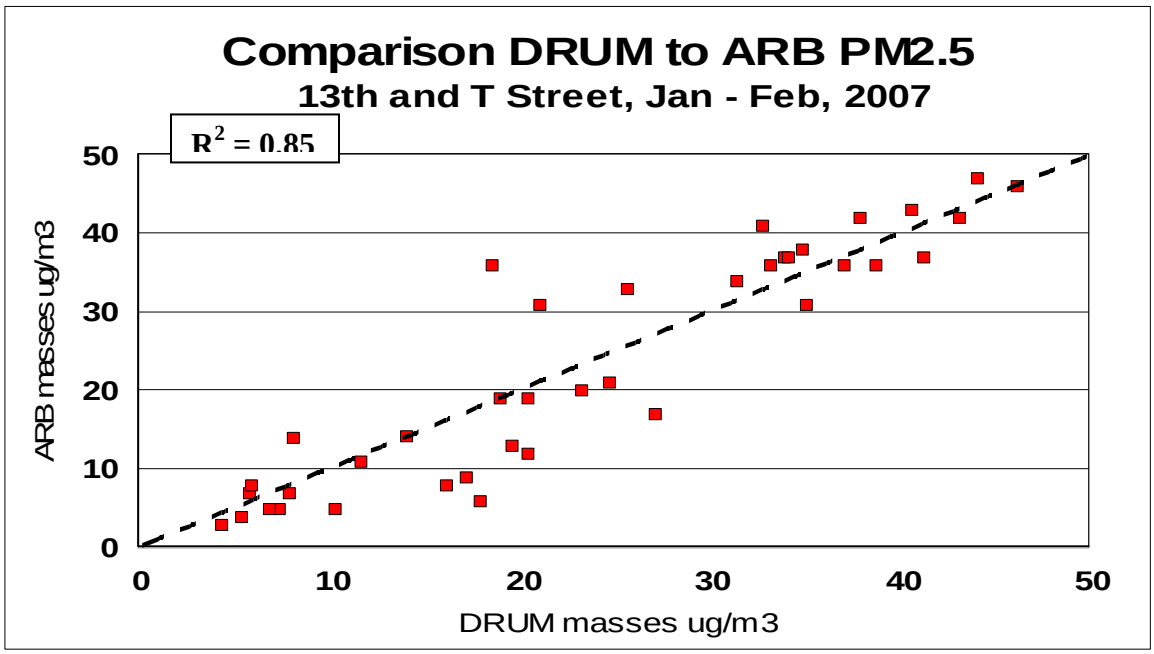


c. Accuracy

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.

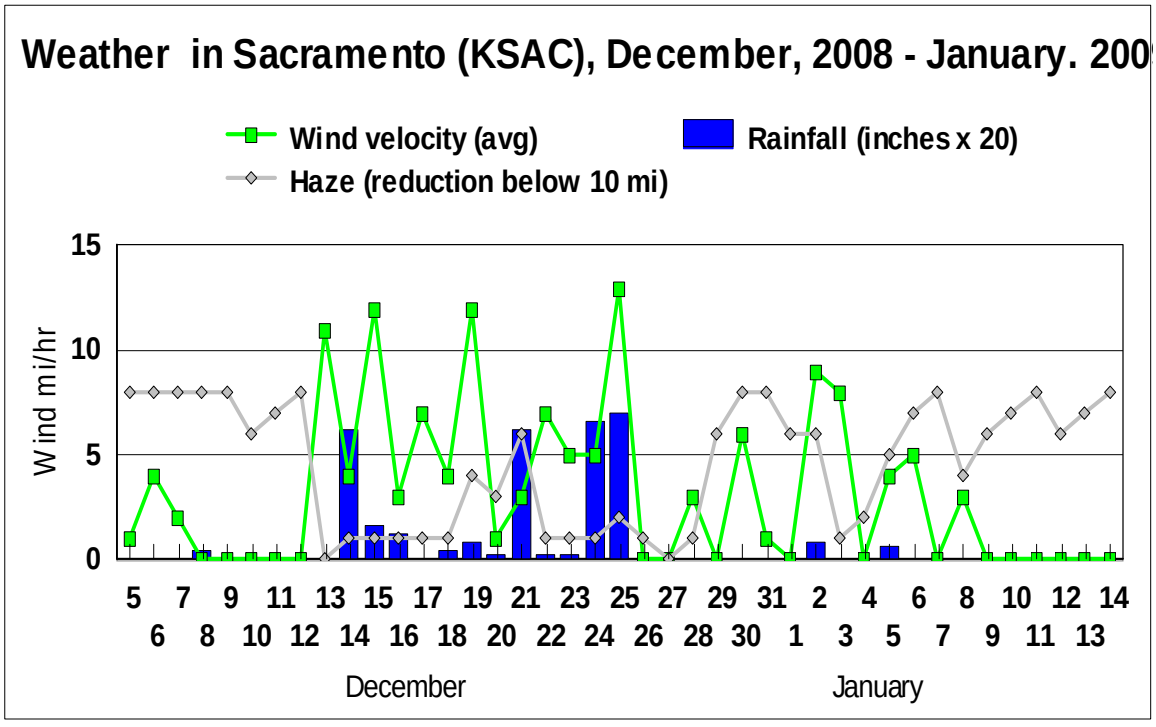
Study and date	Methods	**Average ratio, Al to Fe**	Std. dev.	**Average ratio, Cu to Pb**	Std. dev.
BRAVO, 1999	PIXE vs S-XRF	**0.99**	0.04		
BRAVO, 1999	CNL XRF vs S-XRF			**1.24**	0.14
FACES, 2001	ARB XRF vs S-XRF	**0.93**	0.21	**1.02**	0.08
FACES, 2001	ARB RAAS vs S-XRF	**(0.98)**	0.27	**(0.74)**	0.23
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)



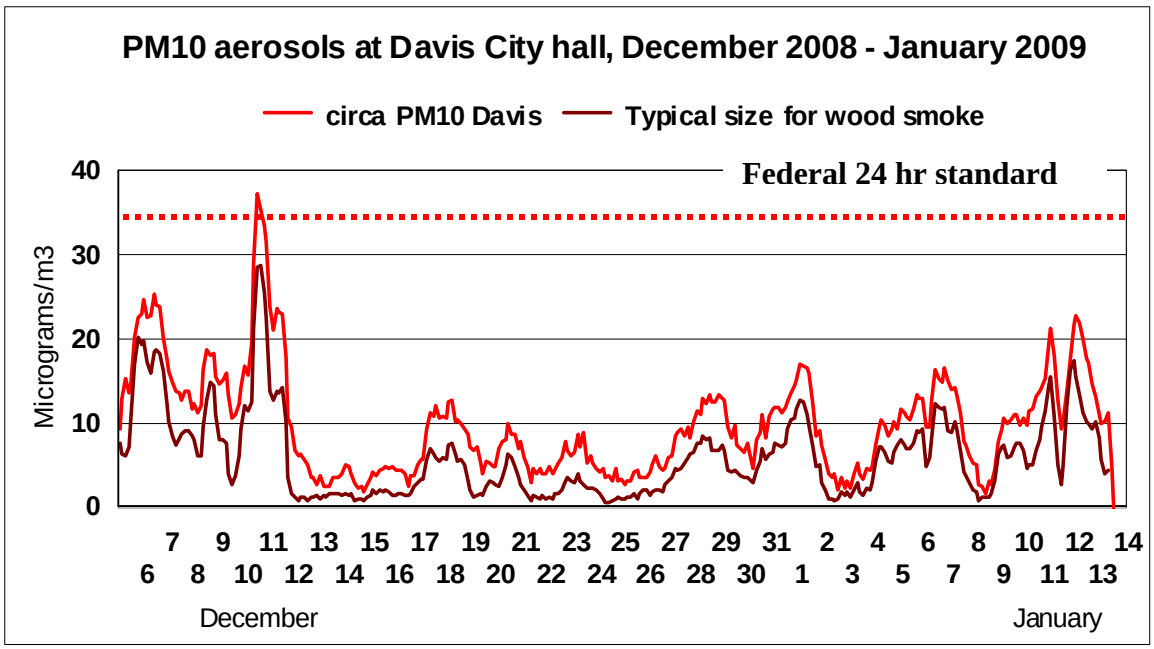
4. Aerosol Data from the DRUM sampler – Period 1

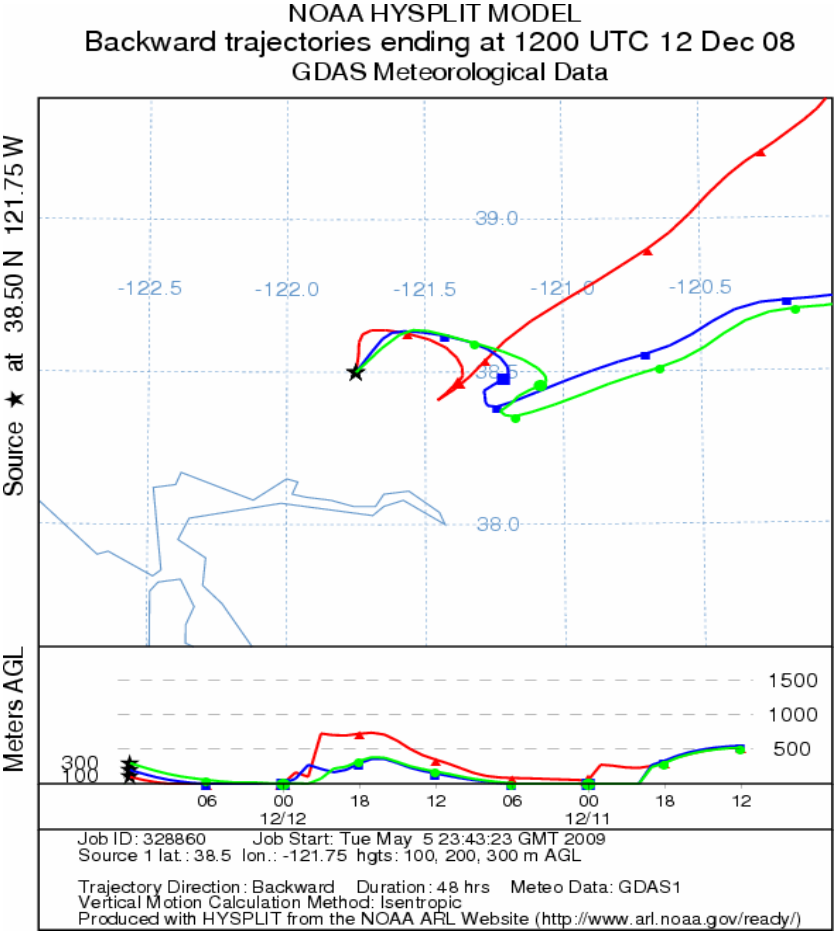
The aerosols from Period 1 are shown below in true color. The top strip is Stage A, circa 10 to 1.15 μm, the second is Stage B, 1.15 to 0.34 μm, and the third Stage C, 0.34 to 0.15 μm aerodynamic diameter.

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.

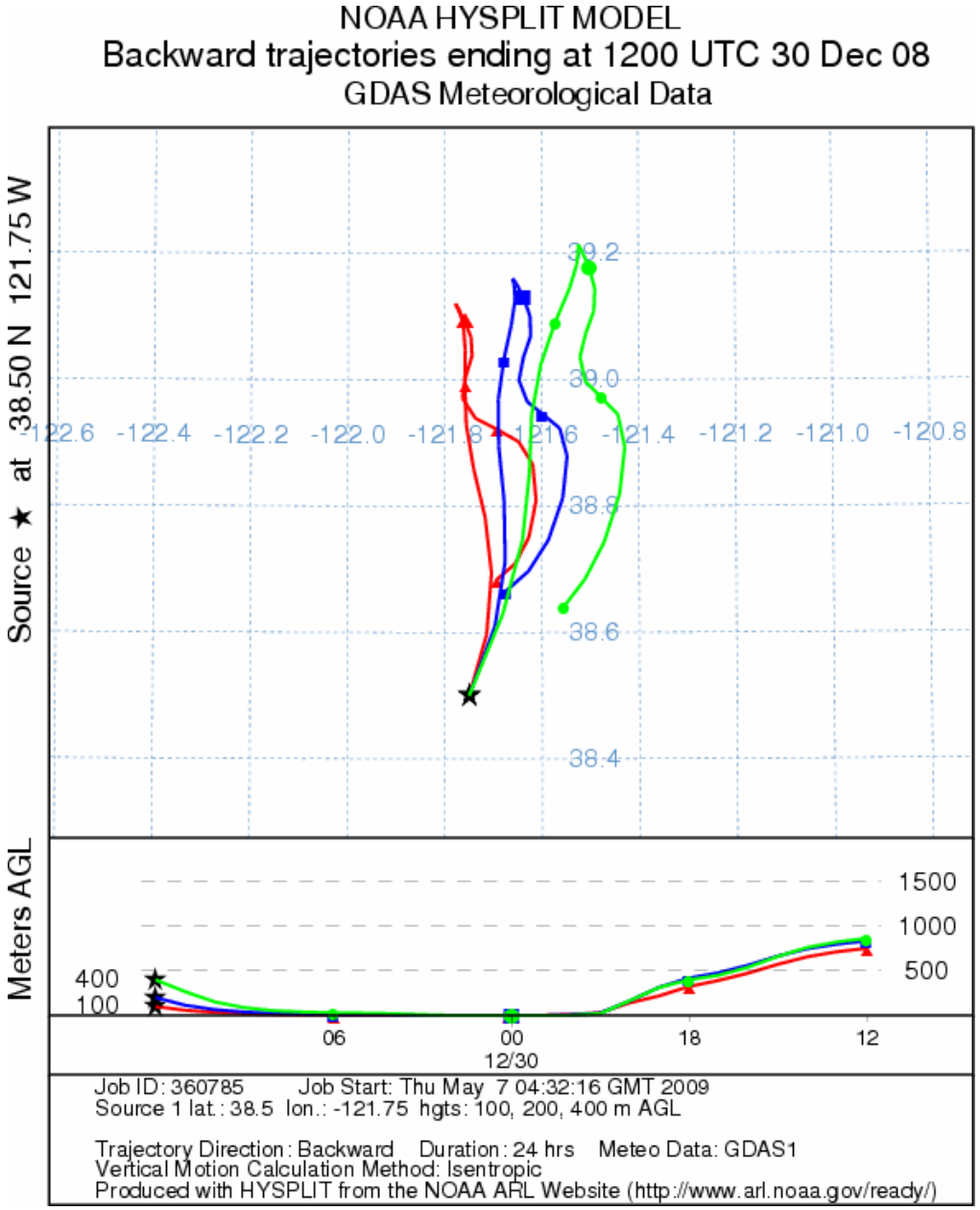
a. Mass data

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.

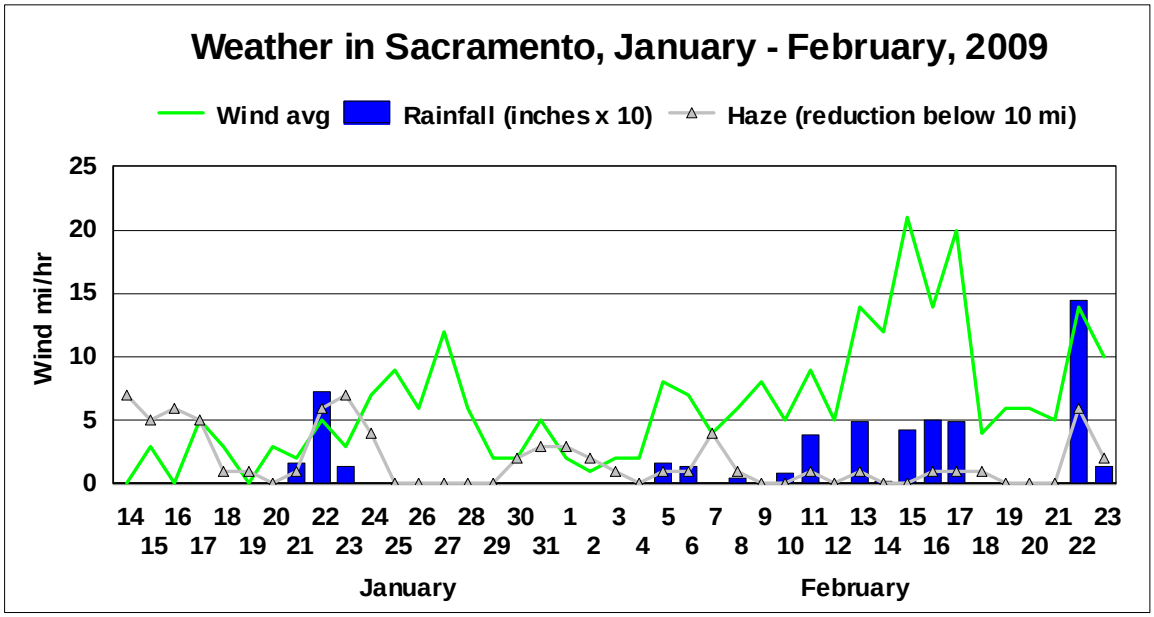


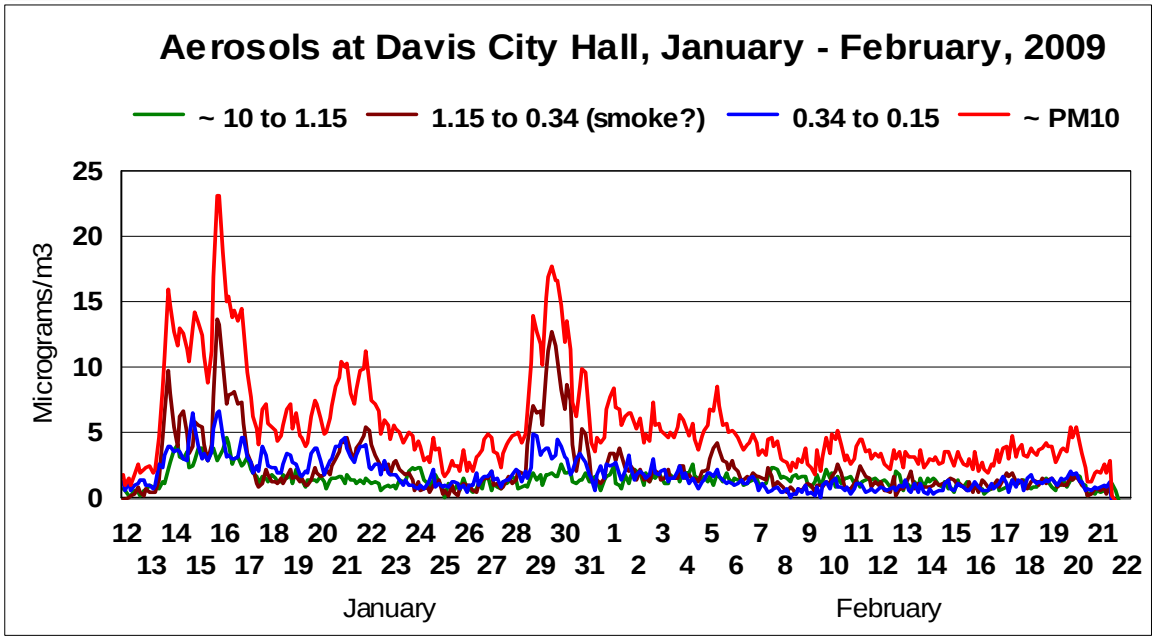
From the HYSPLIT analysis, we can see that the air at Davis on Dec.12, 4 AM, came from the western slopes of the Sierra Nevada, where wood burning is common. The air crossed over Sacramento and finally arrived at Davis. This would explain why the Davis and Sacramento results are so similar – they share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

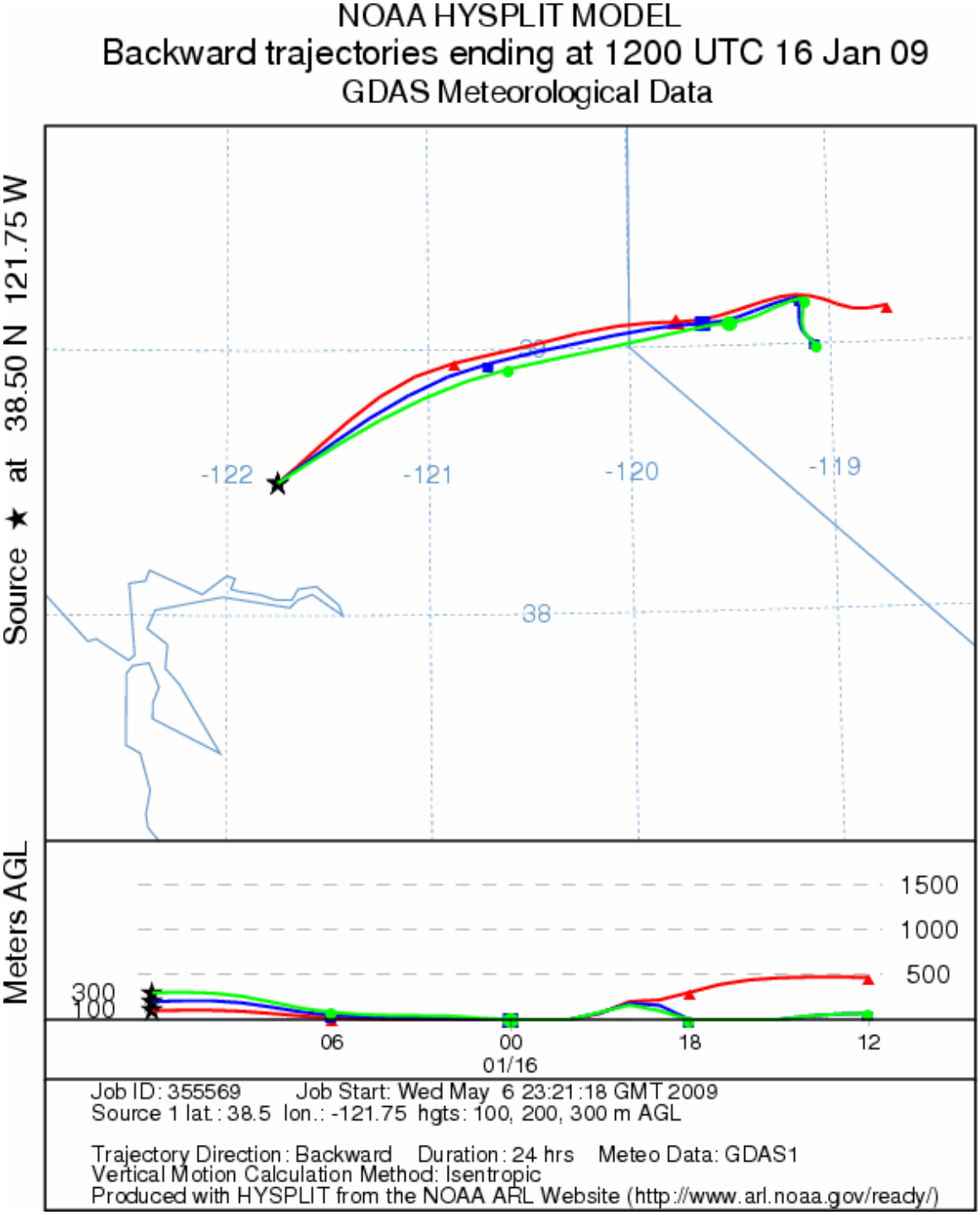
The period from January 14 to February 23 showed an excellent correlation between haze measured at Sacramento (SMF) and mass of fine particles in the range dominated often by wood smoke. The nominal perfect airport visibility is 10 miles, and the reduction below 10 miles is a measure of haze. Clearly,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

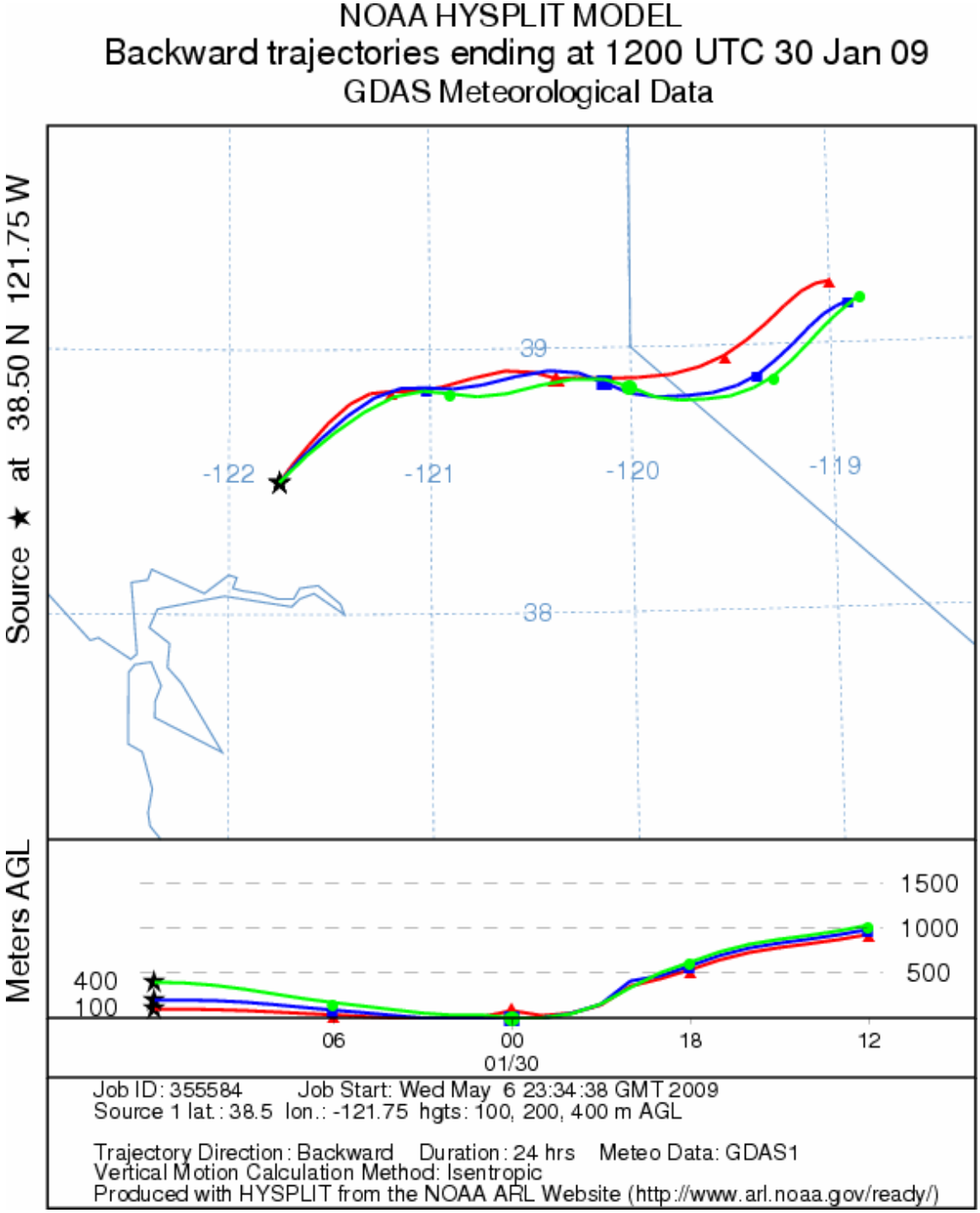




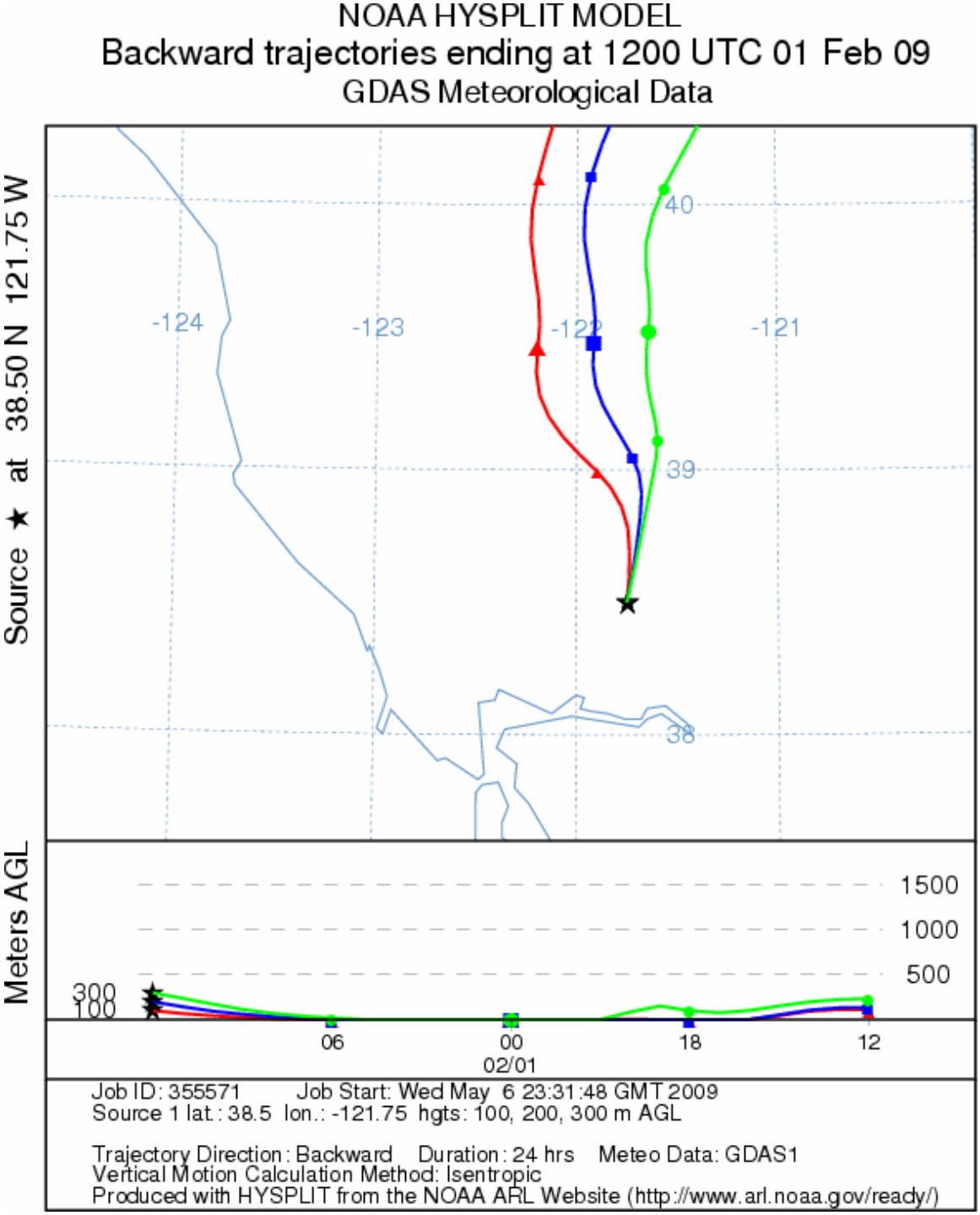
The mean wind velocity for the entire period was 6.3 mi/hr, but during the three aerosol and haze period, Jan 14 – 17, Jan 21 – 22m and Jan 29 – Feb 1, the average was 2.8 mi/hr.

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.

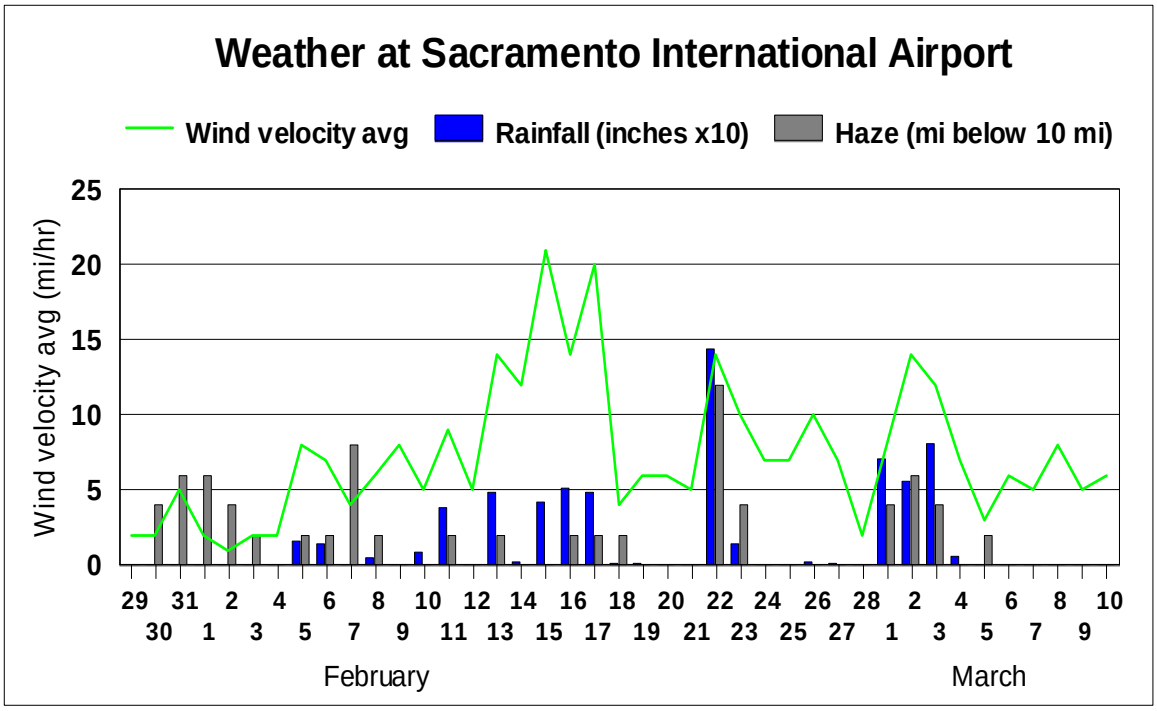


The haze and aerosol episode ended of February 1 as the air returned to a down valley flow from the northern Sacramento Valley.

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 El Campo site in south Davis and additional transects with the DustTrak 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.

.

b. Mass data

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

7. DustTrak 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 DustTrak 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 in static positions. This was true for the City hall site since vibration from the DRUM pump was evident at the DustTrak.

The criteria violated include:

1. The DustTrak 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 DustTrak routinely delivered values an order of magnitude higher than simultaneous Davis (or Sacramento) readings.

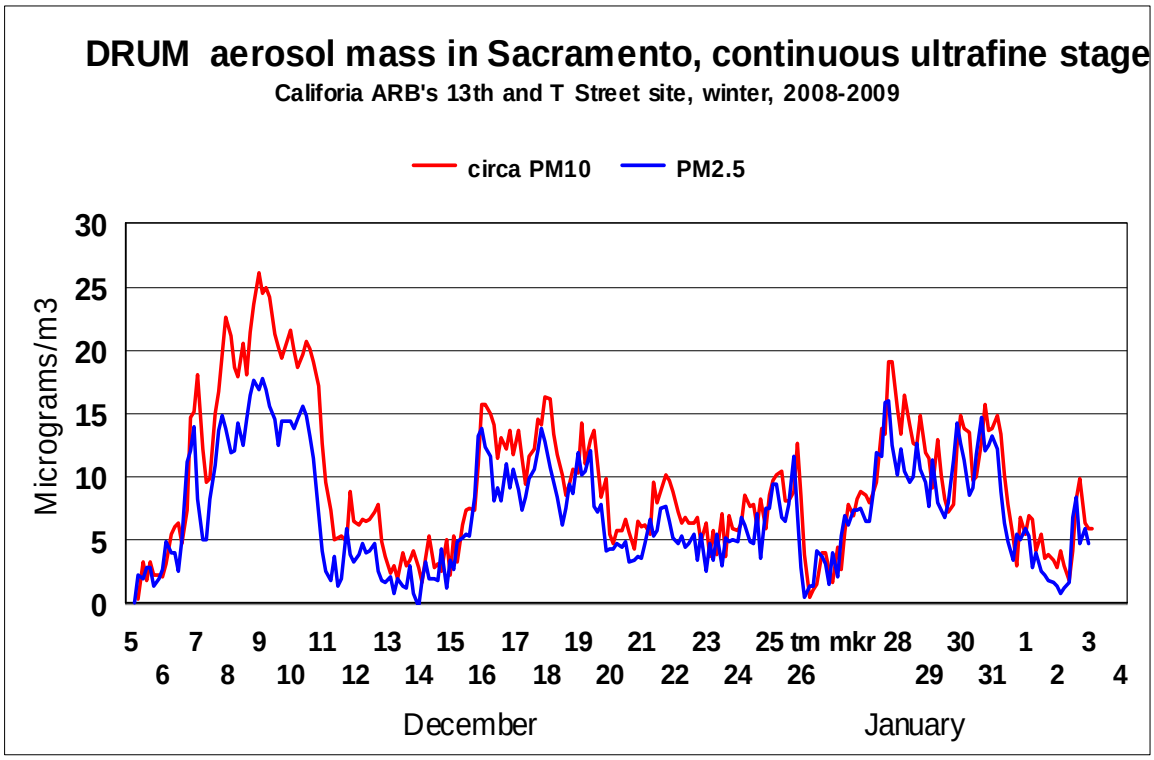
If such readings had been accurate, the visibility in Davis would have been reduced to about 2 km, when in fact often visibilities were many miles. There were a few periods when the Dustrack and DRUM were in rough agreement, but these can not be trusted in light of the other unexplained problems.

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 $\mu g/m^3$ (Cahill and Cliff, 2000) On that basis, we estimate that the smoke was at a level of very roughly 1,500 $\mu g/m^3$ for that 30 minutes, clearly a level that could cause distress. However, it was not observed again. Using a typical fine mass of 10 $\mu g/m^3$ for the other 23 ½ hours, that episode would have raised the average for that day and site to 41 $\mu g/m^3$.

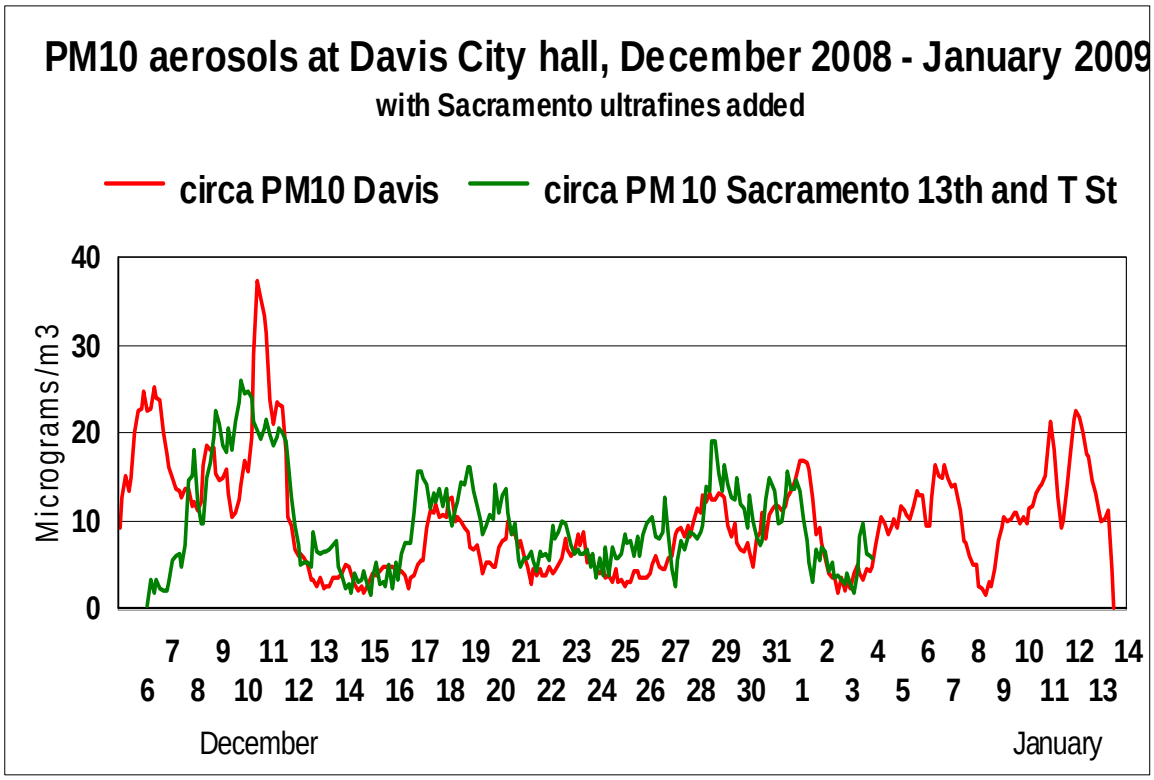
9. Comparison to Sacramento

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.

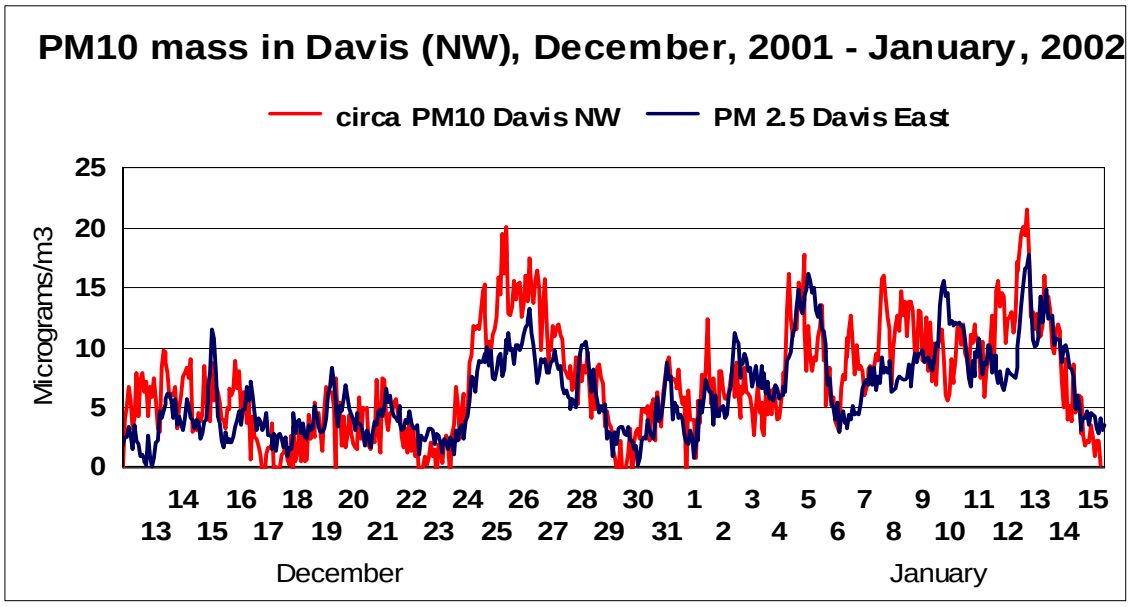


Nevertheless, the plot below is still startling in its implications. The aerosol mass in downtown Sacramento at 13th and T Streets, with freeways carrying over 1,000,000 vehicles/day in all directions, has aerosol data similar in pattern and magnitude to Davis.
However, it is also supported by the fact 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 result confirms earlier data showing that the winter aerosols are regional in nature.

10. Prior data

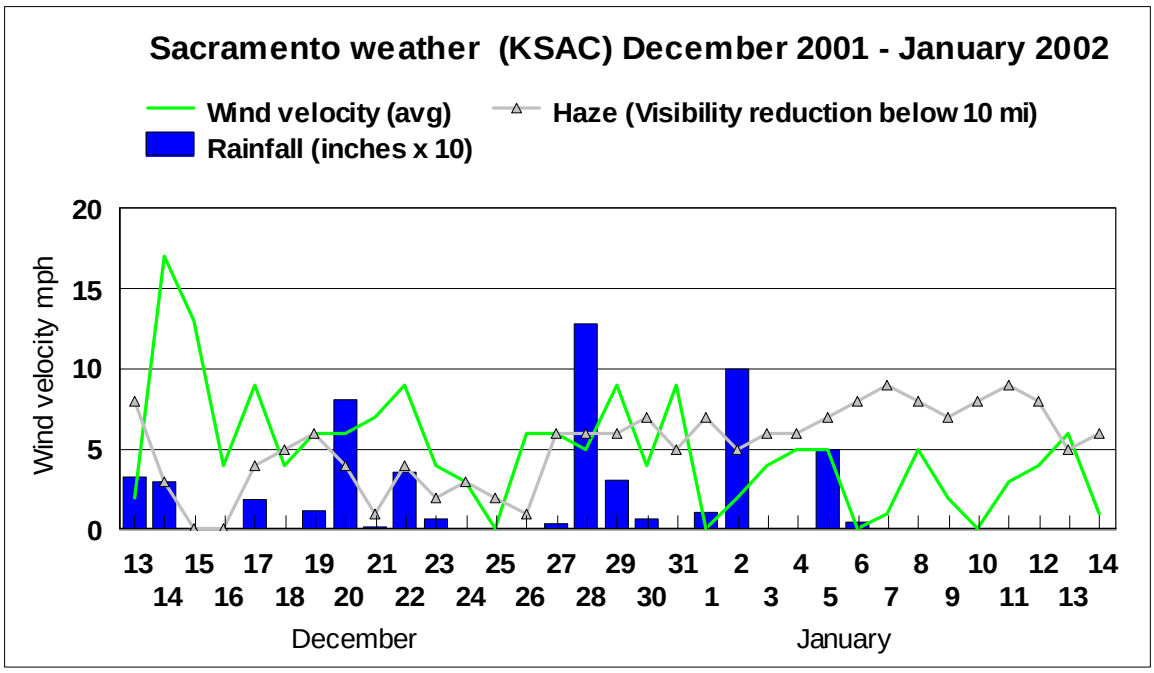
In earlier studies, (see NRC Davis profile) we had shown that there was no measurable increase in aerosol mass or smoke on December 23 1994 (Appendix B, page 27). In 2001 – 2002, we had 2 sites as part of the Breathe California/Sacramento Emigrant Trails Valle Transect. The two sites, one in the city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

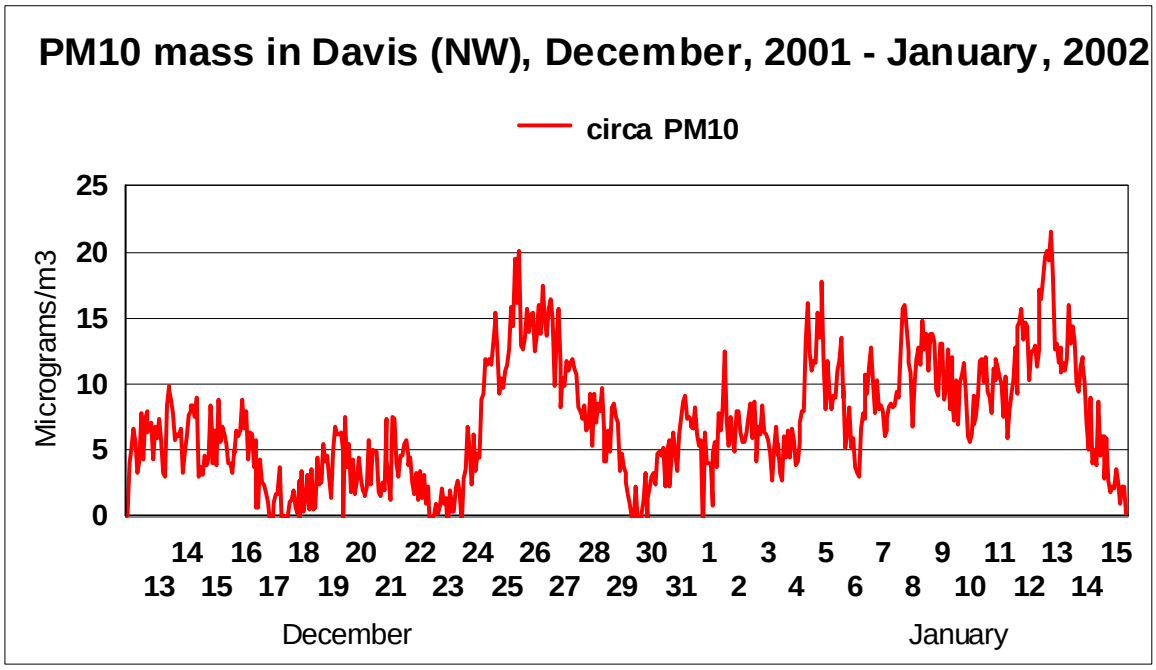


The northwest NW site was in a backyard in Westwood, just west of Highway 113 and 2 blocks north of Russell Blvd. Essentially all homes in this neighborhood were built with open hearth fireplaces. The Davis East site was circa 150 ft south of I-80 on the east portion of the USFS land east of Davis. The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

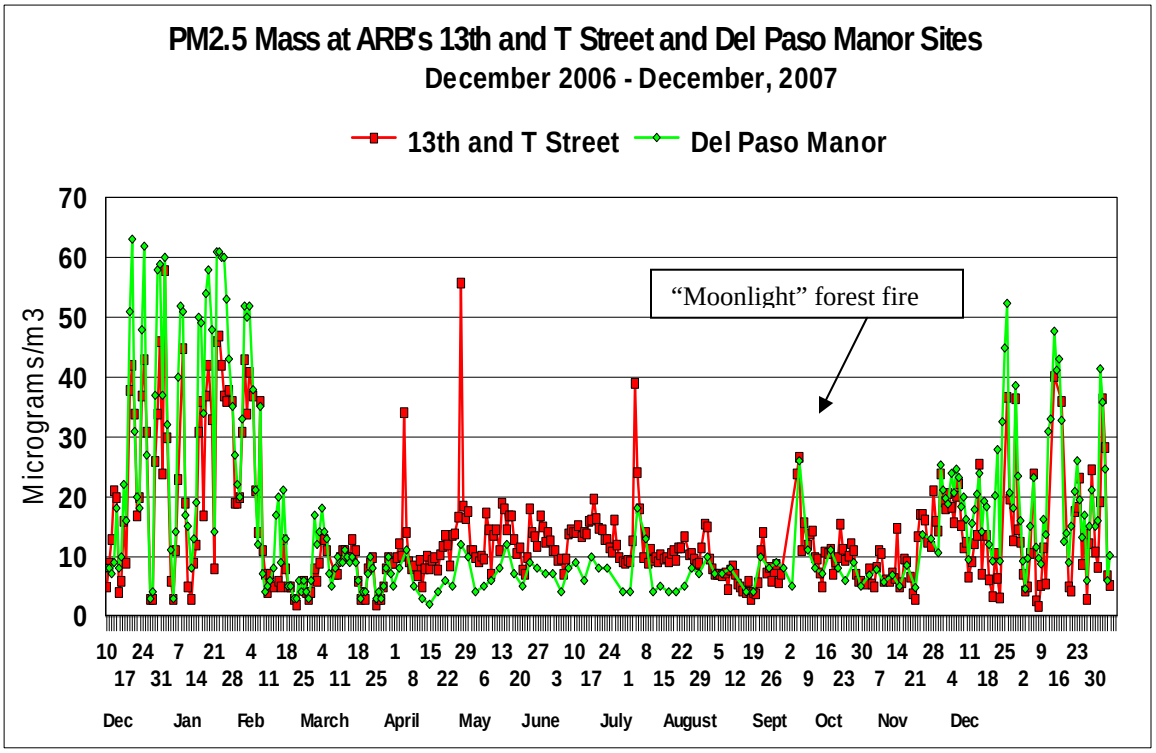
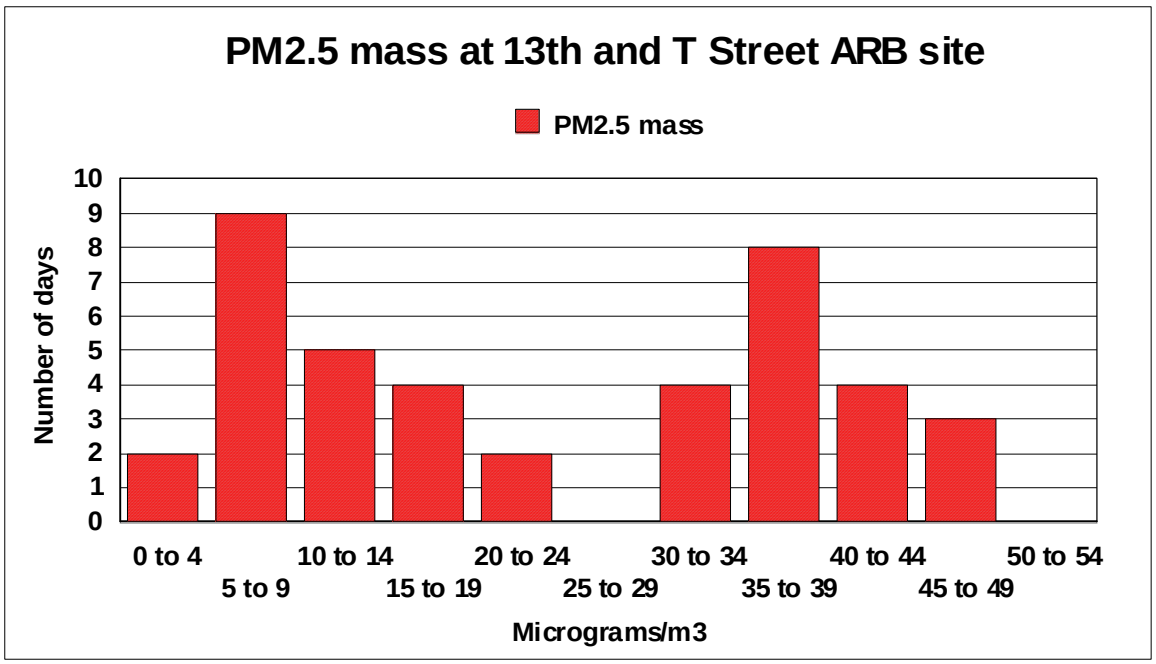


Figure 2 24 hr $PM_{2.5,}$ 13th and T Street and Del Paso Manor, annual, 2007

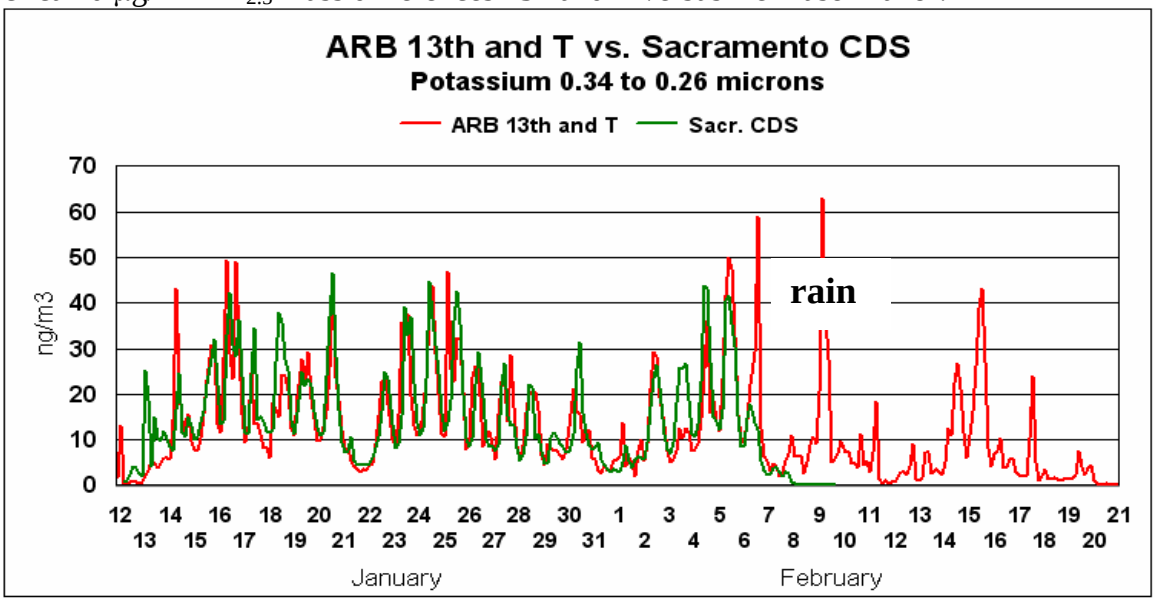
These data illustrate a mass profile that was strongly bimodal in winter, 2007. The air quality was either quite good (median 8 $\mu g/m^3$) or quite bad (median 36 $\mu g/m^3$), with little overlap of the distributions.

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 $\mu g/m^3$ of $PM_{2.5}$ mass (Turn et al, 1997) and thus below the circa 10 $\mu g/m^3$ $PM_{2.5}$ 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

Appendix A

Special to the Enterprise
Thomas A. Cahill, August 2, 2008
756-6146

One of the greatest threats to effective environmental progress is asking the public to bear the cost of environmental actions that later turn out to be unnecessary or unsupported by current science. Such errors erode the political will to do the hard and necessary environmental tasks. Think of the current credibility of the FDA, for example, after they erroneously labeled tomatoes as the salmonella culprit. Davis is in danger of sliding down this slippery slope in instituting a total ban on wood burning when the science is not supportive of such an action. By doing so, Davis will erode its credibility, and that of all air quality regulation, making it that much harder to later convince the public to bear future inconvenience and cost for valid environmental goals (ban on use of leaf blowers, restrictions on sales of diesel fuel, etc.)

There are two problems. One is that the Natural Resources Committee did not have key documents that have actually determined the surprisingly low levels of wood smoke in Davis in winter, a 55 page report submitted to the City Council in March 15, 1995. . This work shows that even on the worst stagnation periods, Davis represents a tiny enhancement over the valley wide winter particulate pollution, which is largely caused by diesels and smoking cars. In addition, for the last month we have been breathing smoke from the much more dangerous wildfires at levels roughly 100 to 200 times what which we saw during our worst stagnation period, the cold, hazy day in Davis on Dec. 23, 1995. Yet Glennah Trochet, MD, Sacramento County Health Officer, noted no increases in doctor's visits or hospital admissions from the present wood smoke even in the worst period of mid to late June, 2008. Similar results were seen in 2004 in Fairbanks, Alaska, in the far more intense wood smoke that persisted there most of the summer. There are also other new and relevant data on wood smoke developed by the Sacramento Metropolitan Air Quality Management District and other groups

The second problem is that the controls are far in excess of what the problem requires. Use of burn - no burn days, especially if keyed to Sacramento's more stringent requirements, would be highly effective in eliminating any residual smoke impact and make the AQI threshold for Davis twice as protective. Or take an alternative tack – permissive burn days, triggered on rain storms and/or high wind conditions when smoke is simply not a problem on any level. This would allow Davis residents the real pleasure of a crackling fire on rainy winter nights, while having essentially no adverse impacts on air quality.

There are real problems with air quality in the Central Valley that we must address, and for this we will need scientific credibility. For example, our reports to the ARB and local American Lung Association, (1997) shown a 60% enhancement of the death rate from ischemic heart disease in the valley. But wood smoke is not the problem, as the impact is maximum in cities with little wood smoke, like Bakersfield, and minimum in cities with more wood smoke (but fewer diesel trucks) like Redding and Red Bluff. Precipitous action by Davis would be used to discredit future and better founded actions by other environmental agencies and by Davis itself. An overbroad regulatory action by the City of Davis might be used by opponents of

environmental regulations to block needed and effective measures to address urgent, life threatening problems.

I have provided a hard copy of the March, 1995 report to the city and I will post my summary analysis on my UC Davis DELTA Group web site http://delta.ucdavis.edu .

Appendix B

To: Members of the Davis City Council
From: Thomas A. Cahill

Re: Proposed ban on wood burning

With all due respect for the motivations and expertise of the supporters of this proposal, I must take a position opposed to this action and request that the Council not adopt the ban as proposed. I propose an alternative to accomplish the goals.

I regret that I can not make this presentation in person, but I have a long scheduled scientific meeting for the National Science Foundation at the Desert Research Institute, Reno, on July 29 and 30.

My general position is based on my long aversion to environmental actions whose costs are not commensurate with their benefits. My specific position is based on

- new data on the lack of health impacts from ambient levels of wood smoke, some generated during the smoke events of the past month,
- my previous studies of wood and diesel/smoking car smoke in Davis presented to the Council on March 15, 1995,
- my publications on the composition and toxicity of wood smoke (1976 – present, especially Turn et al, 1997) and my studies of truck, car, and train diesel smoke,
- extensive studies in the San Joaquin Valley, and especially the results of my IMPROVE site at Sequoia NP,
- and early results of current work in progress on wood smoke in Sacramento for the California Air Resources Board and Sacramento Metropolitan AQMD, due for completion September 30, 2008.

Further, there are alternatives available to the Council that are scientifically supported that will accomplish the stated goals at less impact to the citizens of Davis. One includes Davis adopting mandatory no-burn days as predicted by the Sacramento Metropolitan AQMD even though particulate pollution at Davis lies about as factor of 2 below Sacramento's and below the federal AQI for sensitive populations limit. This is based on the regional meteorology and pollution patterns in winter we measured through Davis and Sacramento, winter, 2001 – 2002 (see below, and provided electronically).

Finally, I fear that a well meaning but largely ineffective action by the Council on wood smoke will lull citizens into ignoring the far more immediate and scientifically impeccable threats in winter particle pollution cause by persistent very fine (vf) and ultra fine (uf) particles from diesels and smoking cars, with impacts documented in our analysis of the death rate from ischemic heart disease associated with fine particles (1997, summary provided electronically). These are the focus of much of my current research and recent legislative actions including testimony to the Inspection and Maintenance Review Committee (2005) and AB1870 (2006), adding smoke detection to Smog Check II, and a proposed vf/uf Central Valley transect scheduled with Breathe California of Sacramento Emigrant Trails and local high schools for winter, 2008.

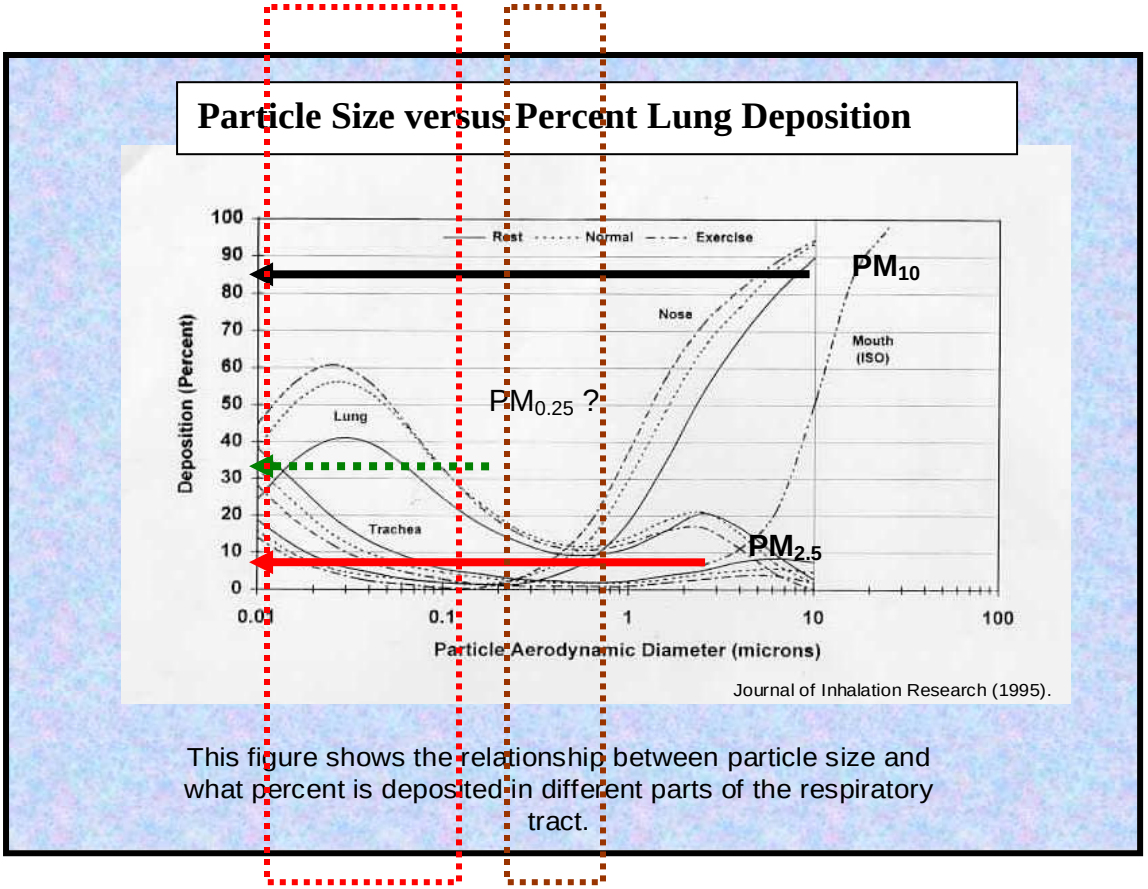
Supporting materials

I am a professor of Physics (recalled) and Atmospheric Sciences (emeritus) at UC Davis, and founder and current Head of the DELTA* Group, with over 38 years of work and circa 350 publications and reports in particulate smog in the atmosphere of California, the nation and the world including currently 9 international, federal, state and local research projects. (CV and publication list appended electronically).

I have been a resident of the City of Davis since 1967, and live in a Streng house with a fire place which I used typically 6 to 8 times/year, 2 to 3 hrs/event. I never have fires on Sacramento Metropolitan AQMD no-burn days. I only burn aged hard wood cuttings from my own trees, and have not bought wood from any supplier in roughly the last 25 years.

1. **Health impacts of wood smoke**

Wood smoke is easy to see and smell, but because of the size of the particles, only a very small fraction (circa 10 %) is captured by your lung (brown shaded area). Conversely, diesel exhaust is very fine to ultra fine in size, goes deep into the lung, and the most toxic components are collected at the 60% level (blue shaded area).



Diesel exhaust **Wood smoke**

*Detection and evaluation of Long-range Transport of Aerosols

Despite the recent high levels of wood smoke, there have been no increases in hospital or doctor's visits in Sacramento even on the worse days of smoke, (Glennah Trochet, Sacramento

Health Officer, quoted in the Sacramento Bee circa June 15, 2008.) My daughter Cathy, did the same analysis for Fairbanks in the massive Alaskan fires of 2004, with levels several times worse than our recent impacts, and found the same result. She did find a small increase in the purchase of inhalers for asthmatics in Fairbanks. Finally, the US EPA (Robert Devlin, head of EPA health research, 2003) listed the 5 components in particulate pollution that may underlie the firm statistical association of atmospheric aerosol mass and health impacts (morbidity and mortality): These were –

1. Acidic aerosols – (evidence weakening)
2. Biologicals (fungi, spores, bacteria , viruses – evidence strengthening),
3. Fine metals such as iron (free radicals and lung damage),
4. Ultra fine (< 0.1 μm) insolubles – (heart impacts – World Trade Center),
5. High temperature organics – (diesel and smoking cars, especially PAHs)

Wood smoke from fireplaces and stoves, a relatively low temperature burn of a non toxic fuel, generating largely water soluble particles (including levoglucosan, a sugar), does not fall into any of these categories.

2. Wood smoke transects in Davis 1994

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.

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

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

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

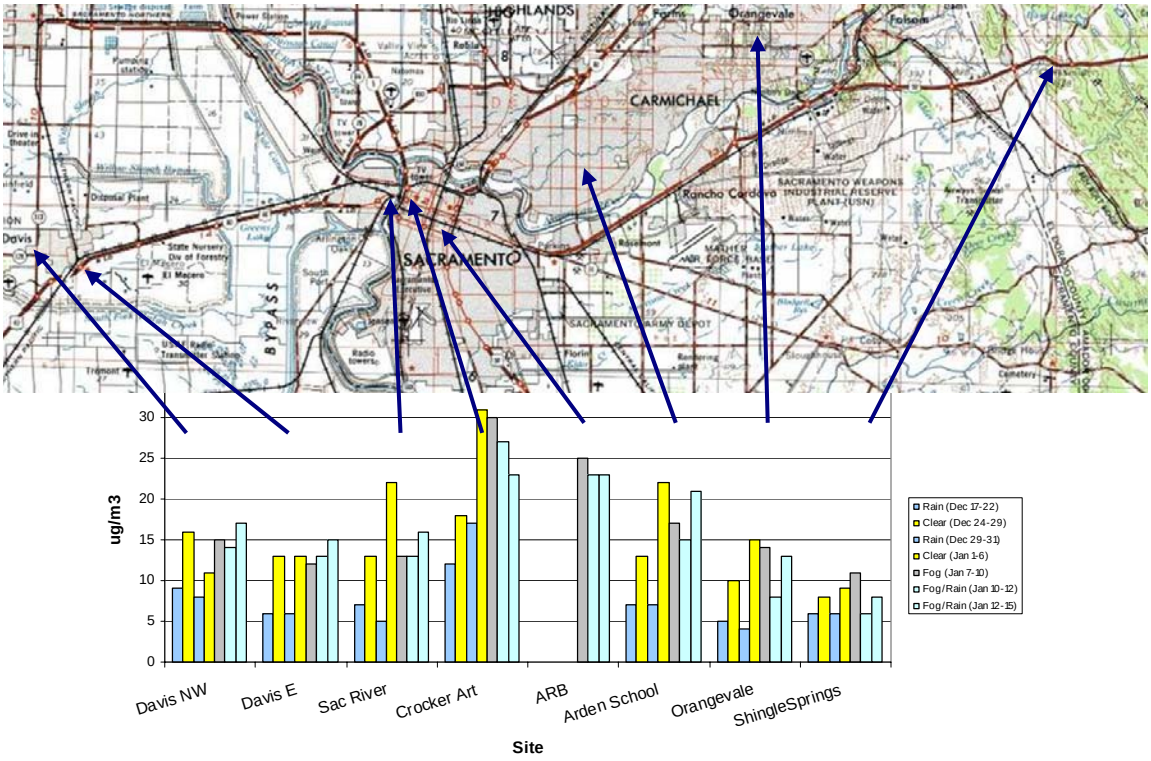
113" and "UCD west fields" sites) as in town (average of other three sites). Note that the wind blew from the town to the west sites only 4% of all hours in December.

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.

3. 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

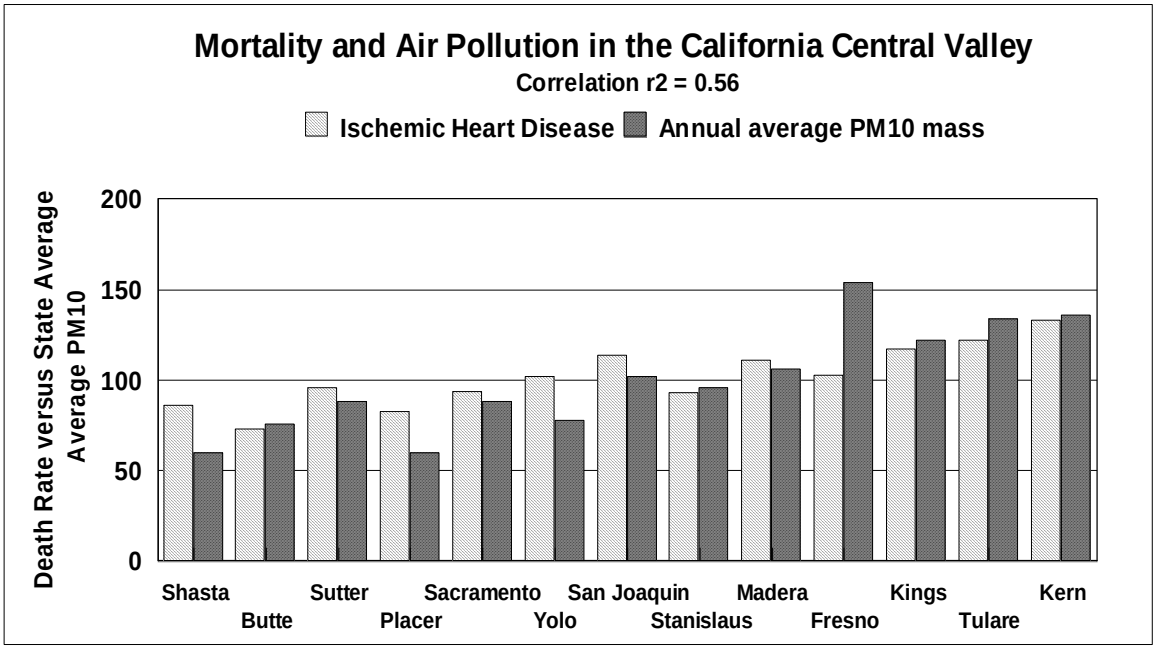
From the transect above, we can see the $PM_{2.5}$ in Davis is about ½ that of Sacramento. Thus, if Davis adopted mandatory no burn days of the Sacramento Metropolitan AQMD, we

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.

Perspective

In 1997, we did a study of stoke and ischemic hart disease mortality data as compared to ozone, aerosol and carbon monoxide in the central valley. A strong correlation was shown between particulate matter and heart disease, while no other parameter or health impact showed such correlations**.**



Regretfully, chemical data are largely absent north of Roseville, but because of the local forests, there is heavy use of wood fireplaces in winter in the Red Bluff /Redding area. I do have data from my relatively low elevation IMPROVE[**] (Malm et al 1994) site at Sequoia NP, I have confirmed that in the winter only a very small fraction of the total fine aerosol mass is wood smoke. Further recent data from the ARB in the San Joaquin Valley show that wood smoke rapidly picks up water in the atmosphere, grows in size, and falls out as a mist

[**] IMPROVE – Interagency Monitoring for Protection of Visual Environments, the national program to protect visibility in national parks, monuments, and wilderness areas that I developed and ran for the EPA and NPA, 1977 – 1997.

References

T. A. Cahill, E. A. Gearhart, and K.T. Paw U, , **"PM-10 Aerosols in Davis from Traffic Sources", d**ated March 2, 1995, to the Davis City Council, March 15, 1995, Air Quality Group and Department of Atmospheric Sciences, UC Davis.

Thomas A. Cahill, M. Roumie (Fulbright Fellow, Lebanon), Lee Portnoff, Victor Ray, Jeanette Martin, Roger Miller (Dept. Physics, CSU Stanislaus), Steve Cliff, and Kevin D. Perry, (Dept. Meteorology, U. Utah), Chinyere Williams, Betty Turner and Earl Withycombe, **American Lung Association – Sacramento Emigrant Trails Sacramento/Interstate -5 Aerosol Transect Study. December, 2002 – January, 2003.** the DELTA Group, University of California, Davis, http://delta.ucdavis.edu,

Flocchini, Robert G., Thomas A. Cahill, Danny J. Shadoan, Sandra J. Lange, Robert A. Eldred, Patrick J. Feeney, Gordon W. Wolfe, Dean C. Simmeroth, and Jack K. Suder**. Monitoring California's aerosols by size and elemental composition**. *Environmental Science and Technology*. 10:76-82 (1976).

Lyons, C.E., I. Tombach, R.A. Eldred, and J.E. Core**. Relating particulate matter sources and impacts in the Willamette Valley during field and slash burning.** *Proceedings of the 72nd Annual Meeting of the Air Pollution Control Association.* Cincinnati, OH, June 25-30. Paper No. 79-46.3.1:2-16 (1979).

Malm, W.C., Sisler, J.F., Huffman, D., Eldred, R.A. and Cahill, T.A.. **Spatial and seasonal trends in particle concentration and optical extinction in the United States. 1994** *Journal of Geophysical Research,* VOL. 99, No. D1, 1347-1370, January 20, 1994

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.

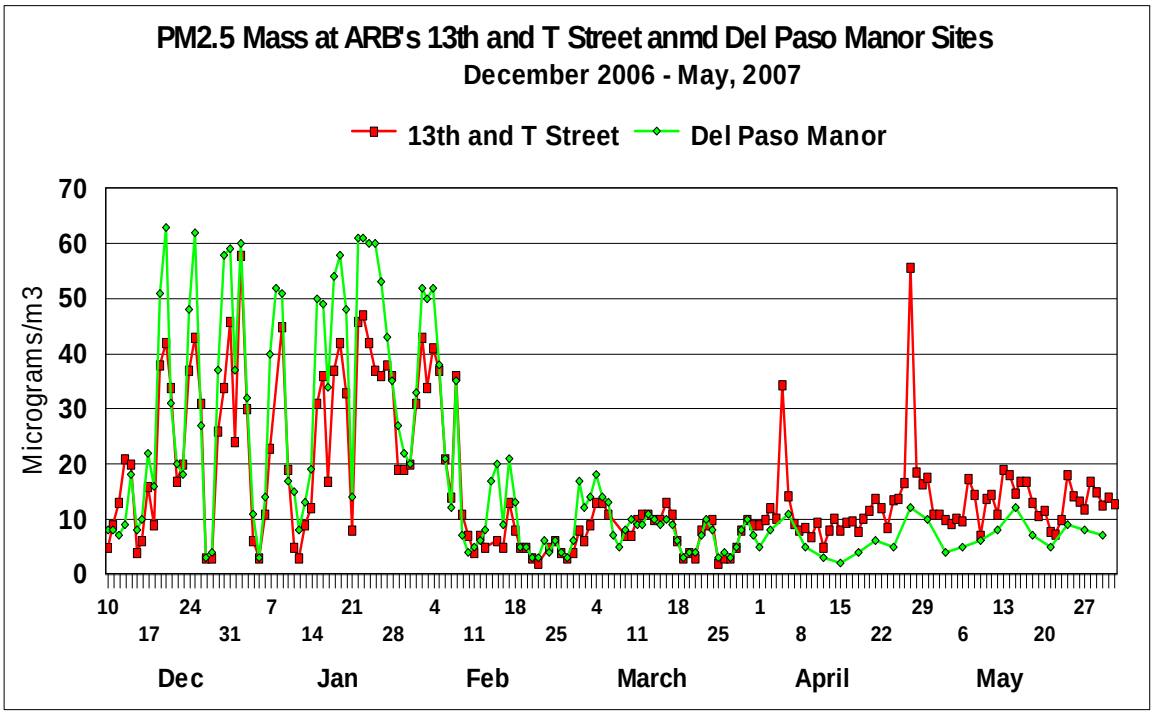
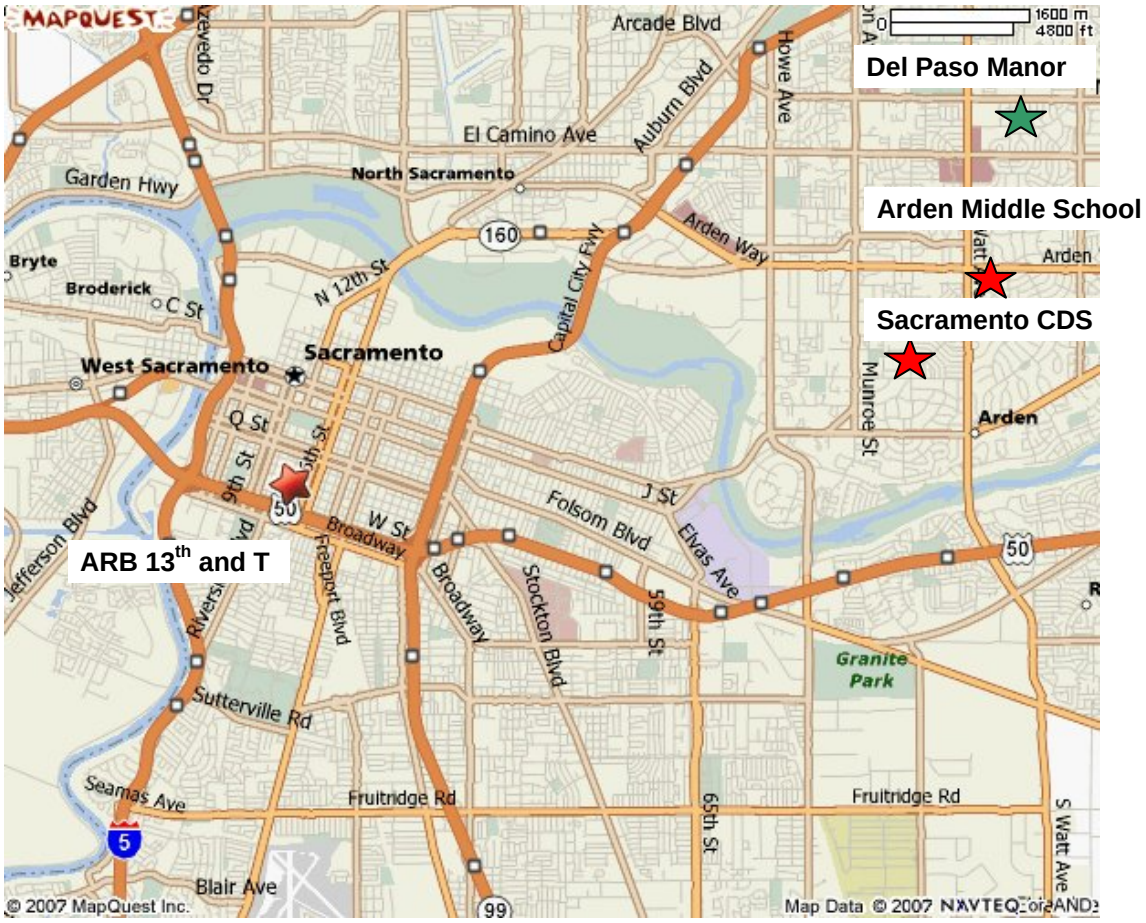


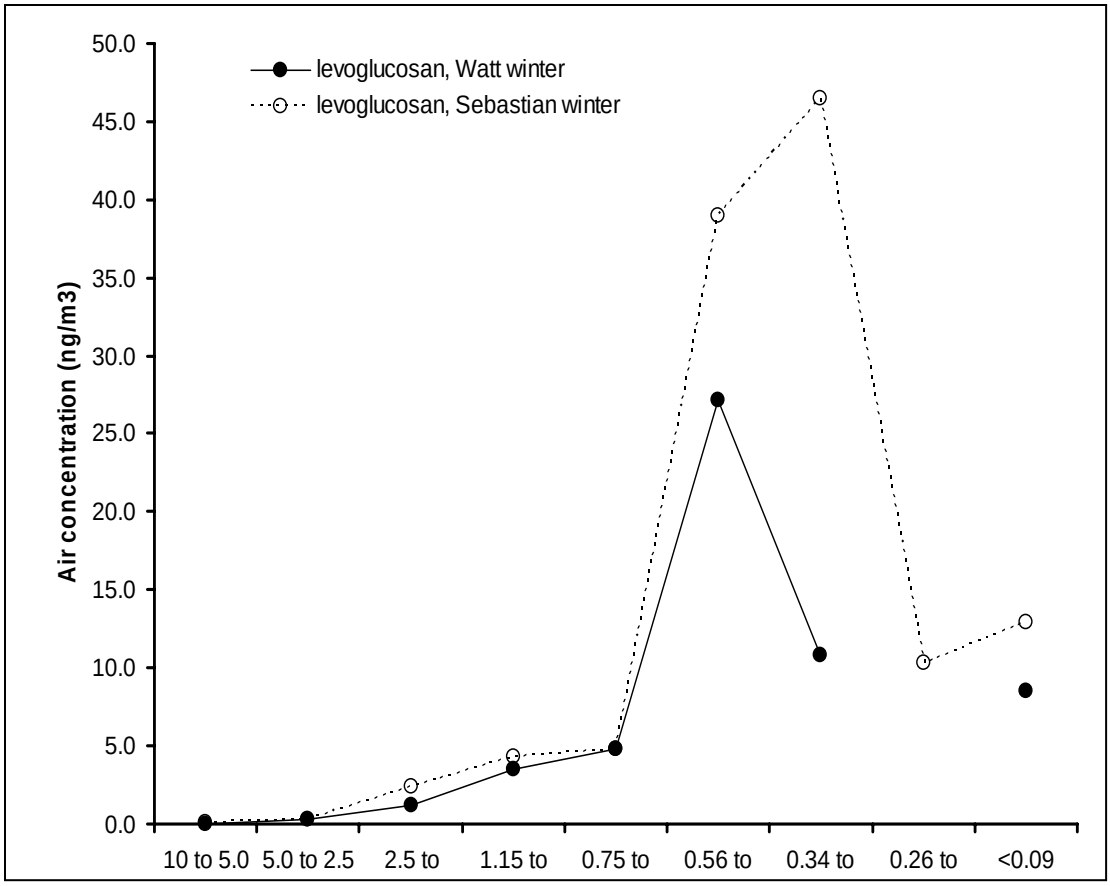
Figure 9 24 hr $PM_{2.5,}$ 13th and T Street and Del Paso Manor, winter – spring, 2007

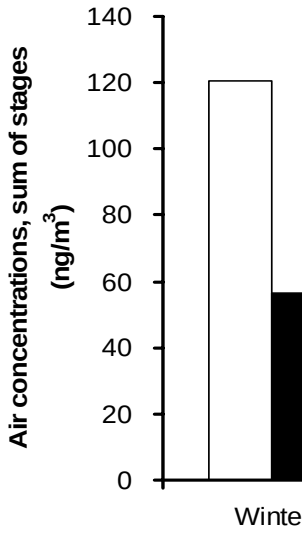
While these studies have many goals, including validation of DRUM sampling technology versus standard ARB/EPA monitoring, one is an analysis of the present wood smoke control measures of the SMAQMD. As part of the DELTA Group offer to Davis, we will provide the mass and elemental data to the city without 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.

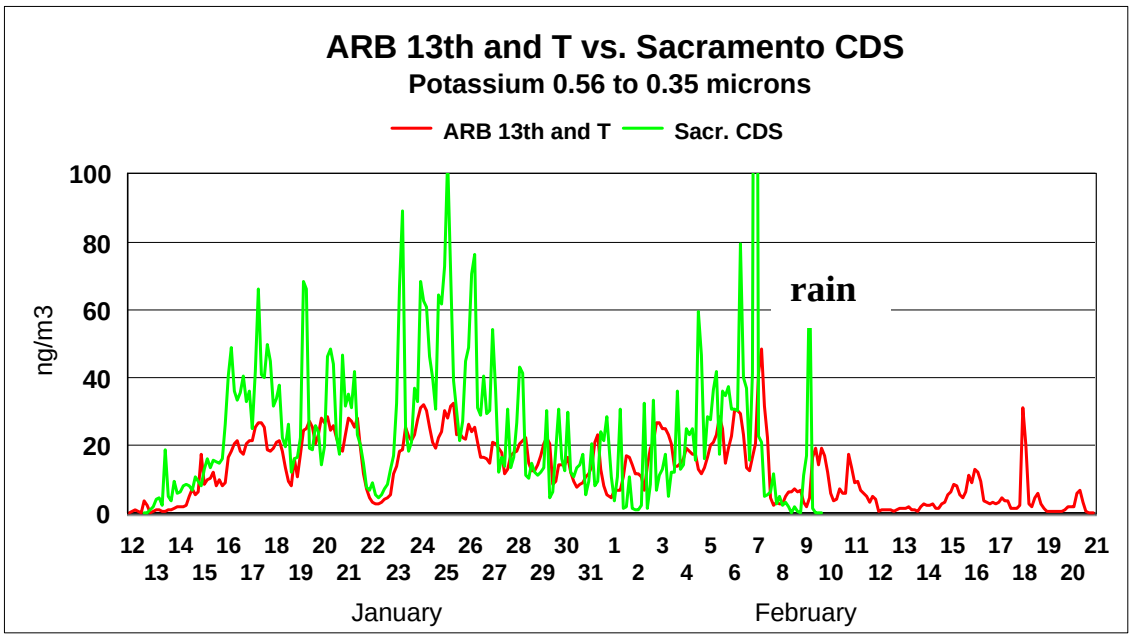


Figure 4 Potassium in the accumulation mode, generally the size mode of most wood smoke.

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.

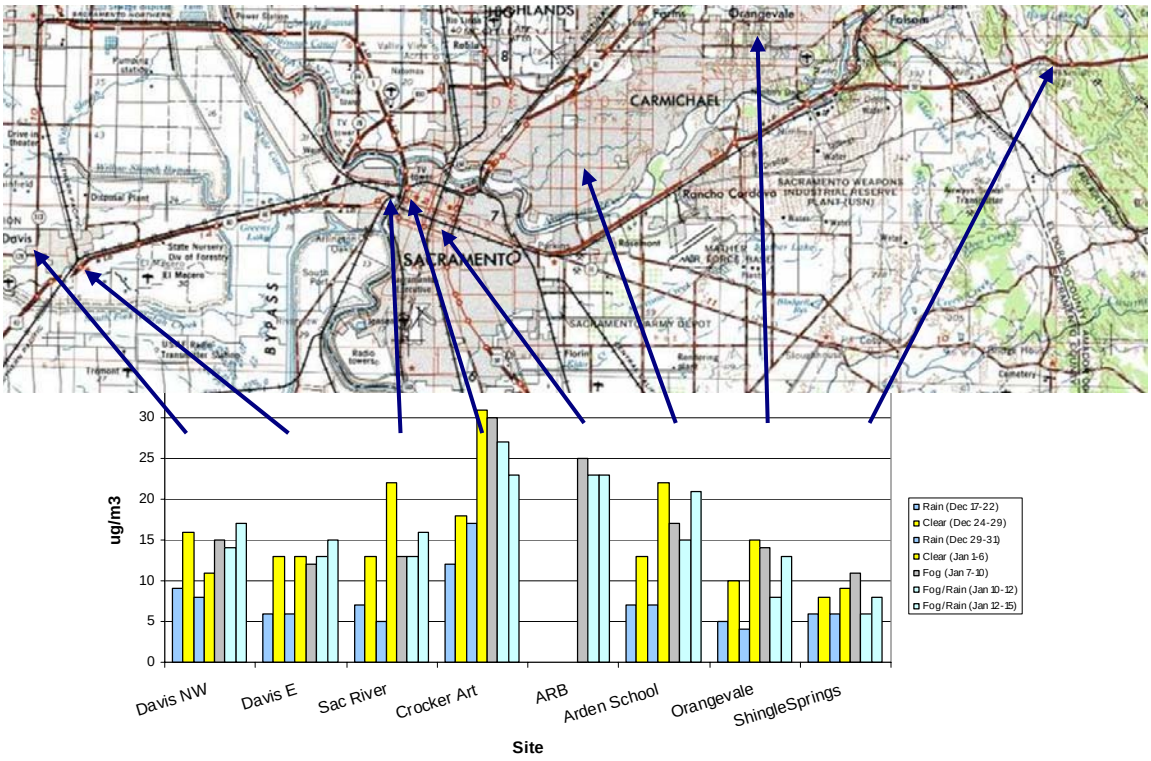
Below I append data from the winter, 2002 study. The full report is available electronically from Breath California of Sacramento-Emigrant Trails (916) 444 5900.

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 $\mu g/m^3$ 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