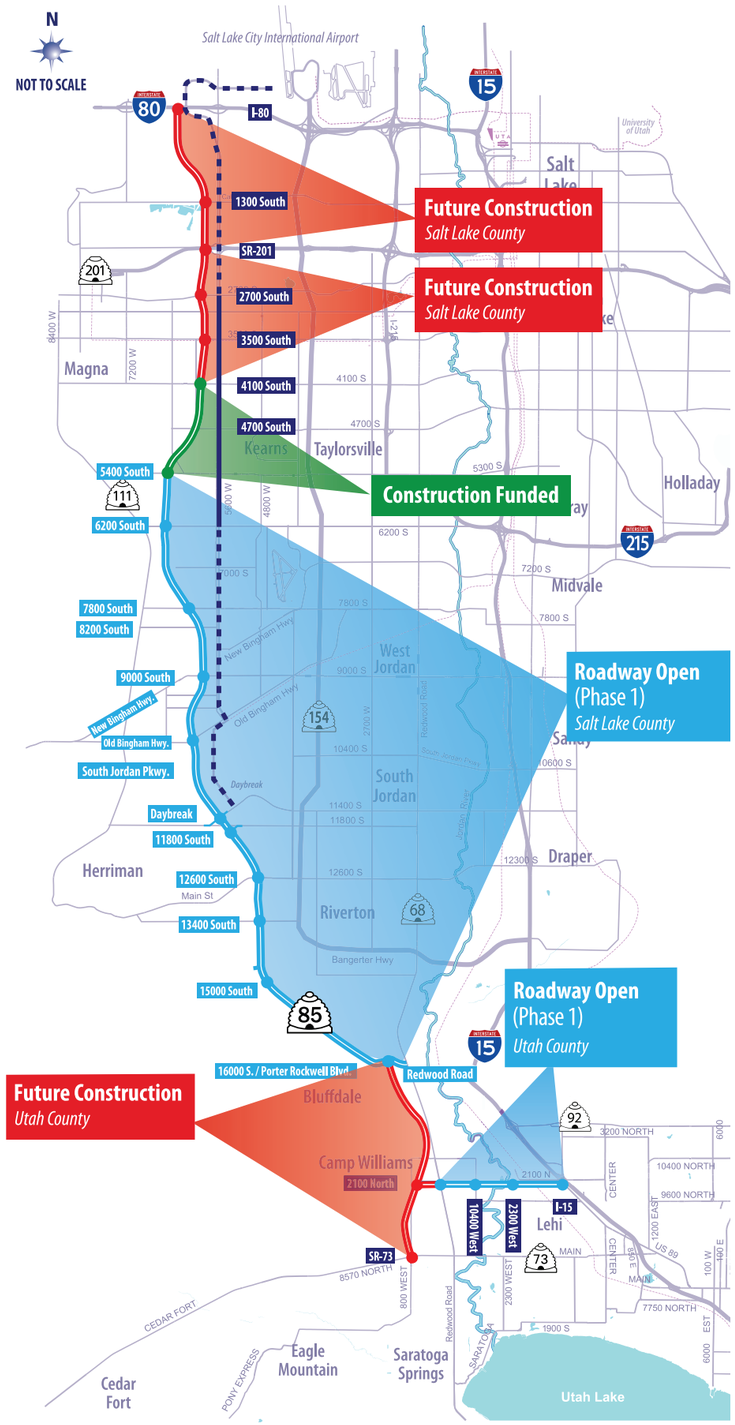
PHASED CONSTRUCTION APPROACH



- Current Intersection/Future Interchange
- Future Intersection/Future Interchange
- Construction Funded from 5400 S. to 4100 S.
- Initial Transit Project
- Future Transit Projects

PHASE 1

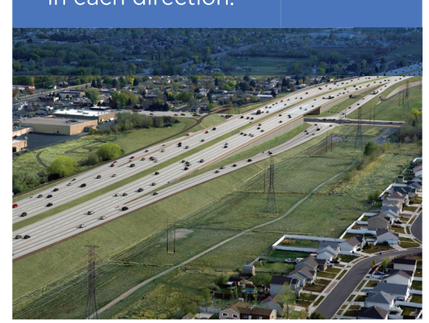
UDOT constructed two lanes in each direction, and the on-and-off ramps of the future freeway from 16000 South to 5400 South. Trail and bike lanes run adjacent to the entire corridor. Future construction will extend the roadway from 5400 South to S.R. 201.

PHASE 2

UDOT will convert the existing signalized intersections to freeway interchanges.

PHASE 3

UDOT will add additional lanes in each direction.



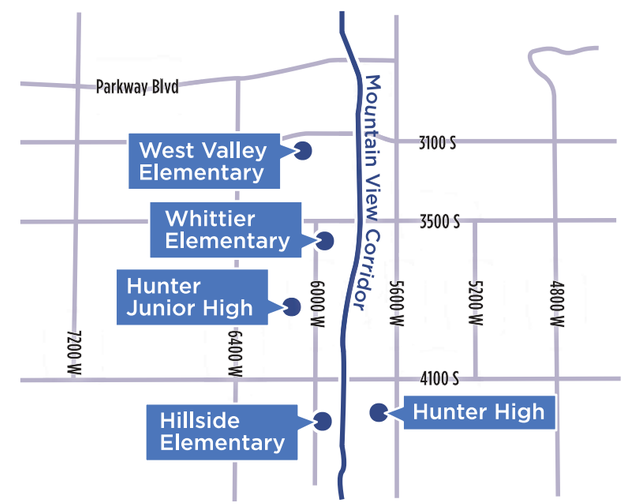
MVC AIR QUALITY WORKING GROUP UPDATE

JANUARY 2015

The Utah Department of Transportation (UDOT) is constructing the Mountain View Corridor (MVC), a planned freeway from Interstate 80 in Salt Lake County to state Route 73 in Lehi.

During the MVC Draft Environmental Impact Statement (EIS) public comment period, UDOT received comments from residents with concerns about the air quality near public schools surrounding the corridor. In an effort to be responsive to the comments, the Record of Decision (ROD) described the creation of the MVC Air Working Group (AWG) to monitor the air quality effects of the new roadway and to address potential impacts resulting from the construction of the roadway near five schools in the Granite School District (GSD).

The decision to incorporate the comments as mitigation commitments does not represent a determination by the Federal Highway Administration (FHWA) or UDOT that the MVC project or any other road will cause measurable adverse health effects on population near roads.



Schools near the future Mountain View Corridor.

The first step of the group was to measure the background pollutant levels and monitor Mobile Source Air Toxics (MSATs), and other relevant pollutants for future comparison, plus evaluate existing ventilation systems in the schools and recommend a mitigation strategy. $1 million for monitoring and $3.1 million for mitigation was allocated.

AIR QUALITY MONITORING

The purpose of the air quality monitoring is to characterize air quality prior to any construction in order to provide a baseline for comparison with future monitoring to be done during and after construction.

The project has four major objectives:

- Monitor background air quality focusing on MSATs and particulate matter less than 10 micrometers (PM_{10})
- Monitor wind speed and direction at the five schools
- Design a mitigation approach to reduce MSATs particles indoors
- Recommend future monitoring and mitigation efforts

Evaluation of air quality and its potential health risks were performed using the data collected at Hunter High School from August 2011 to July 2012. Conclusions from the background-monitoring project include:

Diesel particulate matter (DPM) is the most critical MSAT to monitor since it is the greatest contributor to cancer risk.

Black carbon concentrations, a component of DPM, are higher during the morning and evening commute.

Measured toxic concentrations are comparable to the measurements at the Bountiful, Utah, Division of Air Quality (DAQ) monitoring station* and to observed and modeled urban concentrations nationally.

Expected pollutant concentrations may be higher when winds are more parallel to the roadway.

Ultra-fine particle (UFP) data was collected for comparison with future data collected next to MVC. According to the data, UFP concentrations were about one-half of the UFP concentrations next to US Route 95 in Las Vegas.

**Already existing DAQ monitoring station*
***US Route 95 in Las Vegas has a similiar air quality monitoring project*

Meteorogical monitor at Hillside elementary school.

Air-quality monitor at Hunter High School.

MITIGATION RECOMMENDATIONS/EFFORTS

The recommended mitigation strategy is to replace current filters in the schools with filters that are more efficient at removing pollutants and perform upgrades needed to handle the improved filters.

ESTIMATED COST TABLE

School	HVAC System Upgrades	Ongoing Operation and Maintenance (30 yrs)	Total Cost of Upgrades and Ongoing O&M
Whittier	$26,973	$136,881	$163,854
Hillside	$14,853	$77,806	$92,659
West Valley	$53,020	$119,350	$172,370
Hunter Jr. High	$91,754	$139,411	$231,165
Hunter High	$243,216	$716,233	$959,449
Total	$429,816	$1,189,681	**$1,619,497**

Note: $3.1 million was allocated to the AWG for mitigation costs.

In addition to improved filtration systems in the schools, a number of other recommended mitigation efforts could reduce pollutant concentrations and/or student exposure at schools:

- Install sound walls or vegetated barriers between the schools and MVC
- Eliminate bus idling at schools
- Retrofit existing buses to reduce emissions
- Avoid outdoor activities during morning rush hour
- Minimize outdoor activities during periods with strong inversions
- Install portable classrooms as far away as possible
- Provide training for teachers whose classrooms have characteristics that could defeat the filtration system (windows that open; doors that open to the outside rather than to an interior hallway, etc.)
- Control HVAC systems to minimize filling classrooms with morning rush-hour pollutants
- Eliminate or minimize emissions from indoor sources (cleaning materials, markers, etc.)

Future monitoring near the MVC should determine both outdoor (ambient) and indoor, in-classroom impacts of pollutants from the completed roadway. In addition, some monitoring would be beneficial during construction.

THE AWG CONSISTS OF MEMBERS OF

Utah Department of Transportation (UDOT)
Utah Division of Air Quality (DAQ)
Utah Transit Authority (UTA)
University of Utah Department of Pediatrics
West Valley City (WVC)
Granite School District
Breathe Utah
Parent Teacher Association (PTA)
Sierra Club
Utah Congress of Parents and teachers
Utahns for Better Transportation
Wasatch Clean Air Coalition

The AWG contracted with Sonoma Technology, Inc. (STI) and Environmental Health & Engineering (EH&E) to conduct an air quality monitoring study to evaluate background pollution concentrations prior to construction, and to develop future monitoring and mitigation strategies for the impacted schools.

For more details on the report, visit udot.utah.gov/go/MountainViewAirQuality.

Near-Road Air Quality and Mitigation in Schools Near the Mountain View Corridor (MVC)

Paul T. Roberts and David L. Vaughn
Sonoma Technology, Inc.
Petaluma, California

Jerry Ludwig
Environmental Health and Engineering
Needham, Massachusetts

Cameron Cova
Breathe Utah
For the MVC Air Working Group

Presented to the Utah Air Quality Board
Salt Lake City, Utah
February 4, 2015

Sonoma Technology, Inc.
Environmental Science and Innovative Solutions

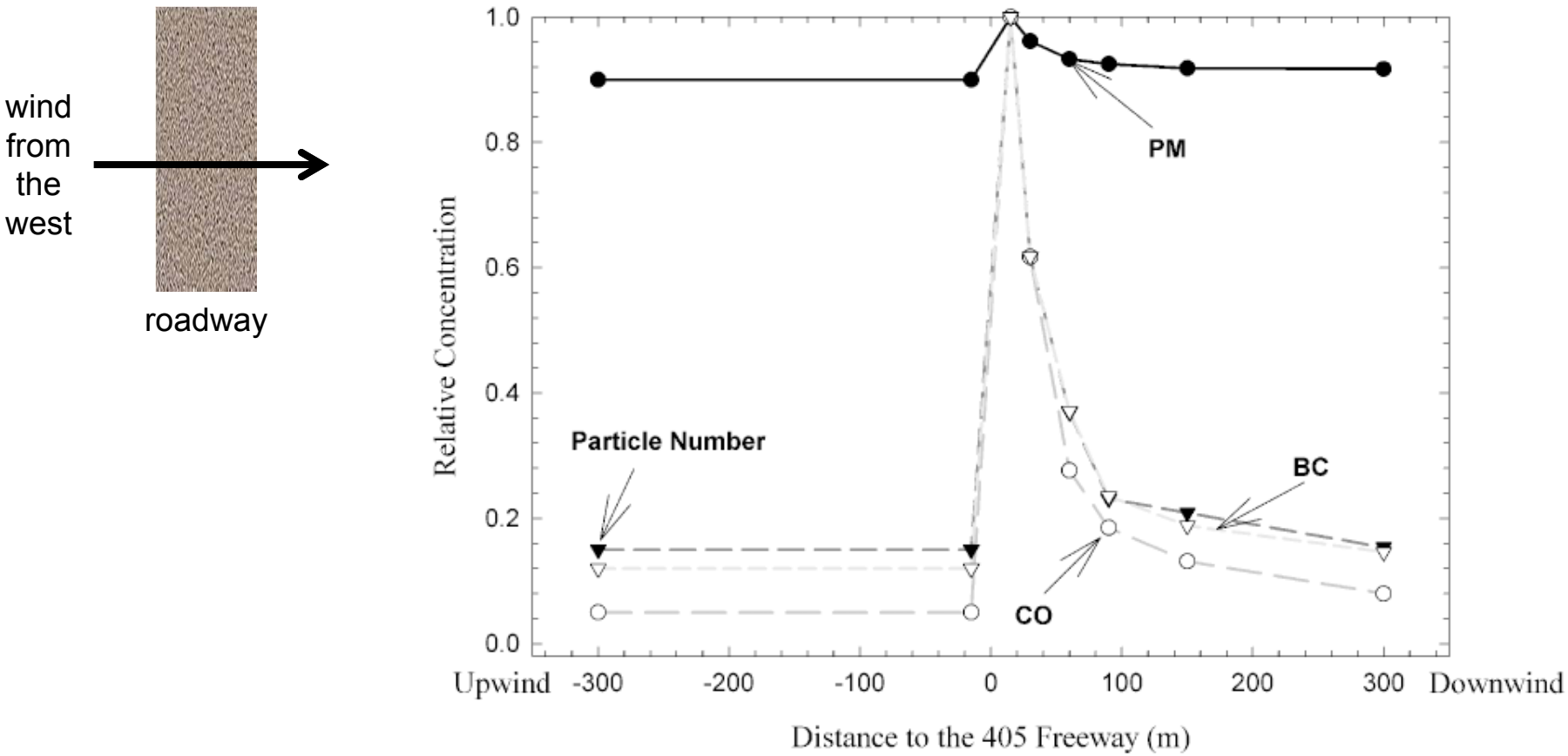
Overview of Today's Presentation

- Background: Why is near-road pollution of concern?
- Background on the Mountain View Corridor (MVC) Air Working Group (AWG).
- Summary of pre-construction outdoor air quality at Hunter High School.
- Current filtration systems' capability to remove diesel particulate matter (DPM).
- Mitigation recommendations for schools.
- Wood smoke in West Valley City

Project Motivation: Near-Road Pollution and Health Effects

- Pollutant concentrations are higher near busy roadways.
- Rob McConnell (USC, Children's Health Study) recently reframed the air pollution problem in general by saying [paraphrasing] "We've been looking at the wrong pollutant mixture; it's not regional air pollution, but near-road pollution, that is the key to understanding the effect of pollution on public health."

Challenge: Gradients Near Roadways



Zhu et al. (2002) Study of ultrafine particles near a major highway with heavy-duty diesel traffic. *Atmos. Environ.,* 36(27), 4323-4335, September.

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HEI Panel on the Health Effects of Traffic-Related Air Pollution

- There is sufficient evidence to infer a causal relationship between exposure to traffic-related air pollution and exacerbation of asthma symptoms.
- Additionally, there is suggestive evidence of a causal link between near-roadway air pollution and
  - the onset of childhood asthma,
  - all-cause mortality,
  - cardiovascular mortality and morbidity,
  - other respiratory problems, and
  - impaired lung function,

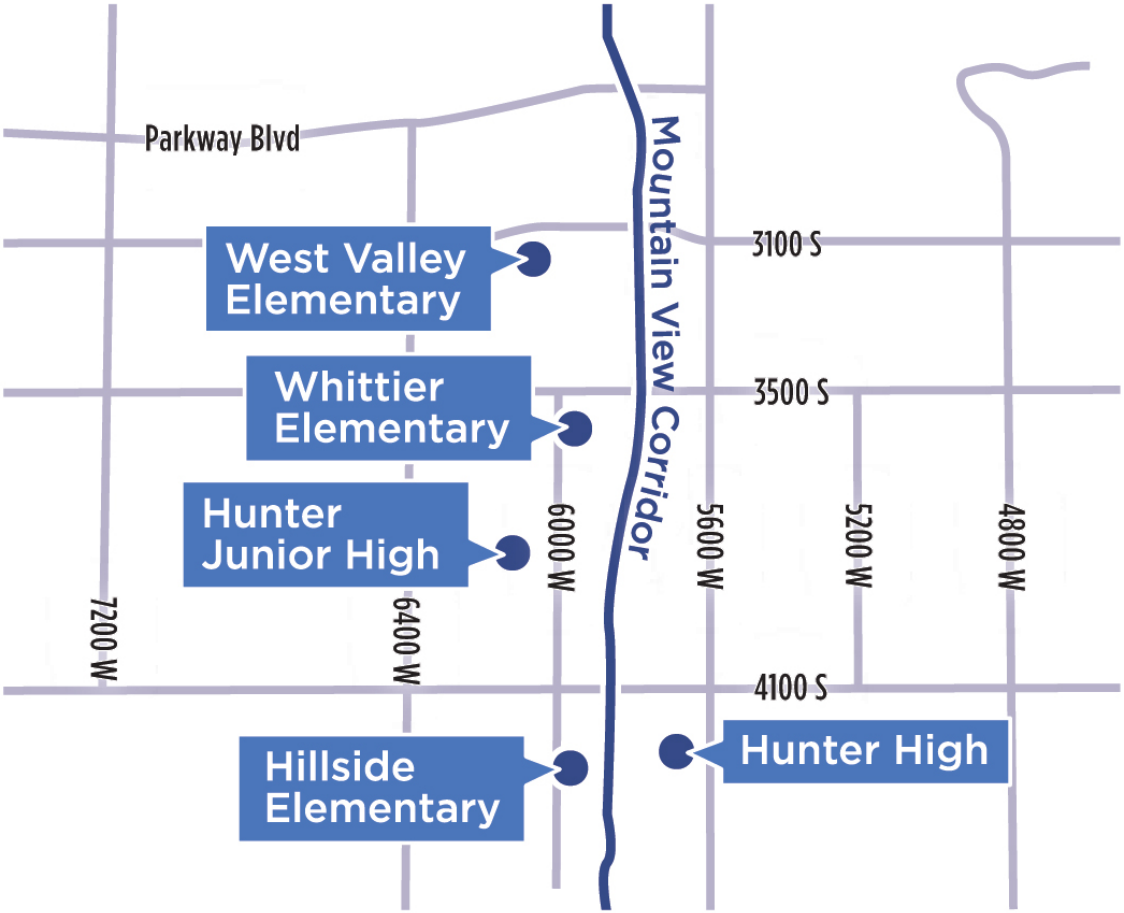
  but more research is needed to confirm that traffic-related air pollution is the cause of these health problems.

From: HEI Panel on the Health Effects of Traffic-Related Air Pollution (2010) Traffic-related air pollution: a critical review of the literature on emissions, exposure, and health effects.

Background on the MVC and Near-Road Air Quality

- Plans developed for transportation alternatives for a new roadway and transit-way in west Salt Lake County and northwest Utah County (2003-2007)
- Concern that children would be adversely affected by air pollution from a new major roadway (MVC) near their schools
- Concerned groups included
  - Utahns for Better Transportation
  - Utah Moms for Clean Air
  - Physicians for a Healthy Environment
  - Sierra Club

The 5 Schools of Concern and the Future Route of the Mountain View Corridor



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The MVC Air Working Group (AWG)

- In Final EIS, UDOT adopted mitigation measures to address near-road air quality impacts
- In the Record of Decision (2008), UDOT and UTA established the AWG and provided $4.1M for monitoring air quality and for mitigation (installing air filters and ongoing maintenance) at 5 schools
- AWG makeup
  - Four members appointed by citizen advisory groups
  - Four members from UDOT, UTA, Utah Division of Air Quality, local government (West Valley City)
  - Include expertise in air quality modeling and medicine

AWG: Working Together Since 2009

- Familiar with transportation and air quality issues
- Educated itself on near-road air quality issues
- Hired a consultant team to perform air quality monitoring and to design mitigation approaches for the 5 schools

The rest of this presentation is a summary of the air quality monitoring results and of the AWG recommendations for mitigation in the schools

Background Air Quality (Pre-Construction)

- Diesel particulate matter (DPM) is likely of most concern near busy roadway.
- We measured black carbon (BC) as a surrogate for DPM.
- Topics for discussion:
  - Measured parameters
  - Wind direction and roadway orientation
  - Annual concentrations
  - Typical diurnal patterns

Parameters Measured at Hunter HS West Valley City 8/1/2011-8/1/2012

Variables Measured	Use of Data	Monitor/Sample Type	Frequency
Winds at 2-3 schools; other parameters at Hunter HS	Determine winds and atmospheric mixing	Meteorology (WS, WD, temp, RH, pressure, solar radiation)	1-minute
Black carbon/“blue” carbon	Represent DPM and woodsmoke	Aethalometer (dual wavelength) Magee AE-33	5-minute
PM_{10}	Determine PM concentrations, for filter loading and during construction	Beta Attenuation Monitor (BAM 1020)	Hourly
pPAH	Represent DPM	PAS 2000	5-minute
Benzene, 1-3 butadiene, acrolein	Annual average concentrations	Canister sampling	24-hr samples every 12 days
Formaldehyde, acetaldehyde	Annual average concentrations	Cartridge sampling	24-hr samples every 12 days
Ultra-fine particles (number concentration)	A near-road potential risk factor	Teledyne-API 651 (borrowed)	5-minute

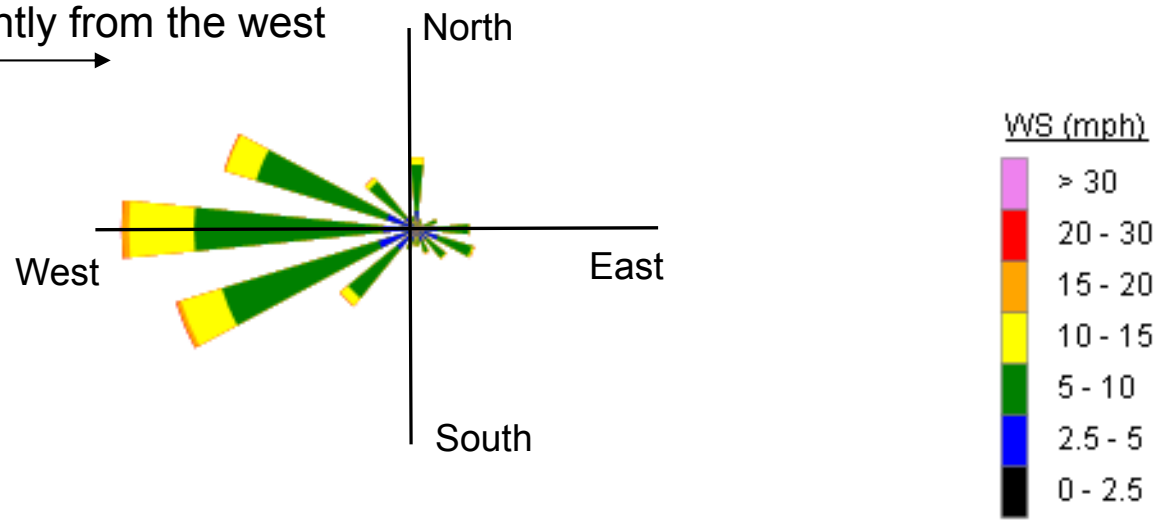
pPAH = particulate polycyclic aromatic hydrocarbon

Wind Rose Interpretation

How to Interpret a Wind Rose

A wind rose provides a summary of wind patterns for a specific time period at a surface meteorological site. The size of the triangle emanating from the center of the wind rose indicates the percentage of time that winds are from a specific direction (position on axes). Wind speed time percentages are indicated with color bins along the length of the triangle.

Winds are predominantly from the west



Wind Comparison Map (very similar for all seasons)

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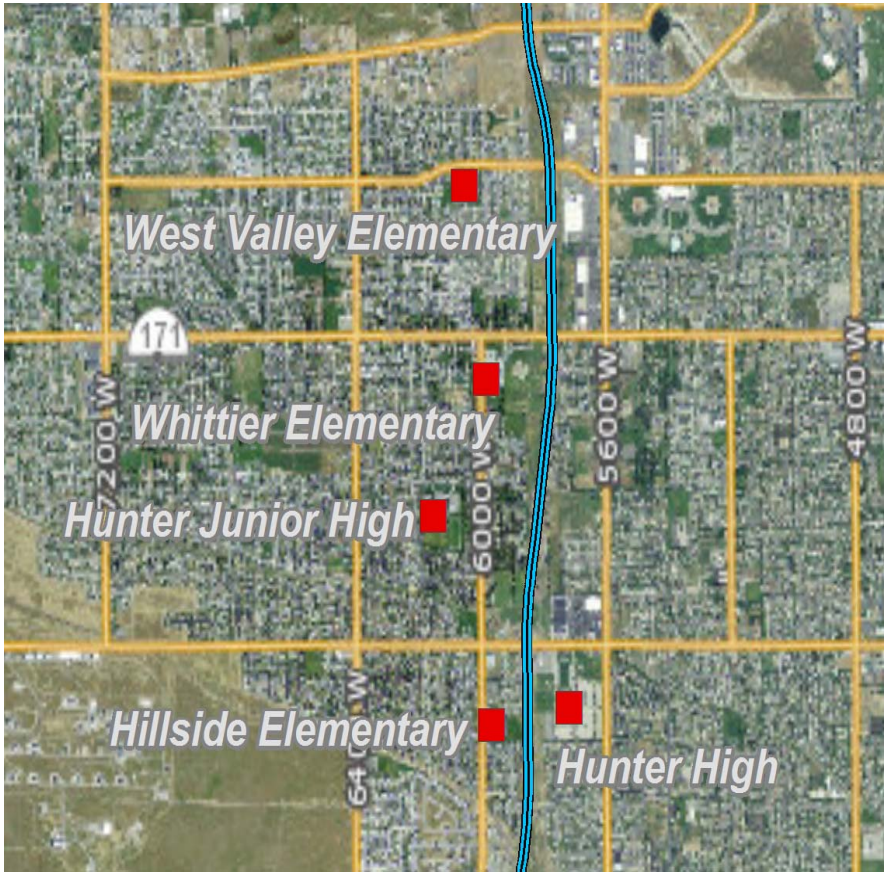
Issues Relative to Wind Direction and Roadway Orientation



- Dominant winds from the south; thus winds almost parallel to roadway
- Winds meander at low wind speeds
- Pollutant concentrations decrease and spread downwind
- Pollutant concentrations higher at lower wind speeds
- Pollutant concentrations higher when winds more parallel to roadway

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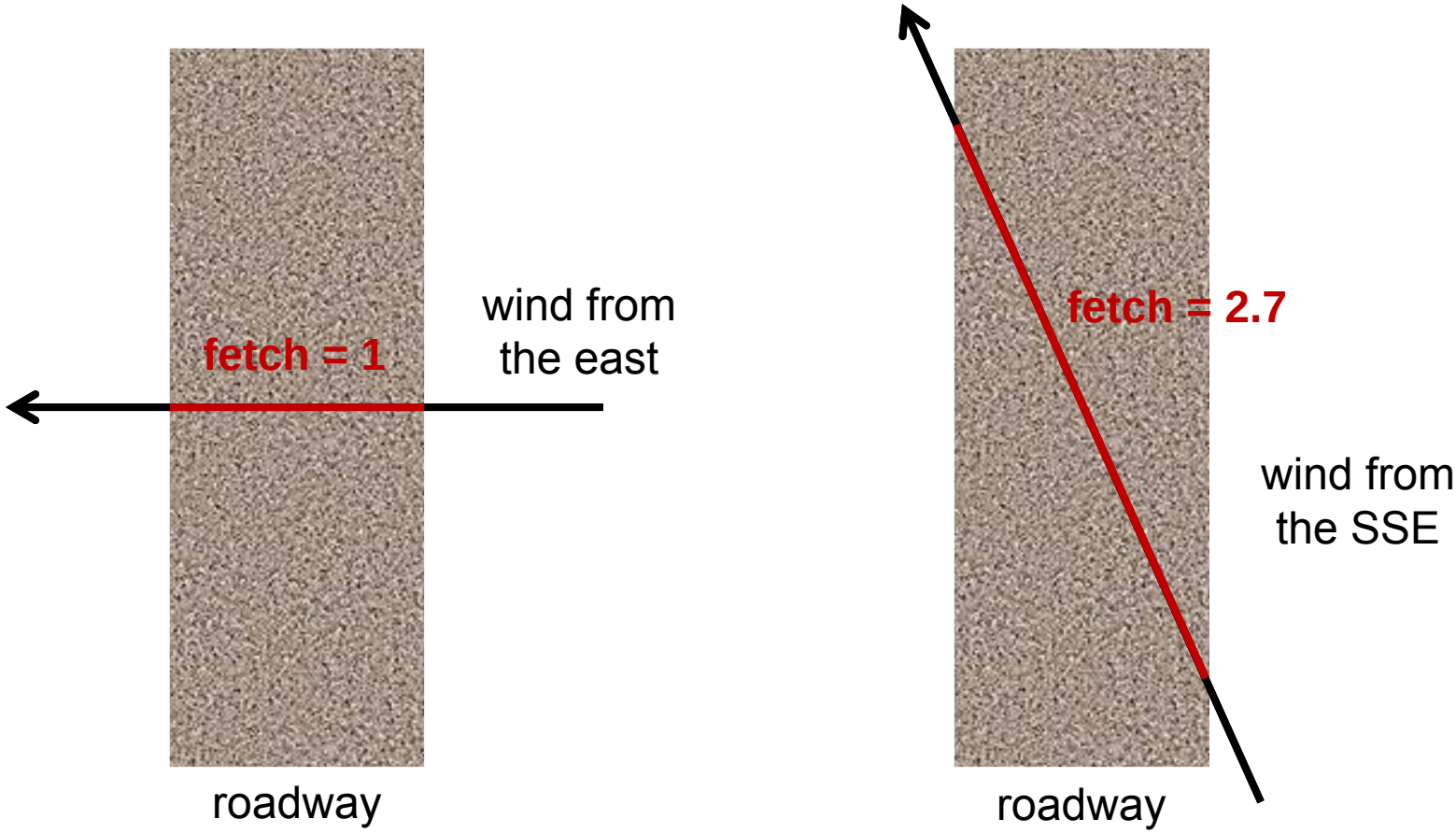
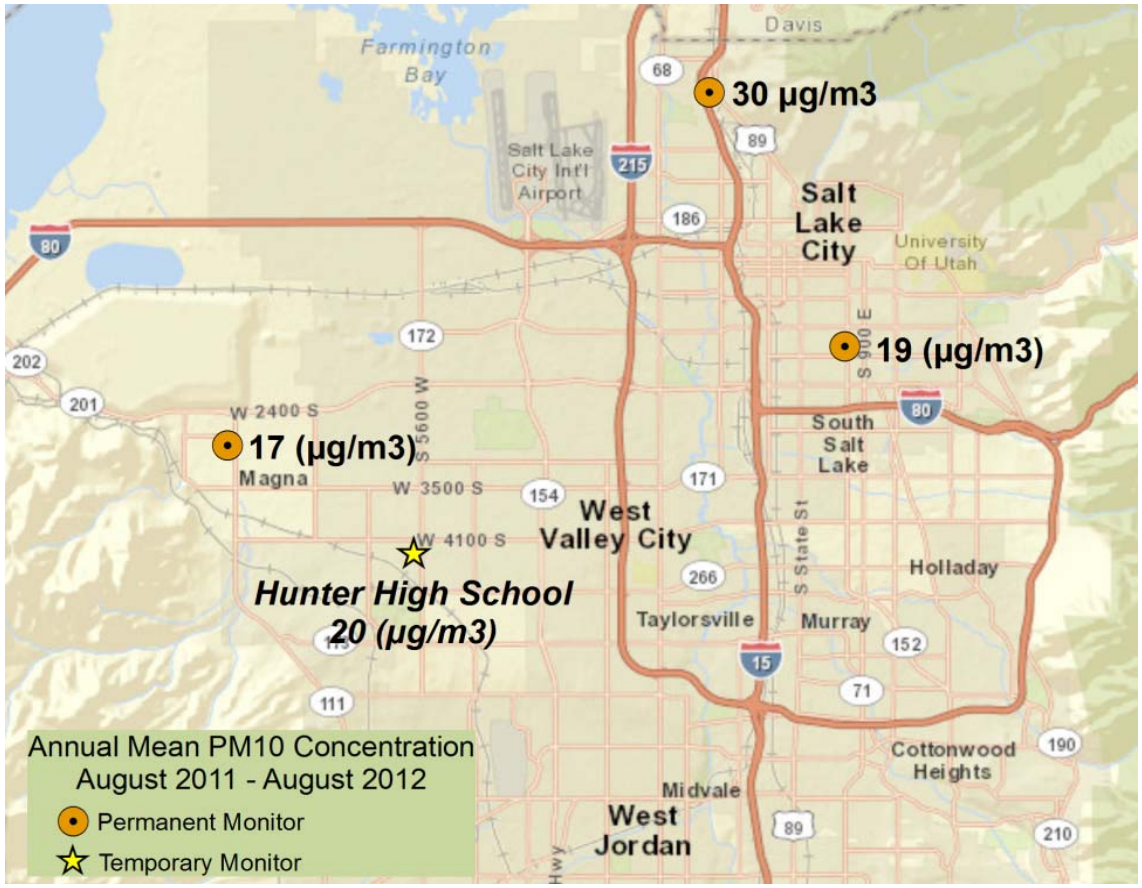
Influence of Wind Direction



Pollutant concentrations will be almost 3 times higher when winds are from the SSE, relative to winds from the east.

Background Air Quality:PM_{10}



PM_{10} annual average at Hunter HS similar to data at nearby sites.

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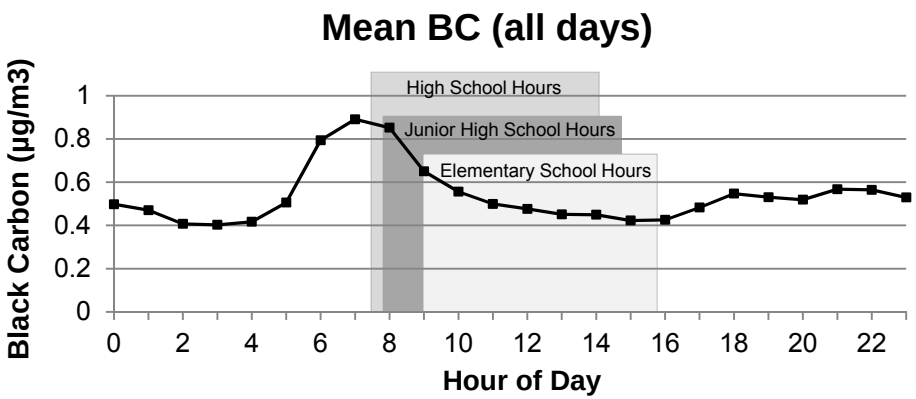
Comparison of BC Concentrations

Black carbon concentrations are highest during the morning rush hour.



Hunter High School: all data 8/2/2011-8/1/2012

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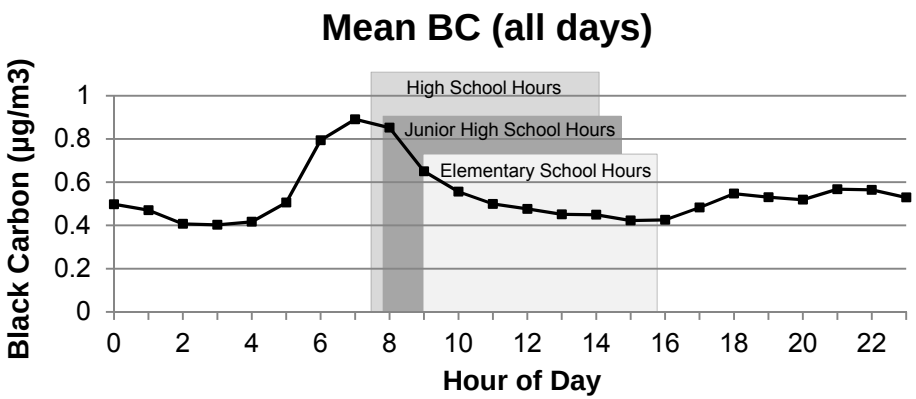
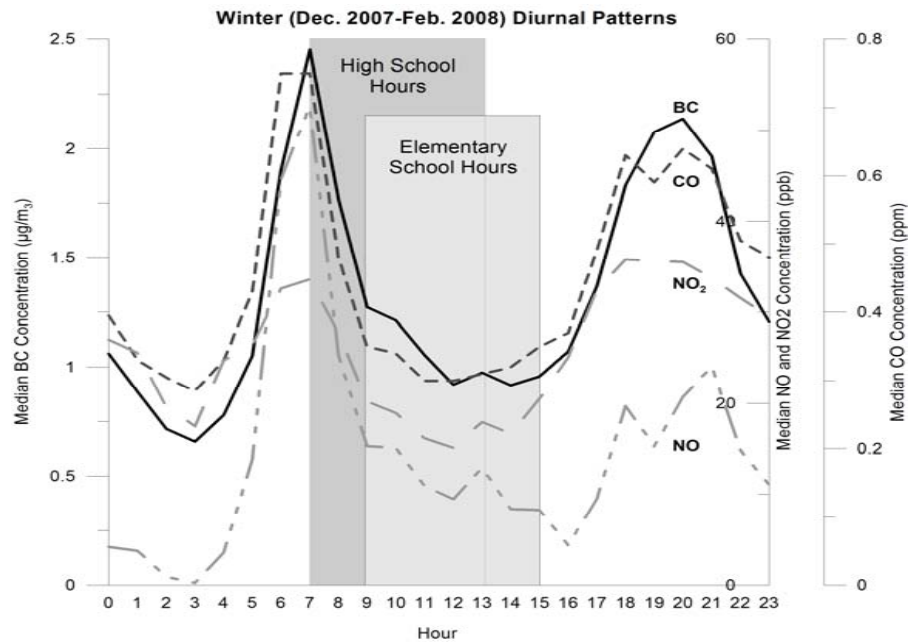
Comparison of BC Concentrations

Black carbon concentrations are highest during the morning rush hour.



Hunter High School: all data 8/2/2011-8/1/2012



Fyfe School, Las Vegas, NV: Dec 2007-Feb 2008

BC concentrations at Hunter High School (pre-roadway) are ⅓ to ½ of BC concentrations next to US 95 in Las Vegas, NV.

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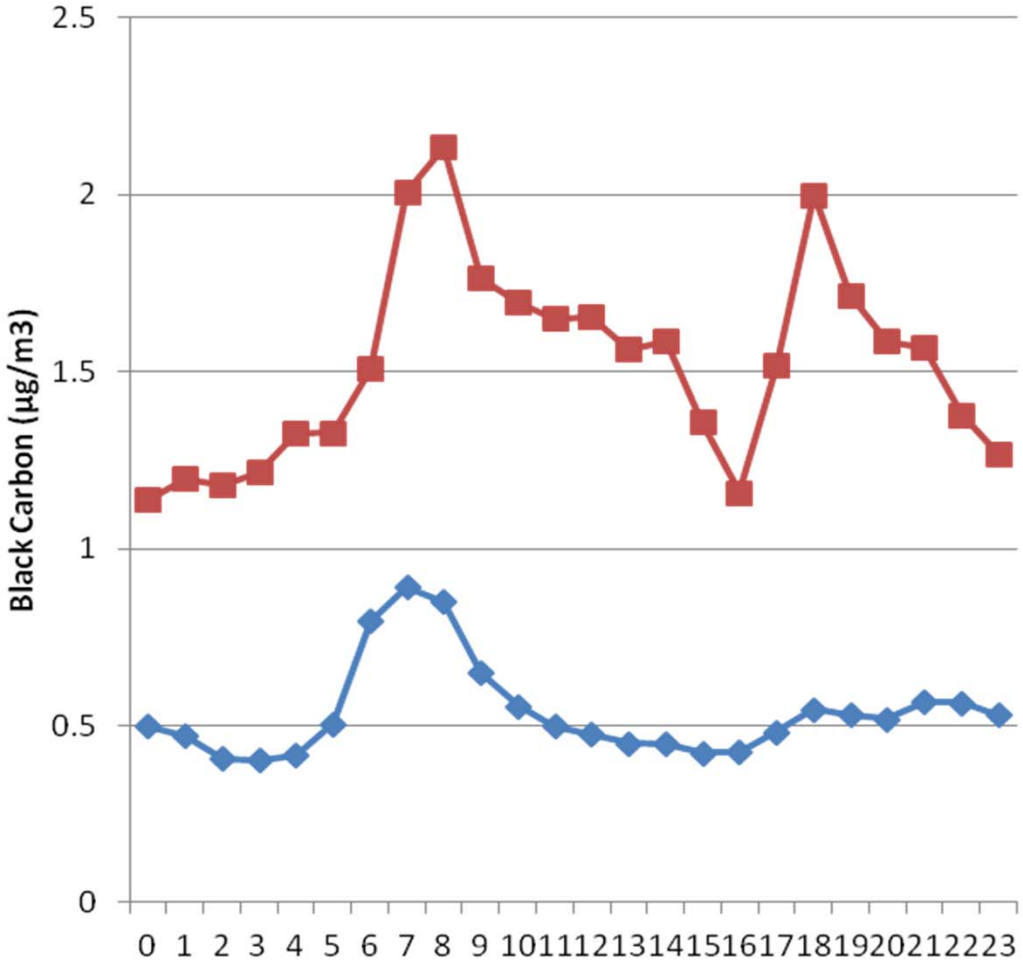
BC Episode Days



Days with highest 5% BC

Days with highest mean BC

Mean BC (all days)

All data 8/2/2011-8/1/2012

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Background Air Quality

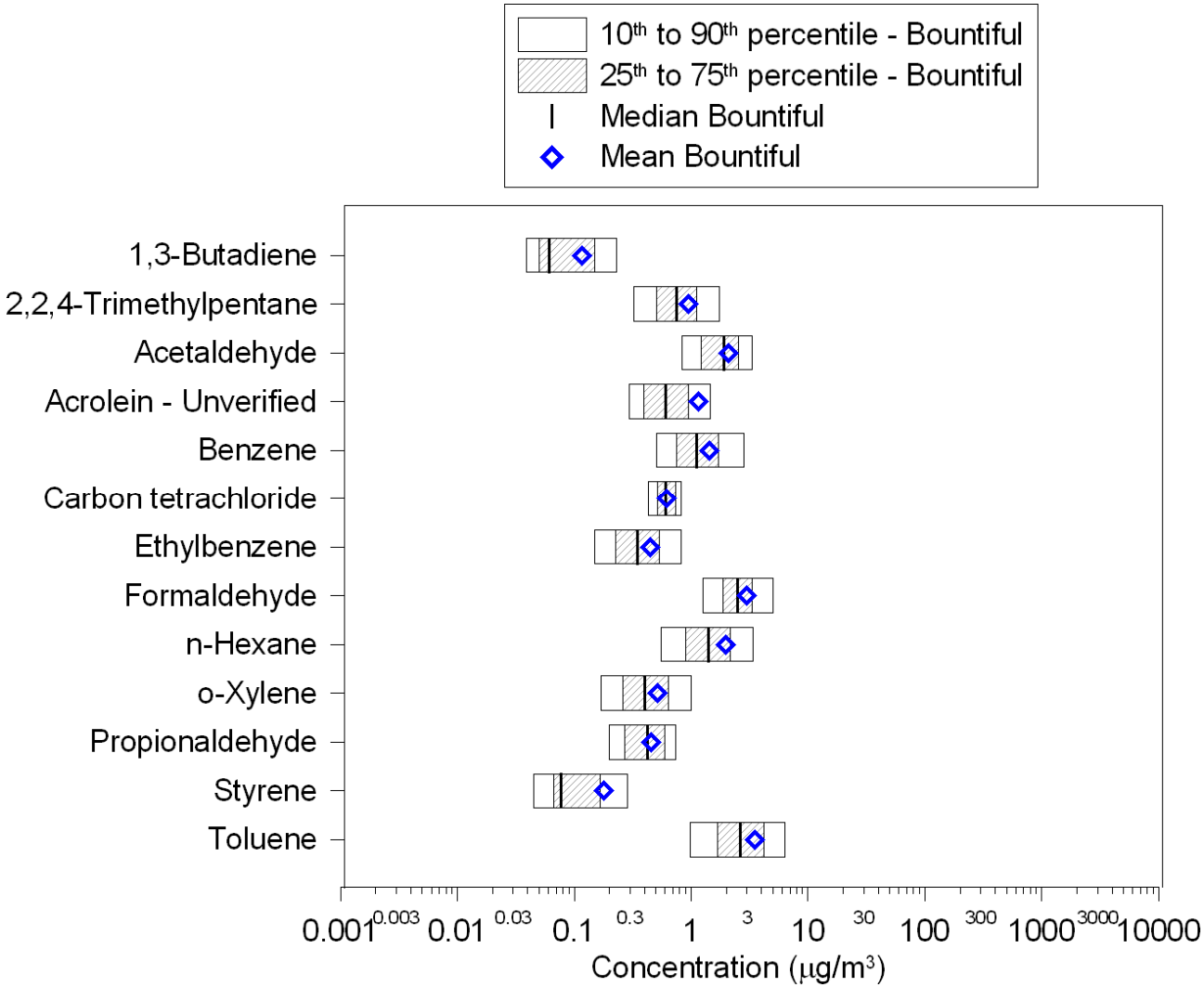
- Volatile organic compounds and carbonyls
  - Annual average characteristics
  - Comparisons with other Salt Lake City measurements
  - Comparisons with cancer and non-cancer benchmarks

VOCs and Carbonyls

- Begin with a graphic showing three years (2008-2010) of National Air Toxics and Trends Station (NATTS) from Bountiful, UT
- Add EPA OAQPS non-cancer reference concentration benchmarks
  - Exposure to concentrations at this level for 70 years would be expected to result in one additional non-cancer effect per million people, such as asthma, neurological effects, or reproductive effects. Concentrations below this level would result in a lower rate and concentrations above this level would result in a higher rate.
- Add EPA OAQPS 1-in-a-million cancer benchmarks
  - Concentrations at this level for 70 years would be expected to result in one additional case of cancer per million people. Concentrations below this level would result in a lower rate and concentrations above this level would result in a higher rate.
- Add Hunter High School data and compare

NATTS, Bountiful, UT

2008-2010



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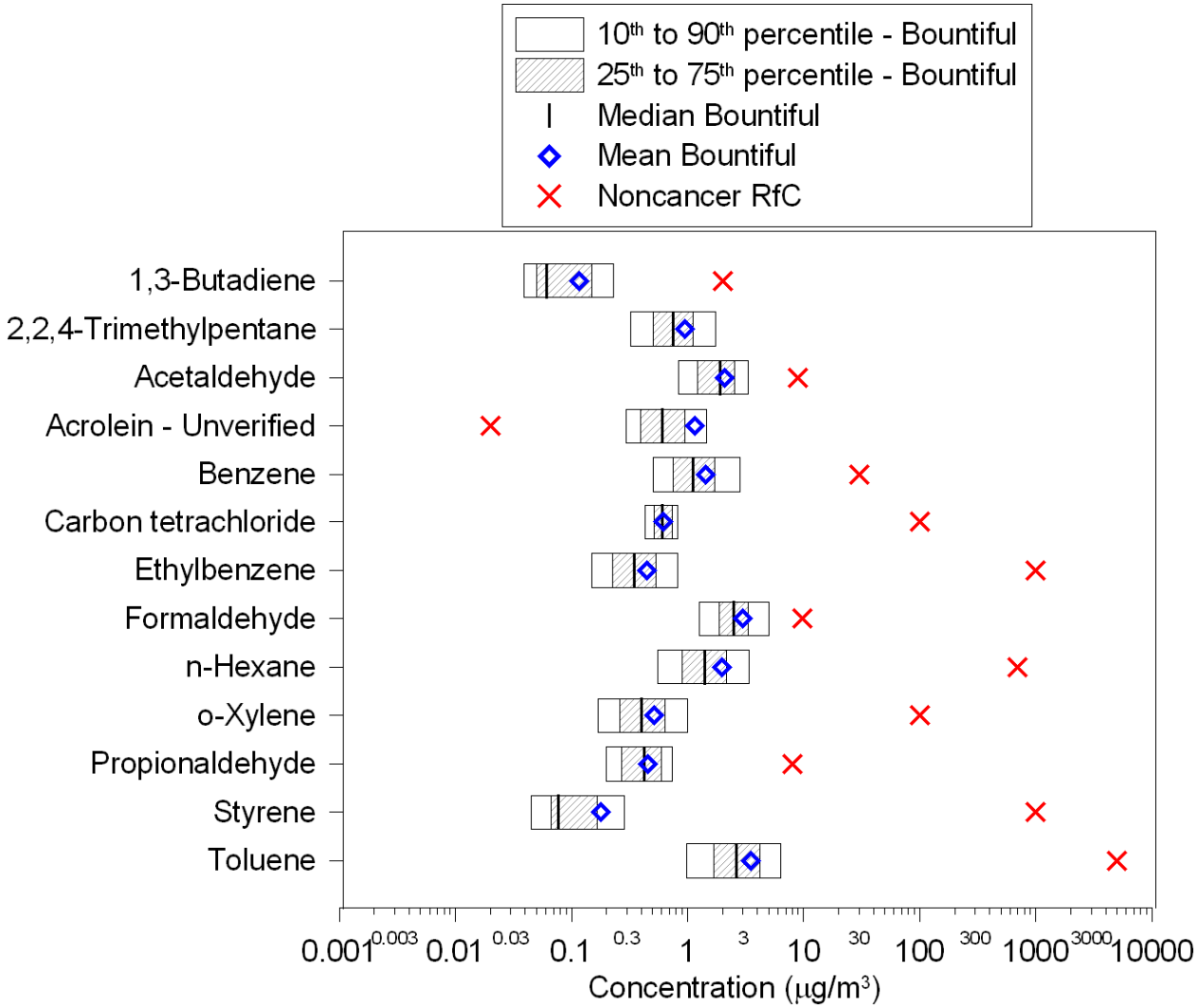
NATTS, Bountiful, UT

Showing EPA OAQPS non-cancer reference concentration benchmarks



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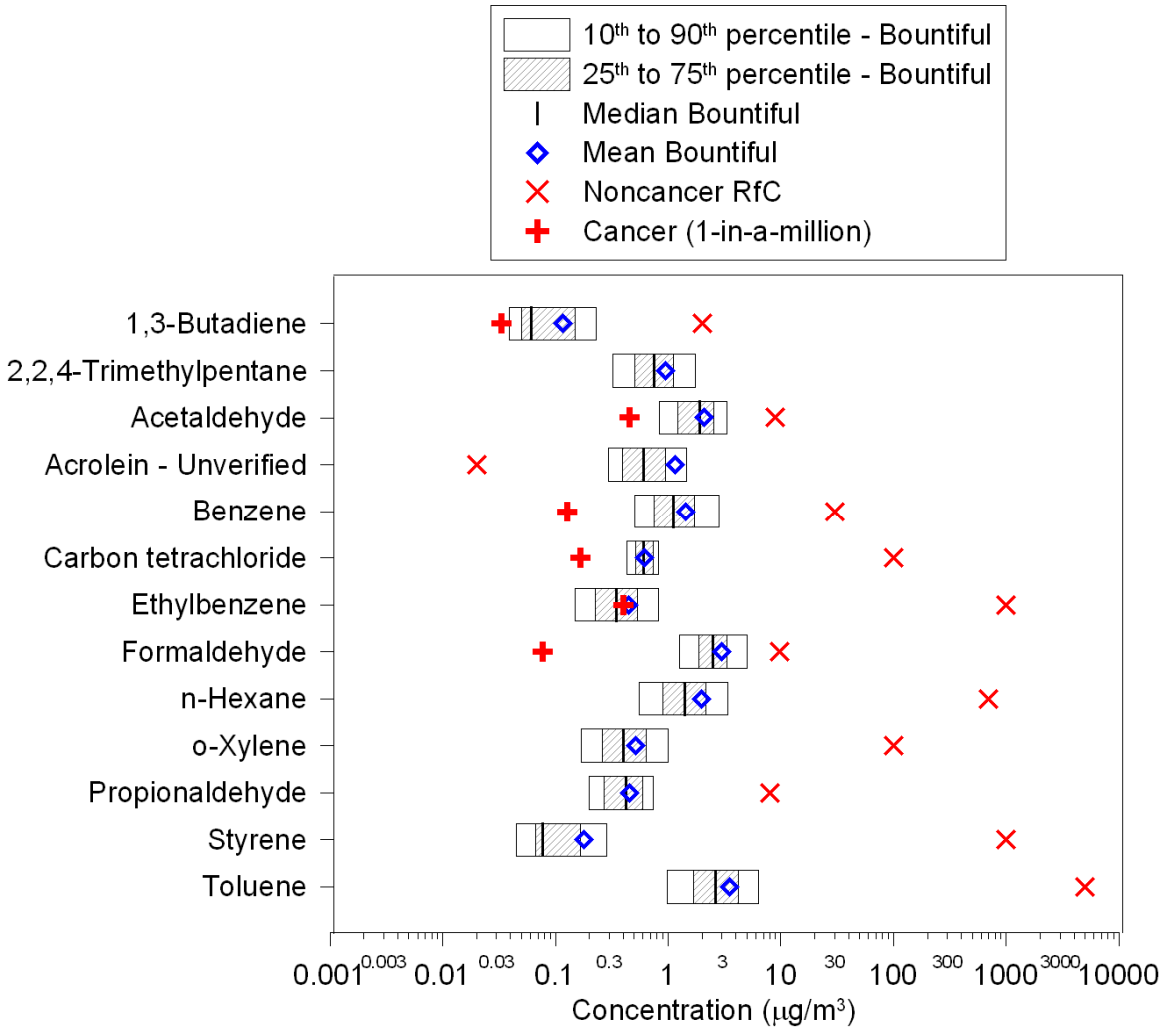
NATTS, Bountiful, UT

Showing EPA OAQPS cancer 1-in-a-million benchmarks



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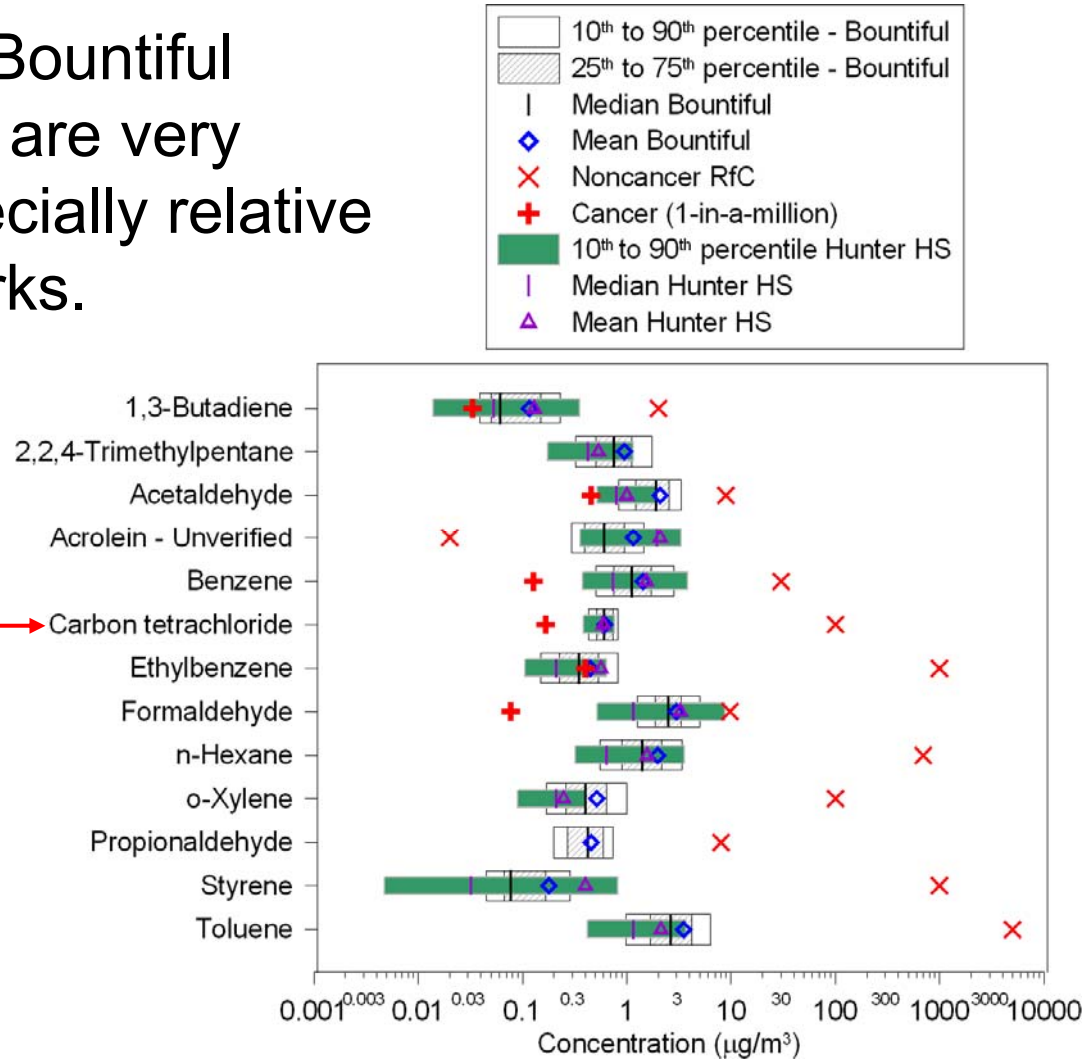
NATTS, Bountiful, UT

with Hunter High School Data

Hunter and Bountiful distributions are very similar, especially relative to benchmarks.

QC check: the same?



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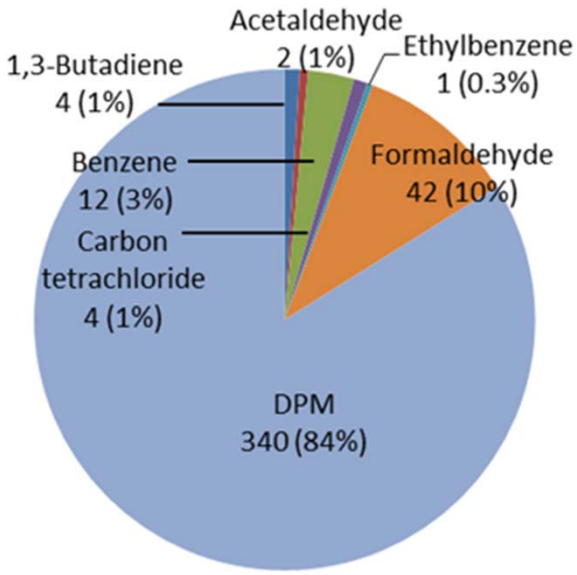
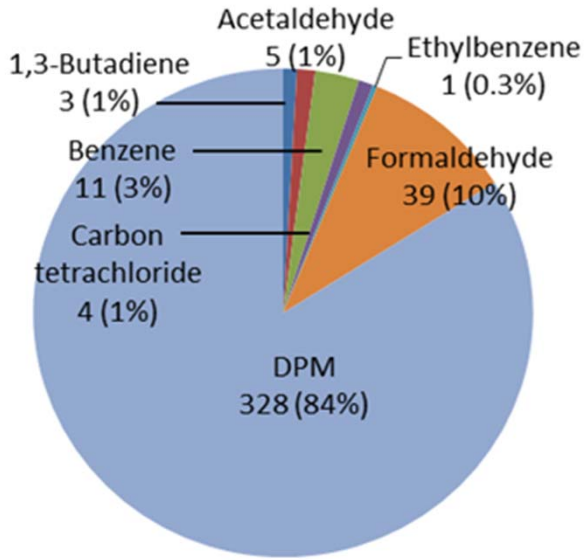
Diesel Particulate Matter is Greatest Contributor to Cancer Risk



(a) West Valley City



(b) Bountiful

Cancer one-in-a-million excess risk at (a) West Valley City (Hunter High School) and (b) Bountiful. The risk value, or chance in a million, and percent of the total risk are shown for each air toxic. DPM is the greatest contributor to cancer risk at 84% (using the California risk factor for DPM).

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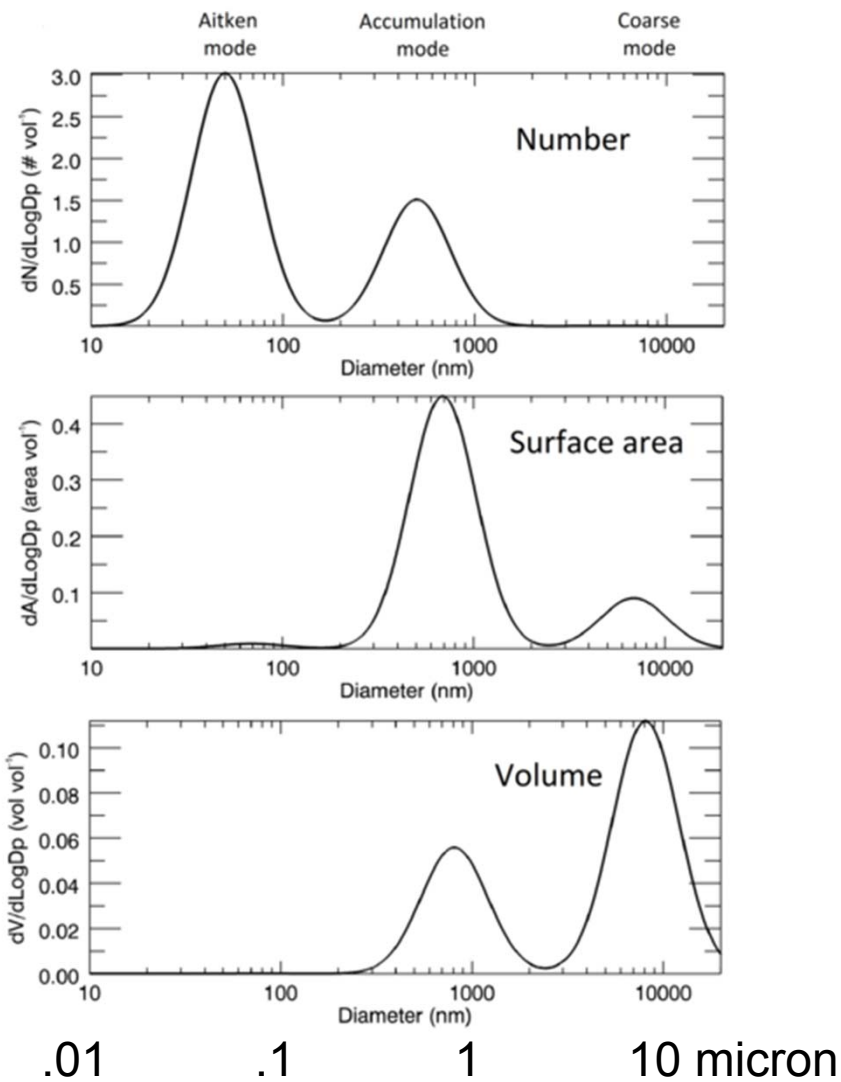
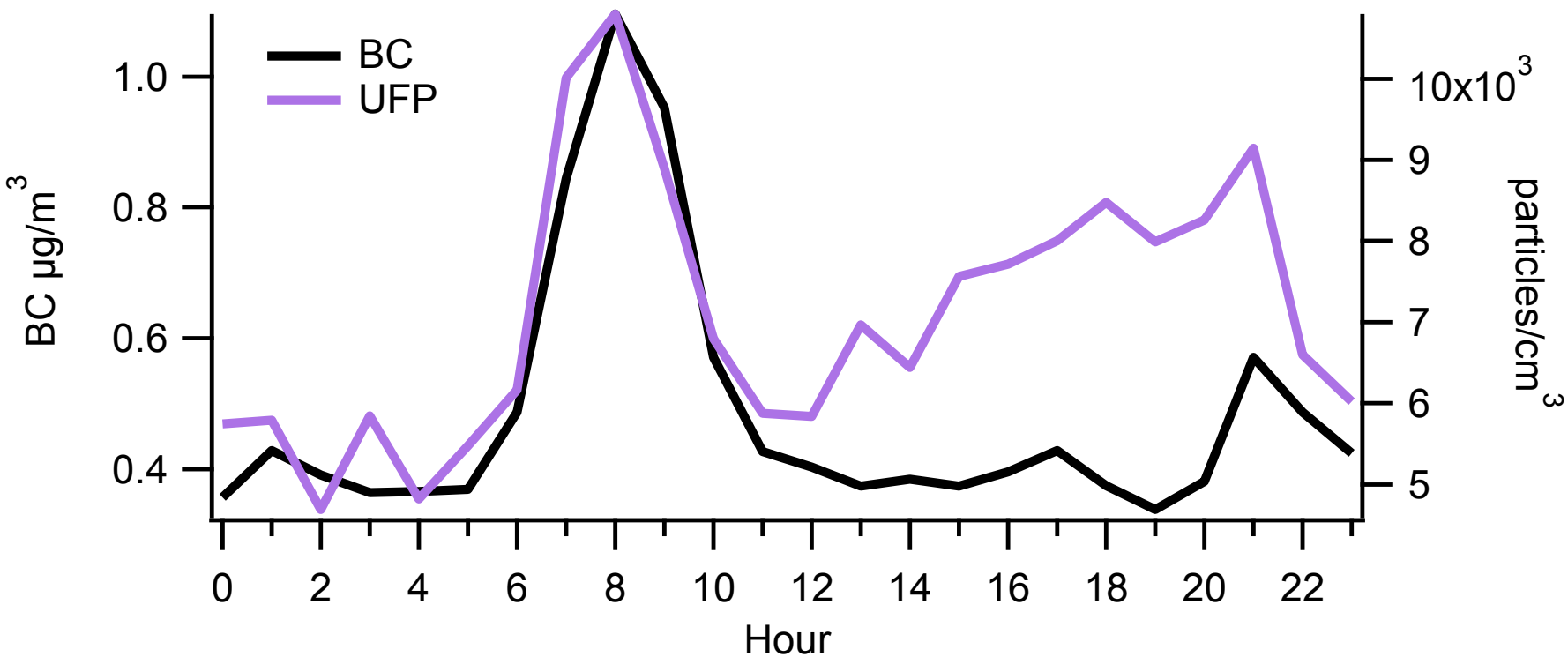
Ultra-Fine Particle Measurements

- Ultra-fine particles (UFPs) are suspected of causing short-term health effects (e.g., heart-rate variability).



Weekday Hourly Average Concentrations
2/9-2/24/13 at Hunter HS



BC and UFP typically have a morning peak, while UFP also has an evening peak.

Hourly data shown

Background Air Quality Summary

- Dominant winds from the south; secondary winds from the northwest.
- BC concentrations have a diurnal pattern.
- Obtained site-specific background concentrations for near-road pollutants of concern.
- As expected, background concentrations of roadway pollutants lower than at near-road locations, but are not zero.

Are Current HVAC Systems Good Enough at Removing Black Carbon (BC)?

School	Filtration Efficiency
Black Carbon	
Hillside Elementary	33.9%
Whittier Elementary	7.2%
Hunter Junior High	29.2%
Hunter High	25.6%
$PM_{2.5}$	
Hunter High	73.1%

Ambient and classroom BC and $PM_{2.5}$ concentrations and filtration efficiency in one classroom in each school, during school hours spring 2014.

Current HVAC Systems Remove 73% of $PM_{2.5}$, but only 7%-34% of Black Carbon

Up to 90%-95% of ambient black carbon was removed in Las Vegas near-road schools with improved HVAC systems and improved filters.

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Summary of Mitigation Task

- Objective: to design HVAC system modifications to remove outdoor black carbon particles from classroom air
- Steps in mitigation analysis:
  - Evaluate existing system design
  - Evaluate available filters and their performance specifications
  - Perform engineering and cost analysis of potential equipment to be upgraded
  - Evaluate sensitivity of costs to assumptions

Mitigation Recommendations

- HVAC system operations are critical for sufficient ventilation in classrooms.
- HVAC systems in portable classrooms are particularly critical.
- Improved filtration systems for portables being designed
- Estimated first cost plus incremental operating costs over 30 years.
- Total first costs of $430k, annual incremental cost of $35k; Net present value (NPV) of $1.8 million, including 10% contingency.

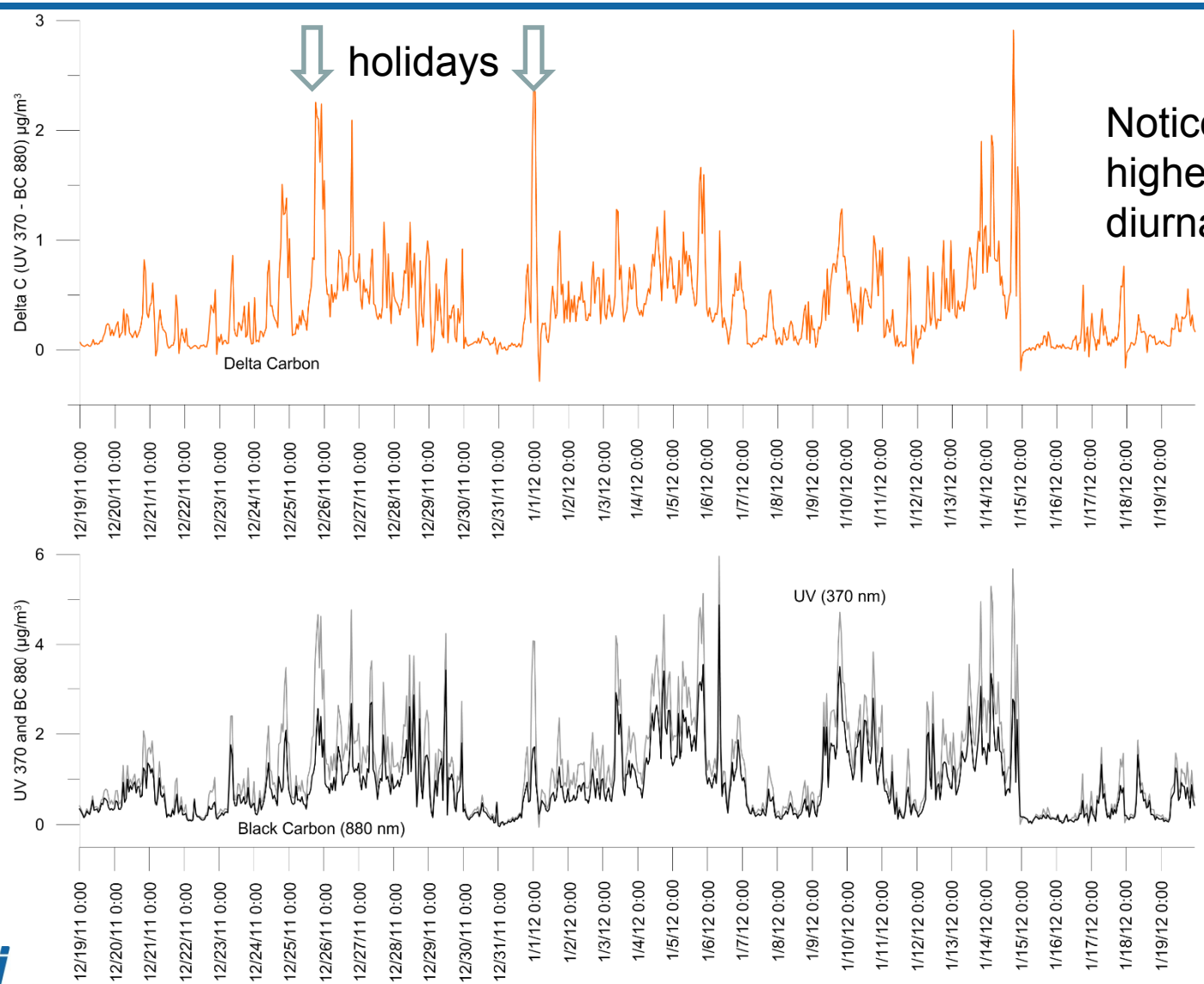
MVC Air Quality and Mitigation: Potential Next Steps

- Presentation and discussions between AWG and GSD (ongoing).
- Construction on MVC to begin in spring 2016 south of 4100 S. (near Hunter HS and Hillside).
- Implementation of mitigation plan in schools (once approved).
- Ambient monitoring to determine student exposure (after MVC is connected to I-80 or SR-201).
- Classroom and outdoor monitoring to demonstrate improved filter effectiveness.

Wood Smoke and Aethelometer Data

- Ran a multi-wavelength Aethelometer 8/2/2011-8/1/2012 (light absorption).
- At Hunter HS (West Valley City).
- Several methods to estimate wood smoke contribution from Aethelometer data.
- Simplest method: difference between UV channel (370 nm) and black carbon (880 nm), Delta-C.

BC, UV, and Delta-C: Winter 2011-2012



Notice episodes: higher baseline and diurnal peaks

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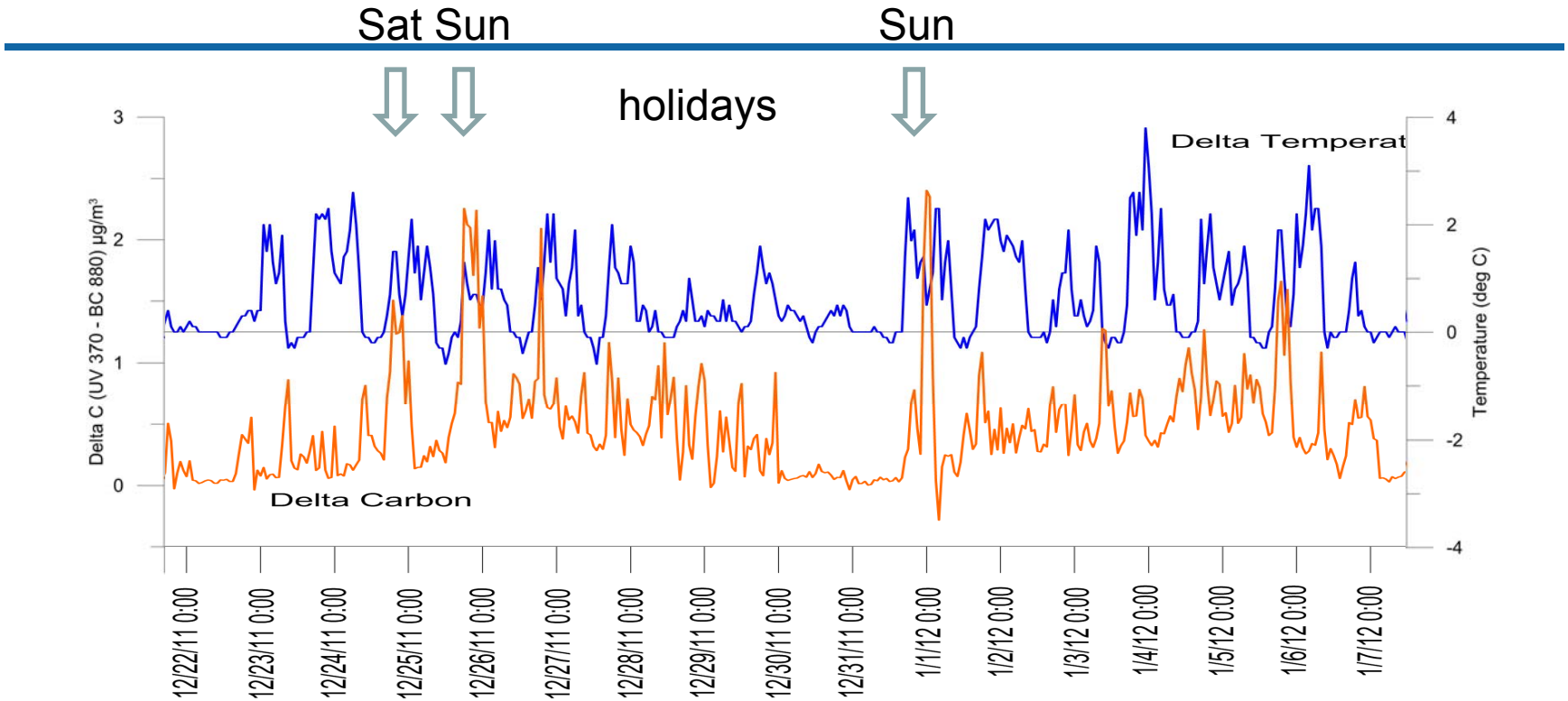
Wood Smoke Contribution for Holidays



Delta Carbon is an indicator of wood smoke.

Delta Temperature is an indication of an inversion.

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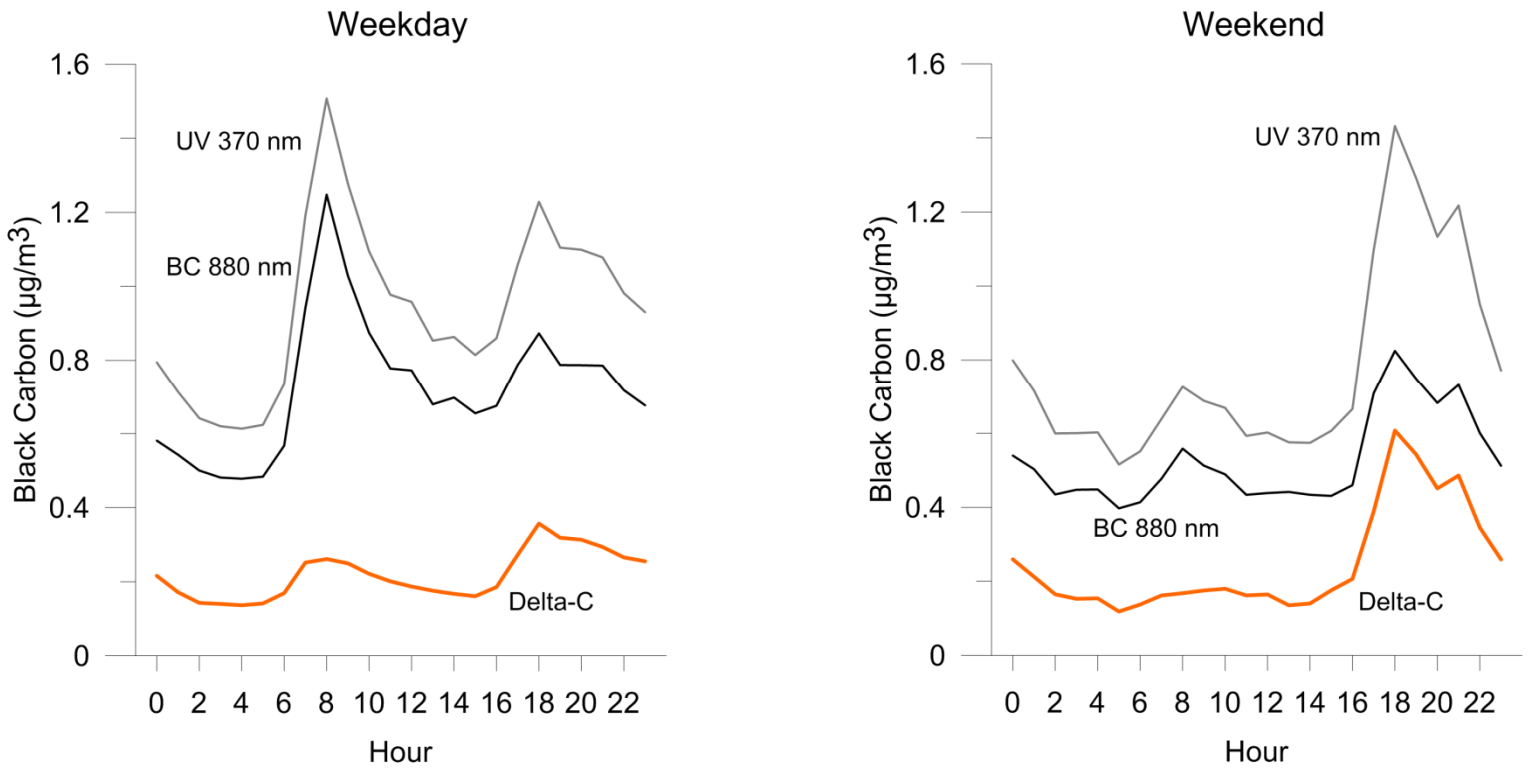
Mean Diurnal Pattern in BC, UV, and Delta-C



- *Nov. 2011 – Feb. 2012*
- *weekend includes Saturday/Sunday*

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Summary of Wood Smoke Results

- Delta-C provides an indication of wood smoke.
- Delta-C increases during weekend evenings (Friday-Sun) and holidays.
- Less indication of wood smoke on evenings during the week.
- Possibly some interference in the delta-c signal during the week due to vehicle emissions.
- Few episodes during this winter but meteorology contributes to high concentrations.

Wood Smoke: Potential Future Steps

- Explore other methods to estimate wood smoke contribution (levoglucosan, potassium, other absorption calculations).
- Monitor black carbon (and collocated $PM_{2.5}$) before/during/after burn bans.
- Understand residential burning patterns (types of stoves, wood types, temporal patterns, compliance with burn bans).

Summary of Background (Pre-Construction) Air Quality and Classroom Measurements

- Diesel particulate matter (DPM) is the greatest contributor to cancer risk from air toxics now. Contribution will be larger with MVC.
- We measured black carbon (BC) as a surrogate for DPM.
- Current HVAC systems remove 73% of $PM_{2.5}$ but only 7-34% of black carbon.
- 90-95% of ambient black carbon was removed in Las Vegas near-road schools with improved HVAC systems and improved filters.

Overview of Today's Presentation

- Background: Why is near-road pollution of concern?
- Background on the Mountain View Corridor (MVC) Air Working Group (AWG).
- Summary of pre-construction outdoor air quality at Hunter High School.
- Current filtration systems' capability to remove diesel particulate matter (DPM).
- Mitigation recommendations for schools.
- Wood smoke in West Valley City

Backup Slides for GSD Presentation

HEI Panel on the Health Effects of Traffic-Related Air Pollution

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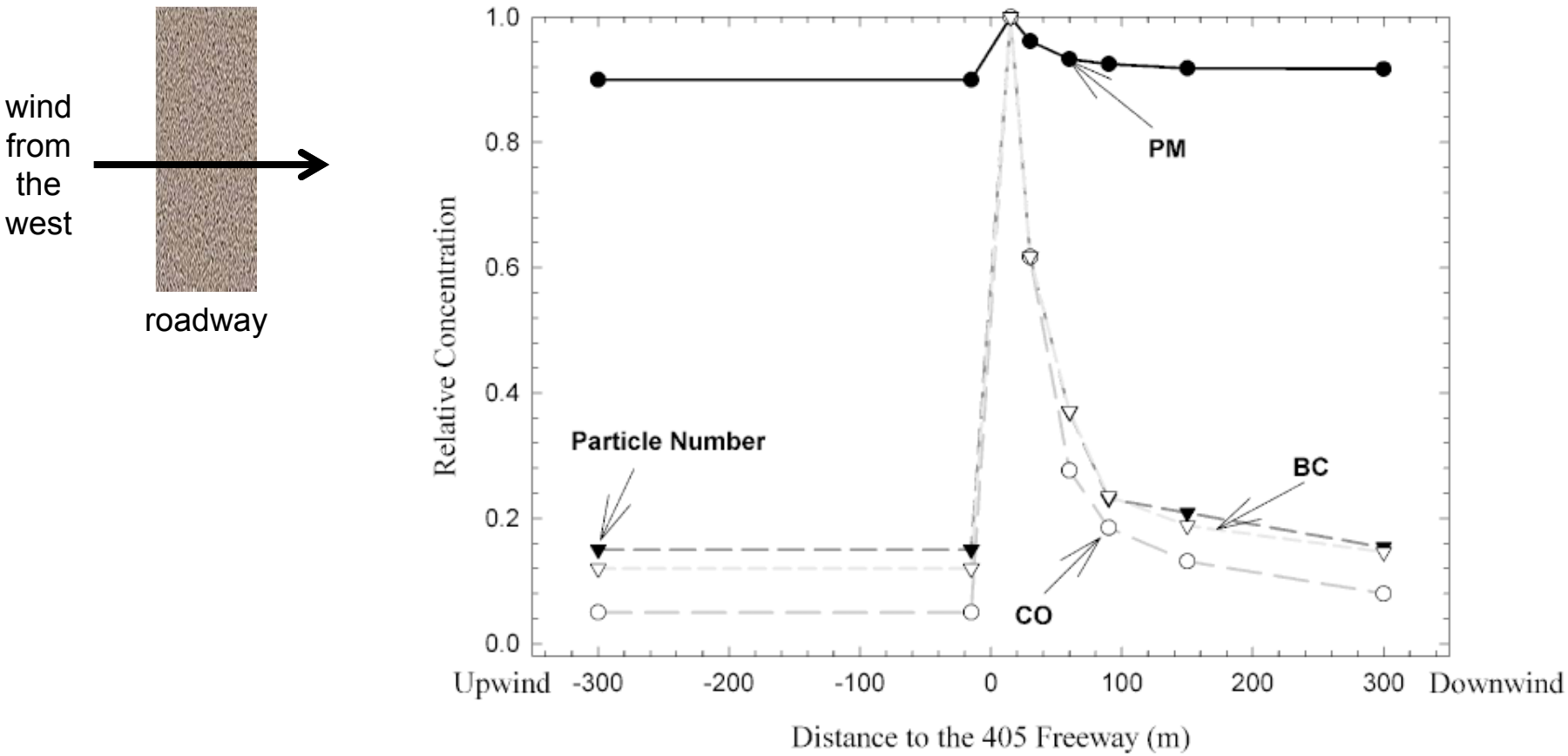
- Additionally, there is suggestive evidence of a causal link between near-roadway air pollution and
  - the onset of childhood asthma,
  - all-cause mortality,
  - cardiovascular mortality and morbidity,
  - other respiratory problems, and
  - impaired lung function,

  but more research is needed to confirm that traffic-related air pollution is the cause of these health problems.

From: HEI Panel on the Health Effects of Traffic-Related Air Pollution (2010) Traffic-related air pollution: a critical review of the literature on emissions, exposure, and health effects.

Challenge: Gradients Near Roadways



Zhu et al. (2002) Study of ultrafine particles near a major highway with heavy-duty diesel traffic. *Atmos. Environ.,* 36(27), 4323-4335, September.

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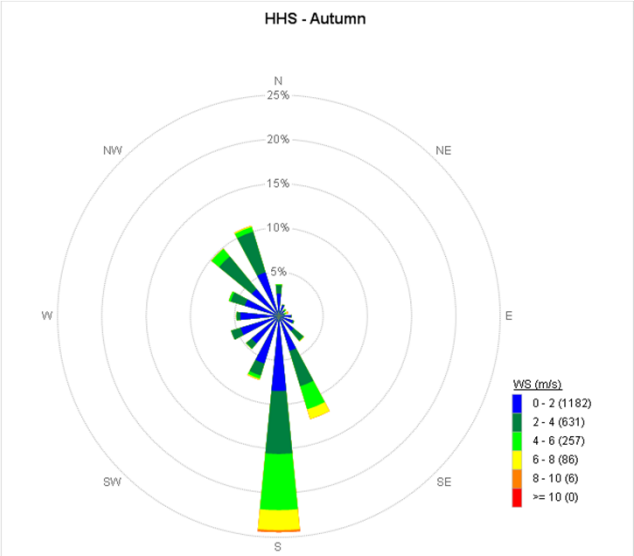
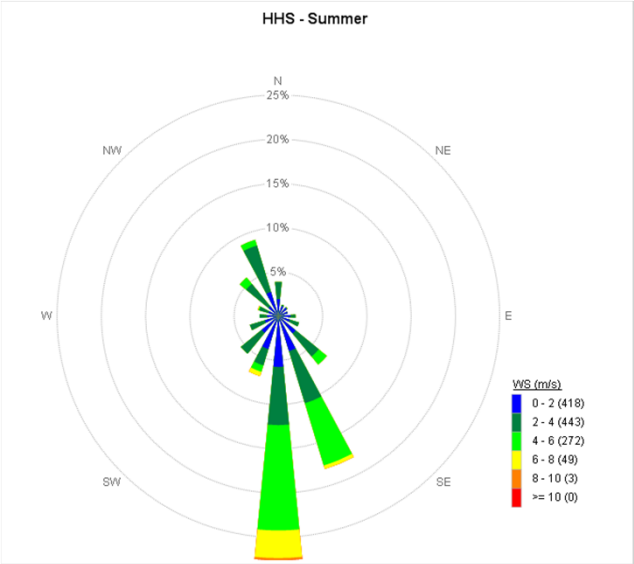
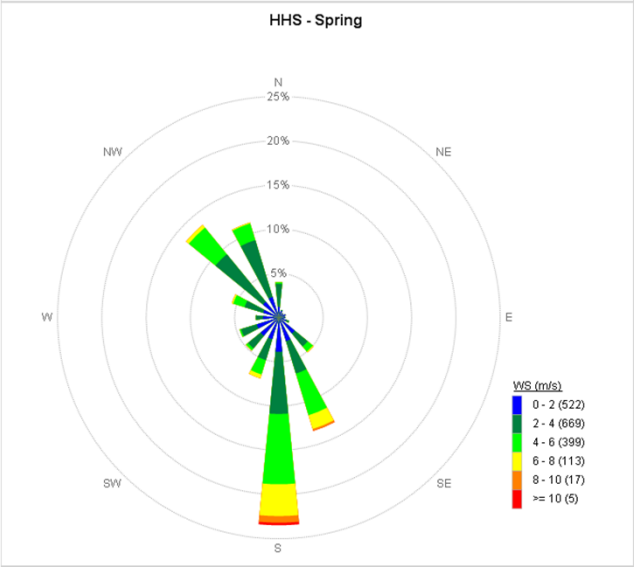
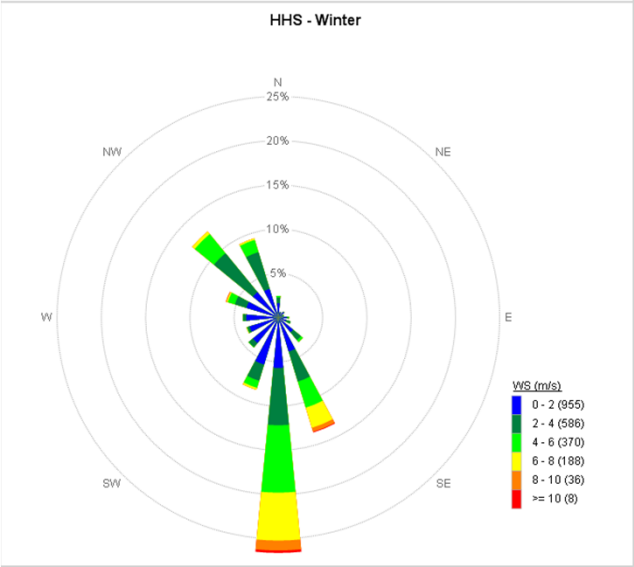
Wind Comparison Maps (2 of 2)

Hunter HS: Few seasonal differences, but lower wind speeds in fall & winter









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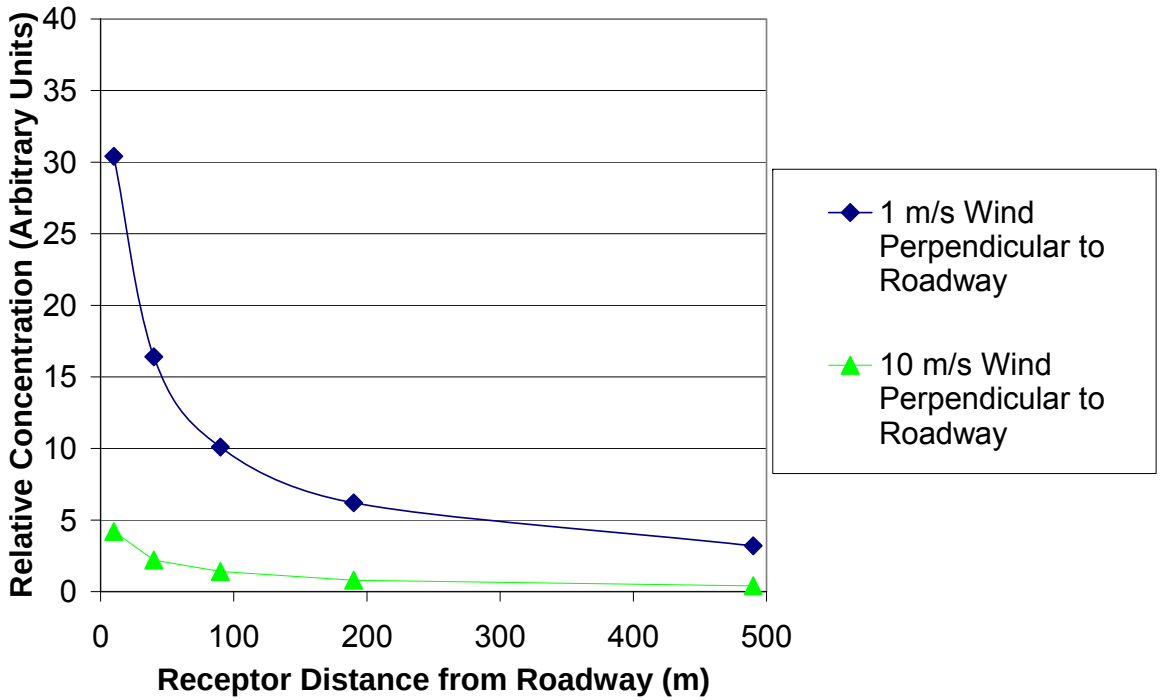
Data Analysis / Early Concept Work



Pollutant concentrations vary with **wind speed** and **road distance.**
CAL3QHC model results, no background concentrations.

From: Tamura T.M. and Eisinger D.S. (2003) Transportation-related air toxics: case study materials related to US 95 in Nevada. Revised Final White Paper prepared for the U.S. Federal Highway Administration Office of Natural Environment, Washington, DC, by Sonoma Technology, Inc., Petaluma, CA, STI-902370-2308-RFWP, March.

Annual and Seasonal Air Quality

Higher BC concentrations during the winter (Dec-Feb). Winter mean is ~ 28% higher than annual mean.

Statistic	BC	PM_{10}	PAH	CO_2
	µg/m³	µg/m³	ng/m³	ppm
	8/2/2011 - 8/1/2012	8/6/2011 - 7/31/2012	8/2/2011 - 4/5/2012	8/2/2011 - 8/1/2012
N	8763	8412	5865	8166
Minimum	-0.08	-3	1.61	362
Maximum	12.88	771	109.64	491
Mean	0.54	19.71	4.78	403.89
Median	0.37	15	3.19	400
St. dev.	0.54	25.45	4.75	13.79

Seasonal Mean	BC	PM_{10}	PAH	CO_2
Aug. 2011	0.67	25.84	3.52	403.37
Fall	0.61	15.94	4.75	404.74
Winter	0.69	20.36	5.85	413.12
Spring	0.37	16.58	3.2	400.33
June-July 2012	0.39	26.6		394.78

PM_{10} missing data in Aug 2011
PAH only 5 days in April
CO_2 only 70-80% of data in Oct-Nov

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Concentrations During School Hours

BC and PM_{10} concentrations during school hours were very similar to winter seasonal highs.

Statistic	BC µg/m³	PM_{10} µg/m³	PAH ng/m³	CO_2 ppm
N	2239	2169	1744	2084
Minimum	0.01	-2	1.89	365
Maximum	12.88	502	109.64	487
Mean	0.67	20.35	6.51	402.59
Median	0.47	17	4.5	399
St. dev.	0.65	23.6	6.03	13.58

PTR2

8/22/11 – 6/1/12, inclusive
M-F only
6 a.m. to 6 p.m.
Excluding (all ranges are inclusive):
10/20/11-10/21/11
10/23/11-10/25/11
11/23/11-11/25/11
12/23/11-1/2/12
4/3/12-4/6/12

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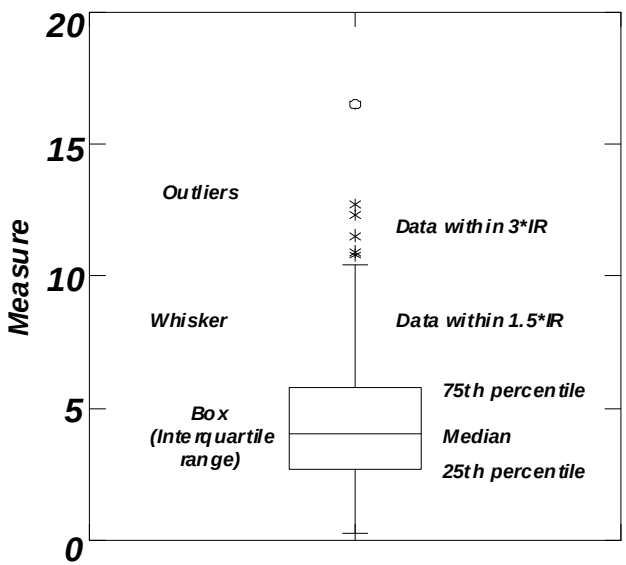
Slide 48

PTR2 Chelsea: can you highlight mean row like previous slide?
Paul Roberts, 12/13/2013

ptr3

Description of a Box Whisker Plot



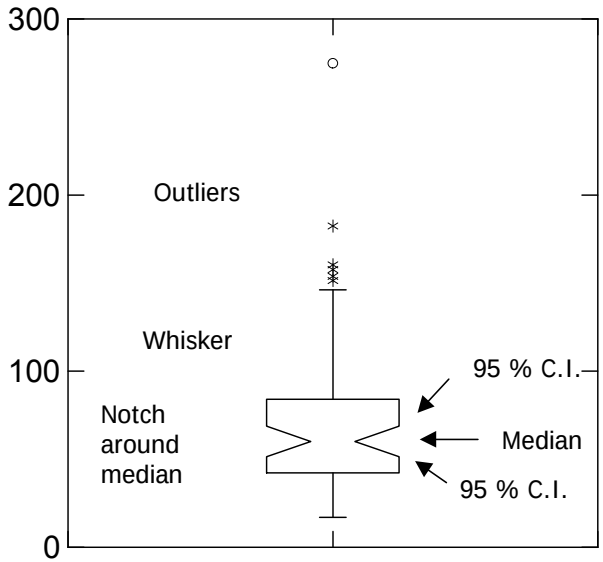


Illustration of box whisker plots and notched box whisker plots used in this project.

In box whisker plots (an example is shown here), the box shows the 25th, 50th (median), and 75th percentiles. The whiskers always end on a data point, so when the plots show no data points beyond the end of a whisker, the whisker shows the value of the highest or lowest data point. The whiskers have a maximum length equal to 1.5 times the length of the box (the interquartile range). If there are data outside this range, the points are shown on the plot and the whisker ends on the highest or lowest data point within the range of the whisker. The "outliers" are further identified with asterisks representing the points that fall within three times the interquartile range from the end of the box and with circles representing points beyond this.

Because we were interested in how similar or dissimilar the data are among time periods, we used an option called a notched box whisker plot to analyze data in this study. These plots include notches that mark confidence intervals. The boxes are notched (narrowed) at the median and return to full width at the 95% lower and upper confidence interval values. If the 95% confidence interval is beyond the 25th or 75th percentile, then the notches extend beyond the box (hence a "folded" appearance). Confidence intervals are a function of sample size; small sample size will increase these intervals.

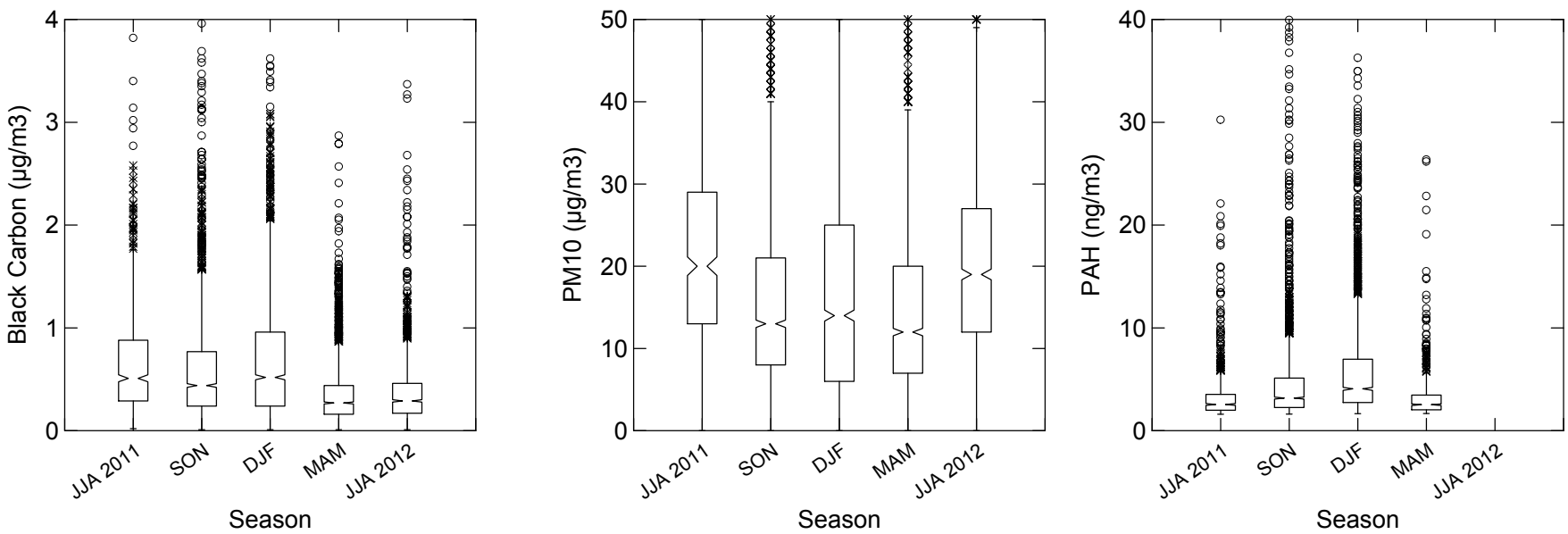
Slide 49

CBJ2 Is anyone going to be able to read all this text? Also, there's a reference to Figure B-1, which isn't here.
Chelsea B. Jennings, 12/12/2013

ptr3 detailed text for reading later in hard copy. B-1 ref eliminated.
Paul Roberts, 12/15/2013

Seasonal Air Quality Concentrations

- BC highest in fall and winter.
- PM_{10} highest in winter (primary PM) and summer (primary plus secondary).
- PAH highest in winter.



All data 8/2/2011-8/1/2012

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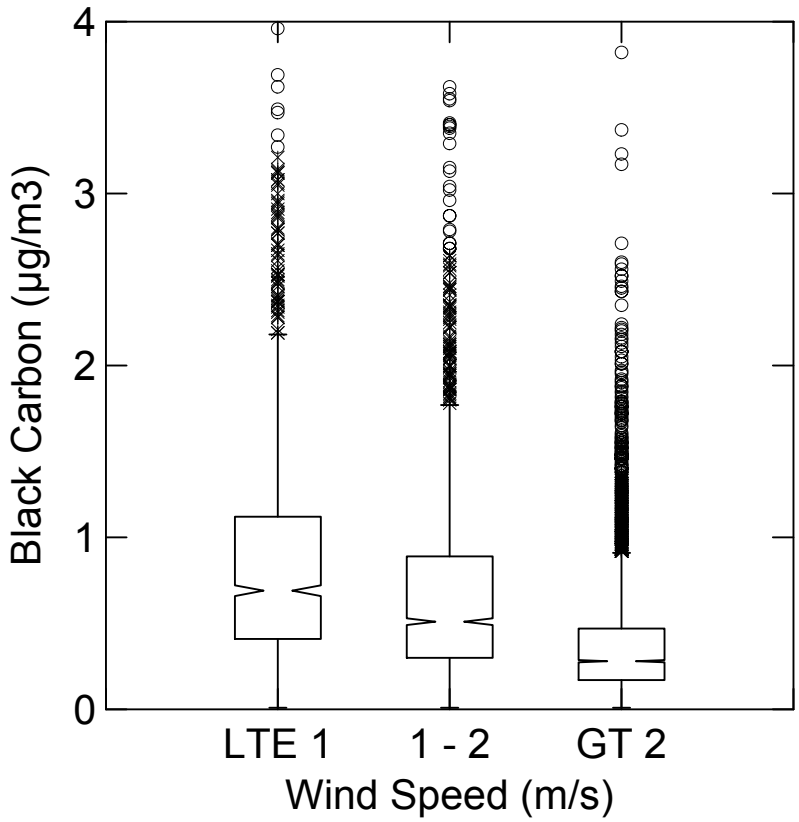
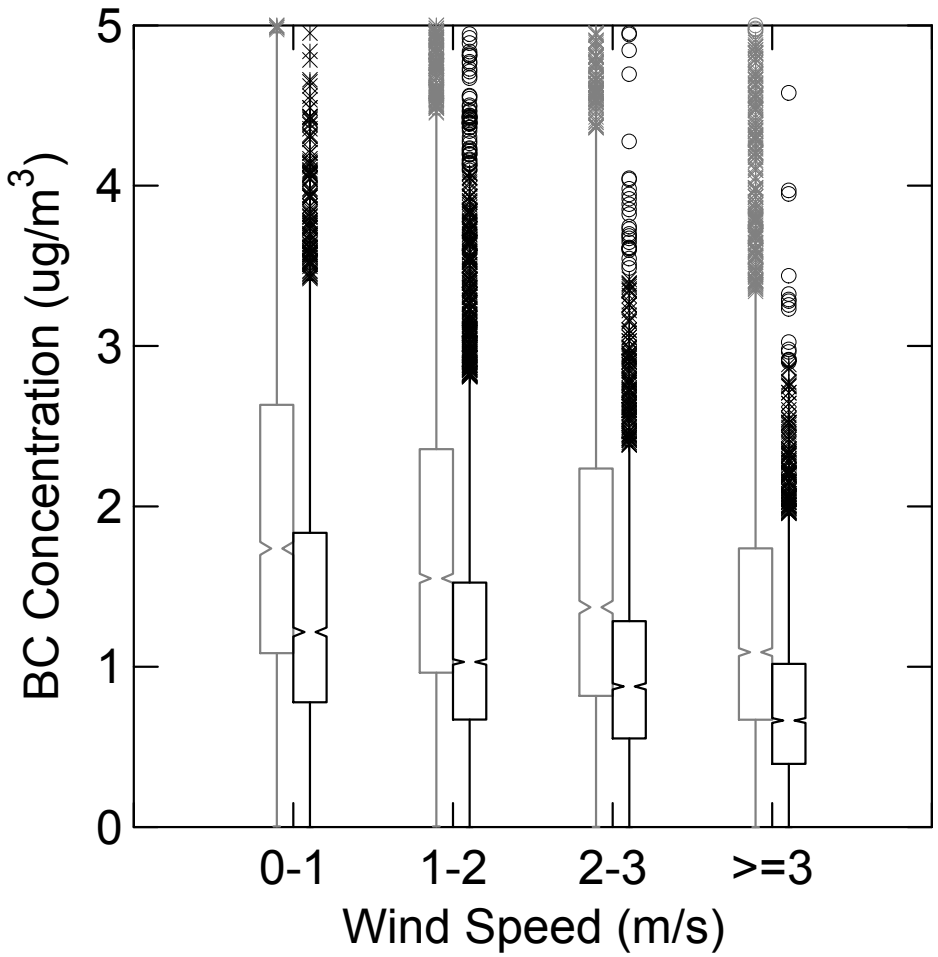
BC Concentrations by Wind Speed



Hunter HS data 8/2/2011-8/1/2012



Fyfe data next to US 95 Las Vegas
(Summer 2007, gray; Summer 2008, black)

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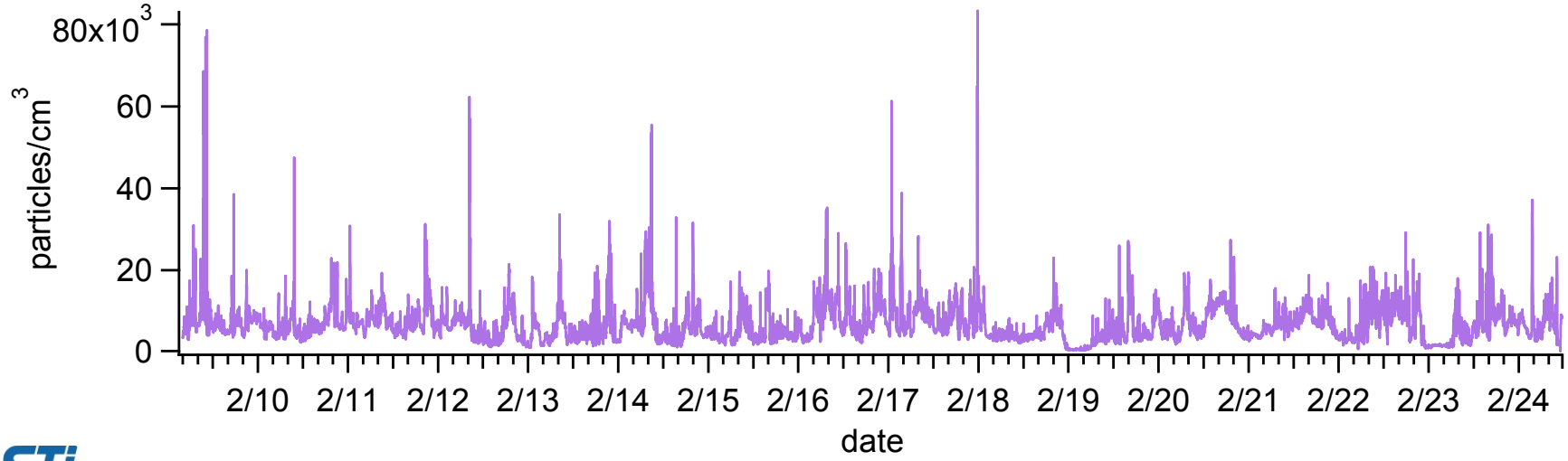
Ultra-Fine Particle Measurements

- UFPs measured by Teledyne-API model 651 water-based condensation nuclei counter.
- Measures particles from 0.007-3 μm.
- Grows particles with water, then counts them with a laser.

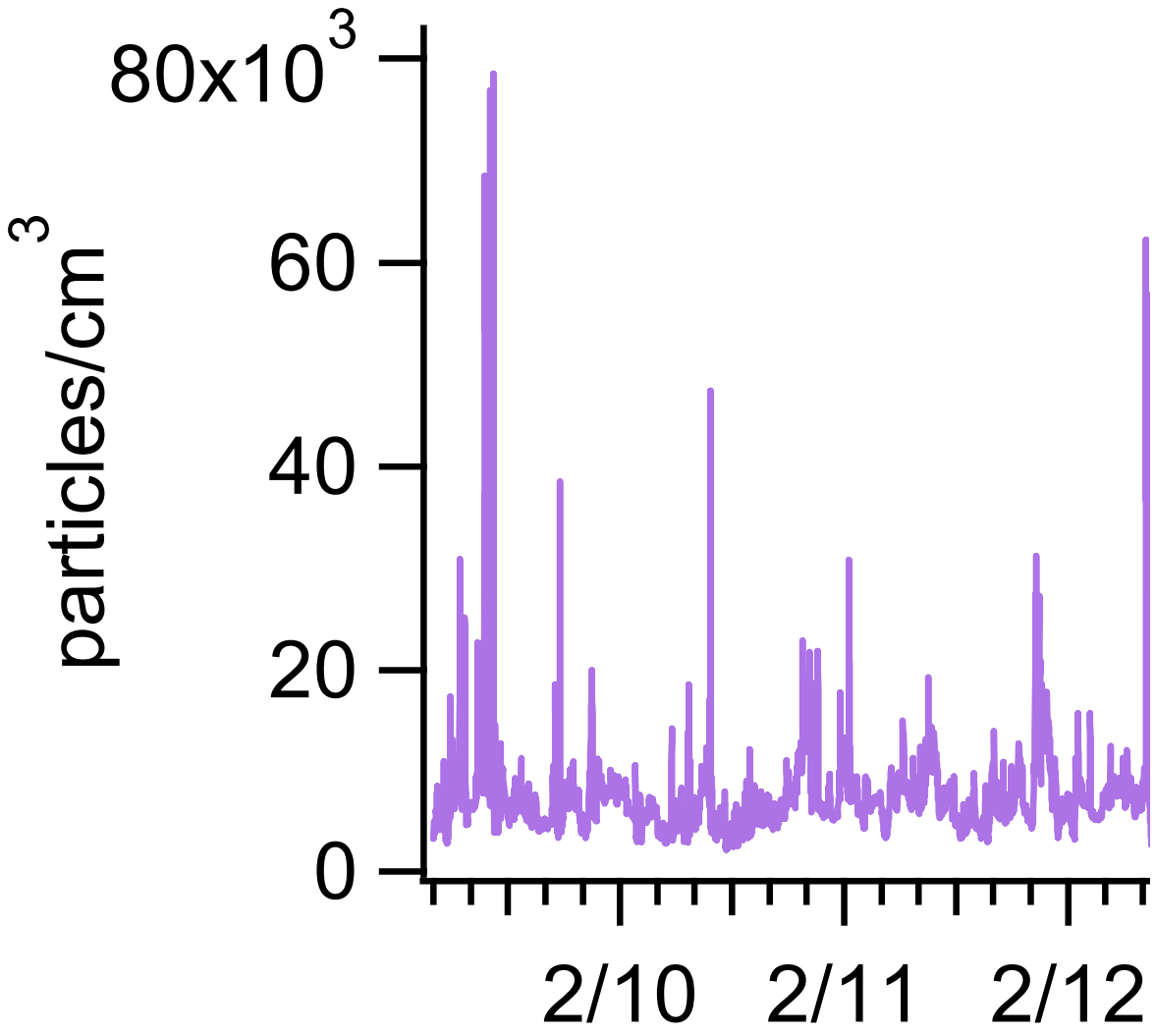
Ultra-Fine Particle Measurements

- UFP data collected from 2/9-2/24
- Max hourly value = 19,587 particles/cm^3
- Average hourly value = 6,755 particles/cm^3
- Compare next to US 95 during spring 2013 average hourly value = 11,022 particles/cm^3



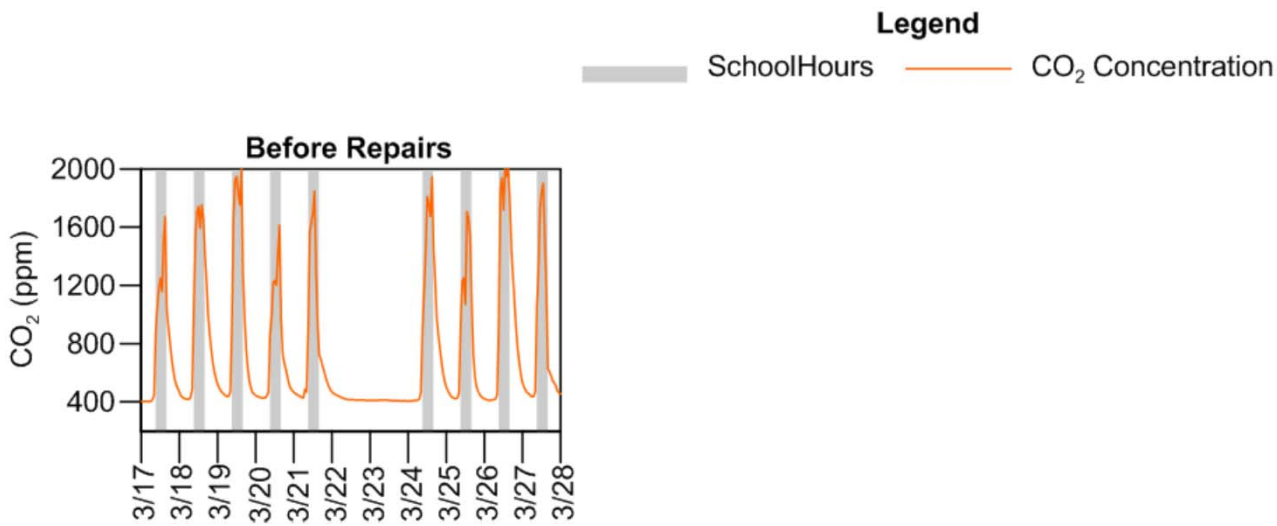
5-minute data shown

UFP Concentrations are Highly Variable



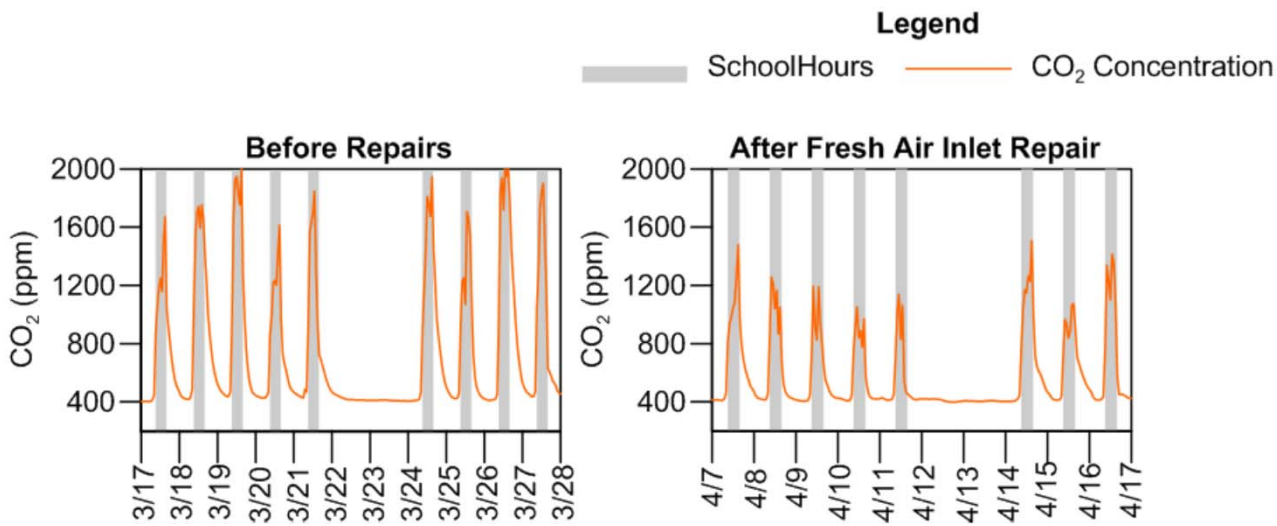
5-minute data shown

CO_2 Concentration and Ventilation Rate



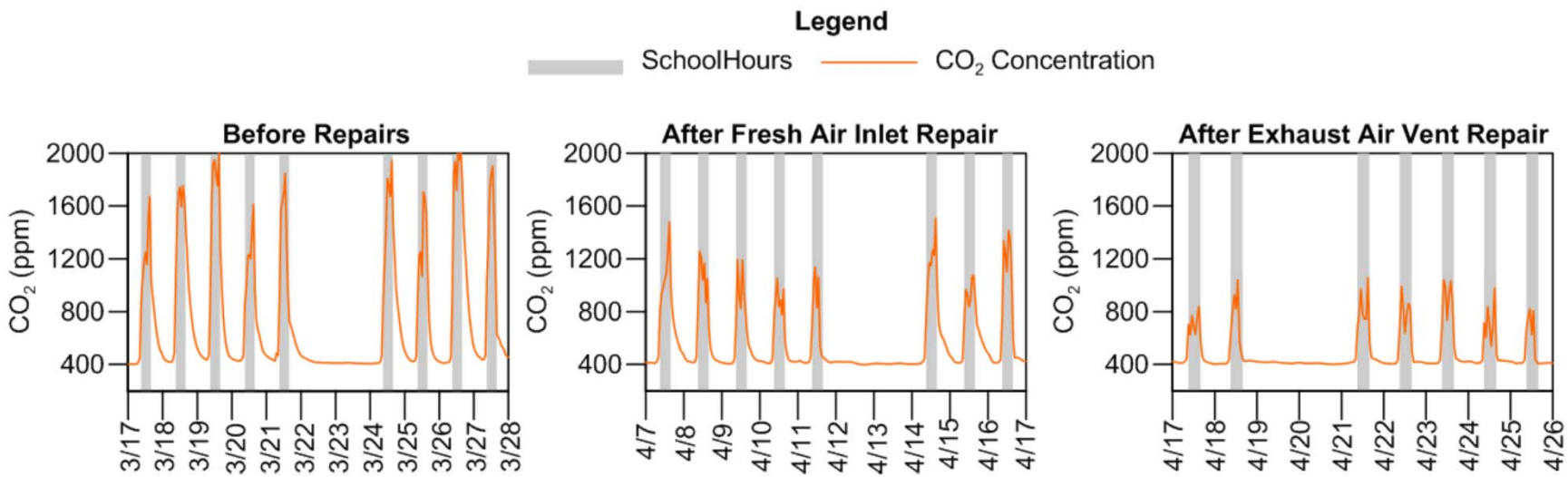
- Initially, CO_2 concentrations in Room 107 at Hillside were reaching 1800-2000 ppm each day (left graph).

CO_2 Concentration and Ventilation Rate



- Initially, CO_2 concentrations in Room 107 at Hillside were reaching 1800-2000 ppm each day (left graph).
- After repair of the fresh air inlet operating system, CO_2 concentrations were reaching 1000-1400 ppm each day (middle graph).

CO_2 Concentration and Ventilation Rate



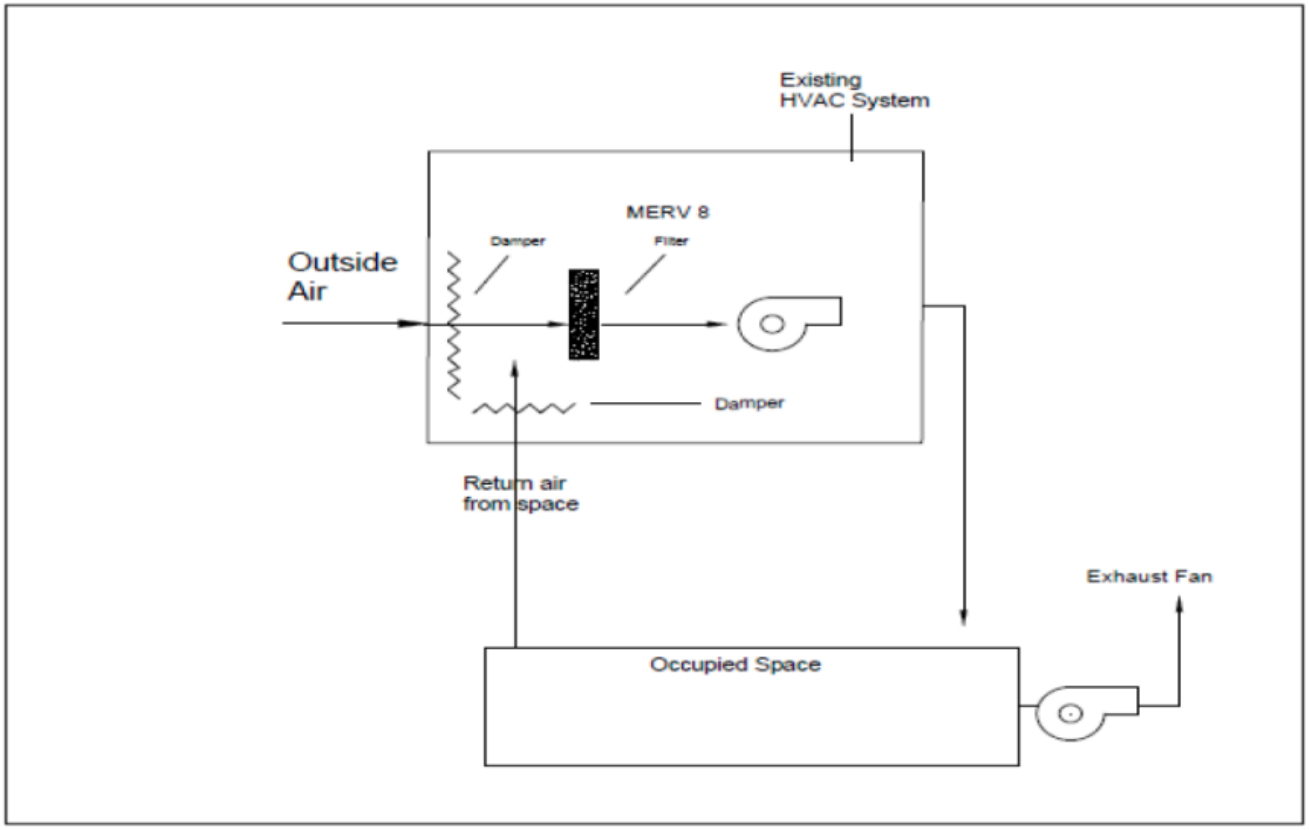
- Initially, CO_2 concentrations in Room 107 at Hillside were reaching 1800-2000 ppm each day (left graph).
- After repair of the fresh air inlet operating system, CO_2 concentrations were reaching 1000-1400 ppm each day (middle graph).
- After repair of the exhaust air vent operating system, CO_2 concentrations were reaching only 800-1000 ppm each day, a significant improvement (right graph).

HVAC System Operations Critical to Meeting Classroom Guidelines

School	Representative Dates	Average Classroom CO_2 (ppm)	Outdoor Airflow Rate (cfm/person)
Hillside Elementary	Mar 17-27 (before repairs)	1,477	5.7
Hillside Elementary	Apr 7–16 (after fresh air inlet repair)	984	10.4
Hillside Elementary	Apr 17–June 6 (after exhaust air vent repair)	806	15.0
Hunter Jr. High	Mar 15–June 6	753	24.2
Hunter High	Mar 24-27; May 7-9, May 15-28 (baseline CO_2 = 400 ppm)	640	44.9

American Society of Heating Refrigerating, and Air Conditioning Engineers (ASHRAE, 2013) recommend that ventilation rates in school classrooms should be at least 13-15 cfm per person, resulting in a steady-state indoor CO_2 concentration of about 1,000 ppm.

General HVAC System in a School



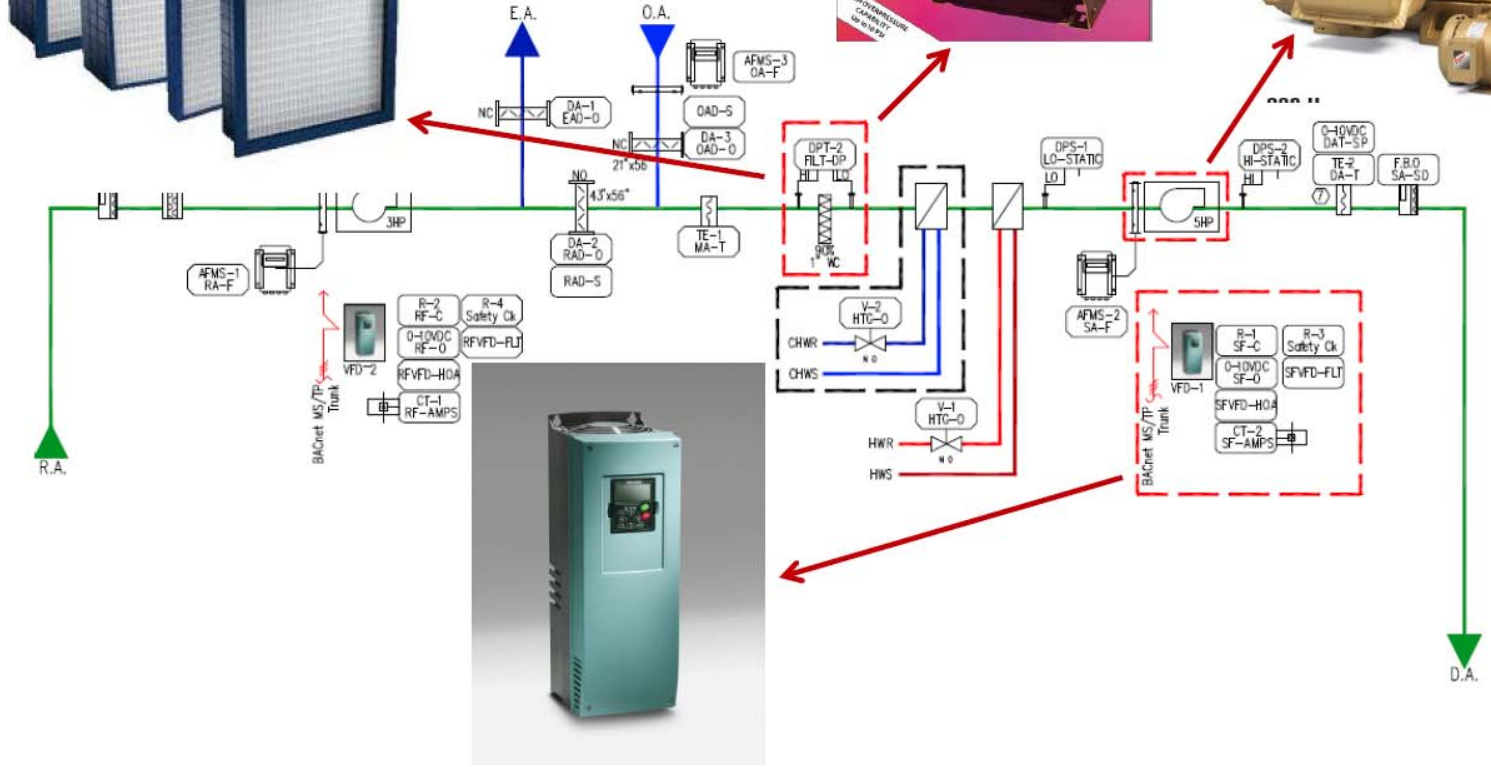
Expectation: Filtration systems could remove up to 90%-95% of outdoor black carbon particles, per results from Las Vegas schools.

Example Modifications to AHUs

Filters

Notification system

Motor



Variable frequency drive

AHU = air handling unit

Capital & Installation Cost (First Cost) Example Hunter High Air Handler-9 (AH-9)

Serves Upper West Classrooms of Hunter High (6,000 CFM)

MERV 13A first filter set	$307
New Premium Efficiency 10 HP motor	$2,897
New Variable Frequency Drive	$4,098
EMS Upgrade for Filter Change Notification	$576
Allowance for new wiring	$690
Share of test & balance cost (1/34) of $11,250	$331
Total cost associated with AH-9	**$8,946**

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Assumptions for Mitigation Cost Estimates

Item	Hunter High	Hunter Jr. High	Whittier Elementary	Hillside Elementary	West Valley Elementary
Time horizon in years	30	30	30	30	30
Time value of money (%)	3	3	3	3	3
Annual inflation (%)	4	4	4	4	4
District labor cost ($/hr)	40	40	40	40	40
HVAC operating (hours/week)	80	55	65	55	65
HVAC operating (weeks/year)	37	37	37	37	37
PM_{10} concentration (μg/m^3)	20	20	20	20	20
District electric cost ($/kWh)	$0.0375	$0.0375	$0.0375	$0.0375	$0.0375
District demand cost ($/kW)	$17.69	$17.69	$17.69	$17.69	$17.69
Filter cost ($)	Varies	Varies	Varies	Varies	Varies
Filter pressure drop limit (in-H_20)	Per Engineer of Record	Per Engineer of Record	1.0	1.0	1.0

Assumptions approved by AWG and Dr. David Gourley, GSD

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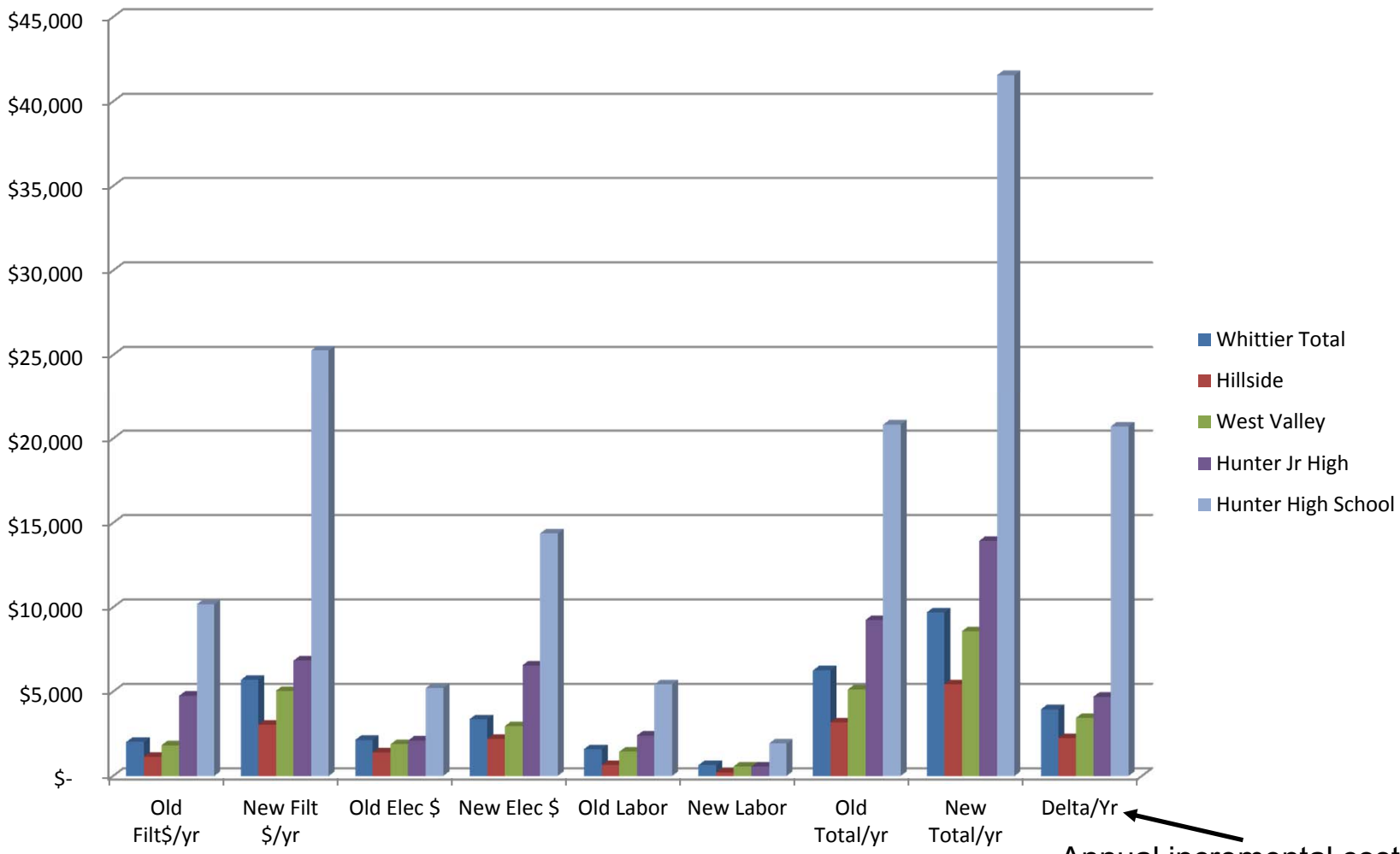
Characteristics of the Five Schools

School	Total Enclosed Area (ft^2)	Percent of Enclosed Area	Number of Students	Percent of Students
Whittier	104,922	14%	687	14%
Hillside	54,667	7%	625	12%
West Valley	88,920	12%	584	12%
Hunter Jr High	172,120	23%	1,047	21%
Hunter High	340,000	45%	2,086	41%
Total for five schools	**760,629**		**5,029**	

Example of Cost Analysis Results: Estimated HVAC Operating Cost by School



Annual incremental cost
Total for 5 schools $34,352

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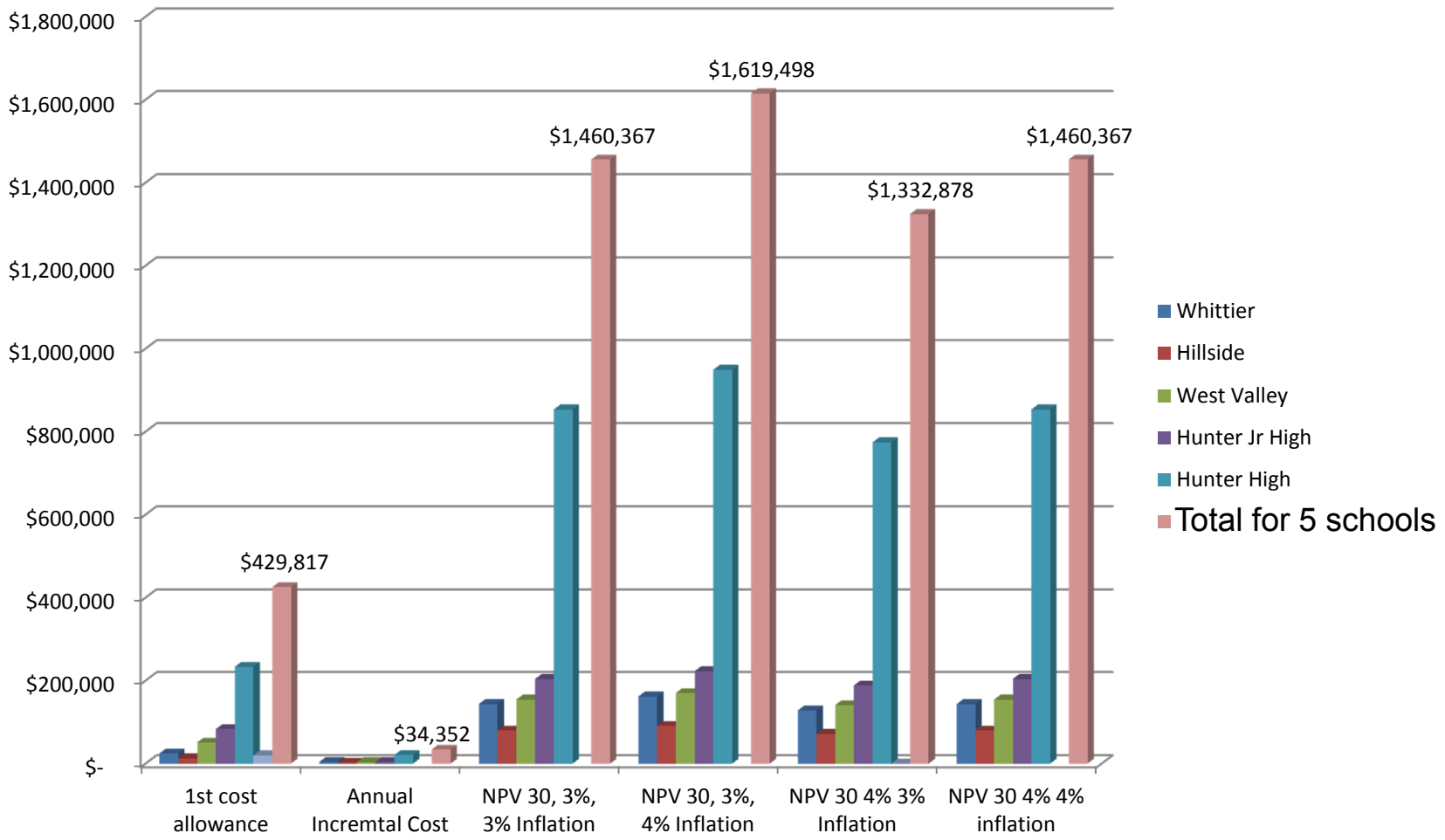
Estimated Net Present Value (NPV) for the Five Schools



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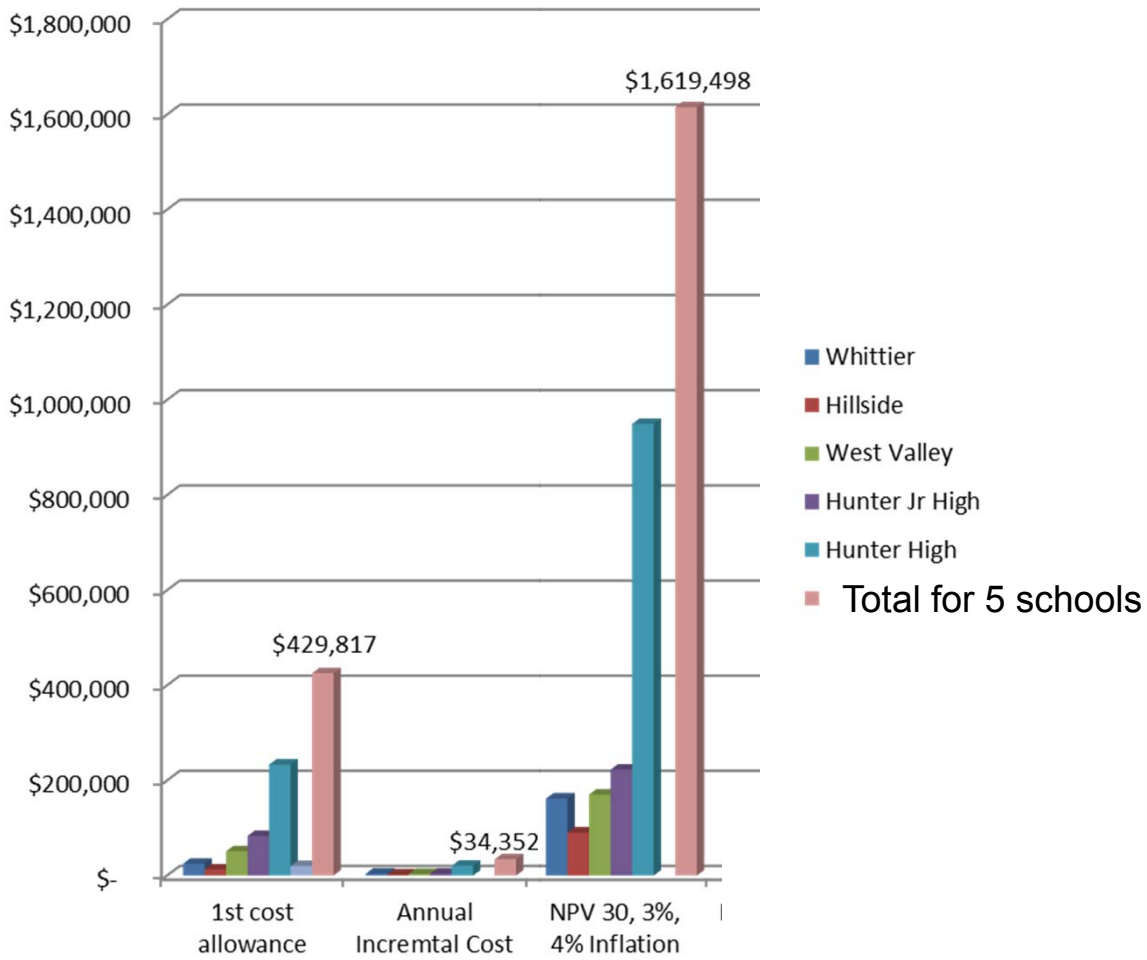
Estimated Net Present Value (NPV) for the Five Schools



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Estimated Project Cost by School

School	First Cost Allowance	Annual Incremental Cost	NPV 30, 3% Interest, 4% Inflation	Total Enclosed Area (ft^2)	Number of Students	Dollars/ ft^2/ Year	Dollars/ Student/ Year
Whittier	$26,973	$3,952	$163,854	104,922	687	$0.045	$6.89
Hillside	$14,853	$2,247	$92,659	54,667	625	$0.049	$4.28
West Valley	$53,020	$3,446	$172,370	88,920	584	$0.056	$8.52
Hunter Jr High	$91,754	$4,025	$231,165	172,120	1,047	$0.039	$6.38
Hunter High	$243,216	$20,681	$959,449	340,000	2,086	$0.081	$13.28
Total for five schools	**$429,816**	**$34,352**	**$1,619,497**	**760,629**	**5,029**	**$0.062**	**$9.30**

Based on annual incremental operating cost plus first cost (capital & installation cost) allocated over 30 years at 3% interest, 4% inflation.

Improved Filtration Yet Longer Filter Life

- Replacement MERV-13A filters will hold 100 grams of dust before their pressure drop exceeds the predetermined level
- Current MERV-8 filters are by practice replaced 4 times a year
- Typical aerosol has most of its mass in the large particles
- MERV-13A will do a better job filtering smaller (respirable-size) particles
- MERV-13A filters increase mass filtration efficiency from 70% (MERV-8) to 92% for typical aerosol
- Choice of filters and changing based on pressure drop rather than calendar

Components of Mitigation Costs

- First cost: Purchase of replacement or new equipment, required modifications, adjustments, etc.
- Operating costs: Increase in filter costs, increase in energy costs, reduction in labor due to fewer filter changes
- Time value of money
- Inflation

Outline of Assumptions for Mitigation Cost Estimates

The following assumptions have a significant influence on the mitigation cost estimates. We want these assumptions to be consistent with how the Granite School District views their projects. The assumptions can be classified in three groups:

- Financial
- Operating conditions
- Technical conditions

Financial Assumptions for Mitigation Cost Estimates

- Expected time horizon for this mitigation project (expected life of the equipment or years until the next major school renovation)
- Time value of money over the expected time horizon
- Inflation over the expected time horizon
- District labor cost for filter replacement

Technical Assumptions for Mitigation Cost Estimates

- Electric costs based on current values
- Electric cost inflation will track general inflation assumed for the project
- Filter performance based on filter test and specification data for products currently available and priced by vendor for this project
- Ability of Air Handler Units based on original design drawings for Whittier Elementary, Hillside Elementary, and West Valley Elementary

Technical Assumptions for Mitigation Cost Estimates

- Ability of Air Handler Units to accommodate the enhanced filters based on limitations prescribed by the “engineer of record” for the recent air conditioning projects completed at Hunter High and Hunter Junior High
- First cost estimates are based on information from vendors that have been or are currently working at the school district

Mitigation Recommendations (other than improved filtration)

- Place portable classrooms as far away from MVC as possible.
- Avoid outdoor activities during morning rush hour.
- Minimize outdoor activities during periods with strong inversions.
- Provide training for teachers with difficult classrooms (windows that open; doors that open to the outside, rather than to an interior hallway).
- Control HVAC systems to minimize filling classrooms with morning rush-hour pollutants.
- Eliminate or minimize emissions from indoor sources (cleaning materials, markers, etc.).