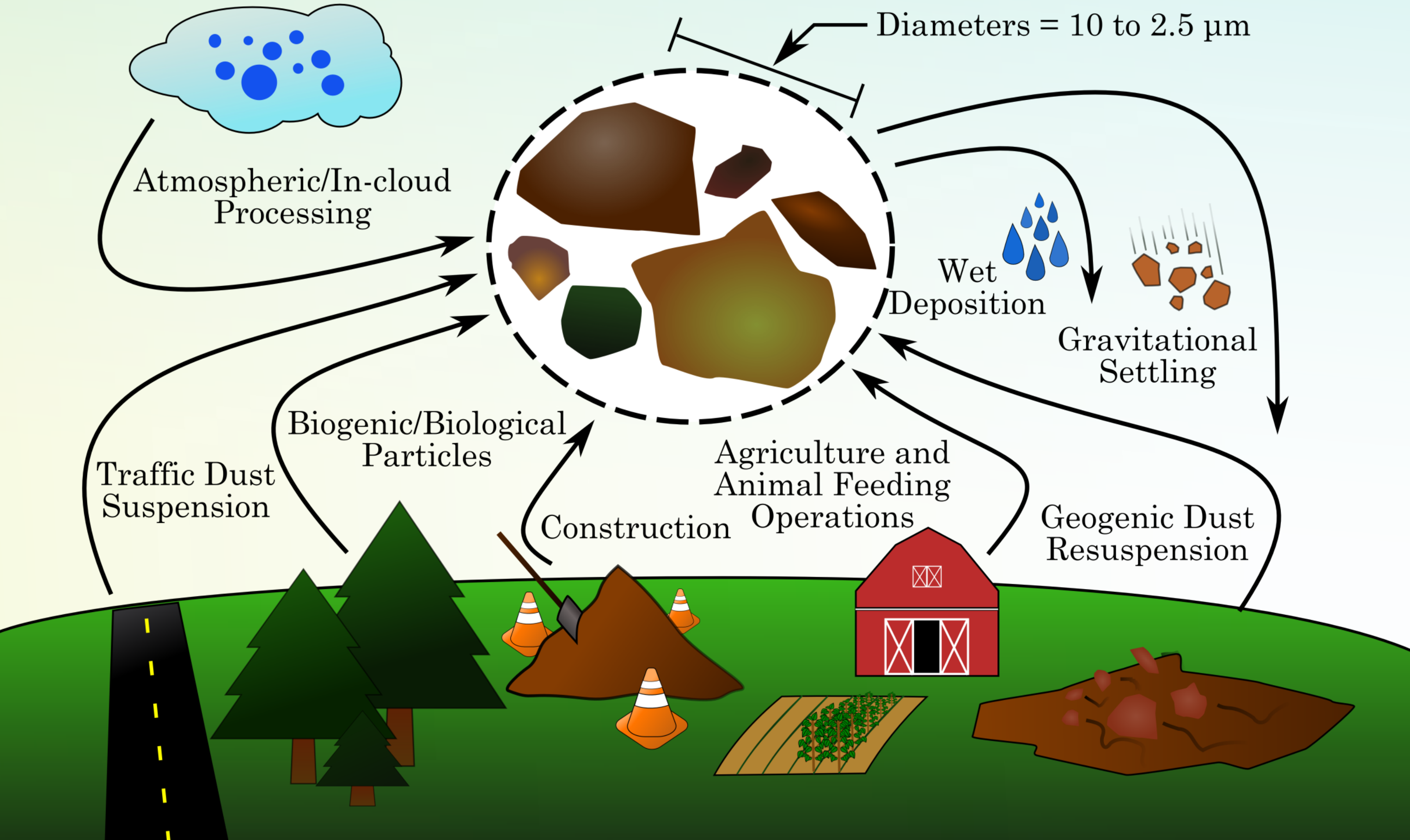
The CCRUSH Study: Characterization of Coarse and Fine Particulate Matter in Colorado

Michael Hannigan



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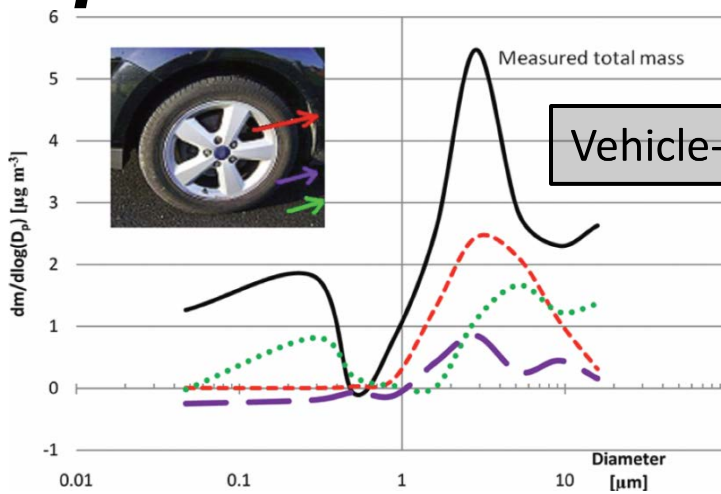
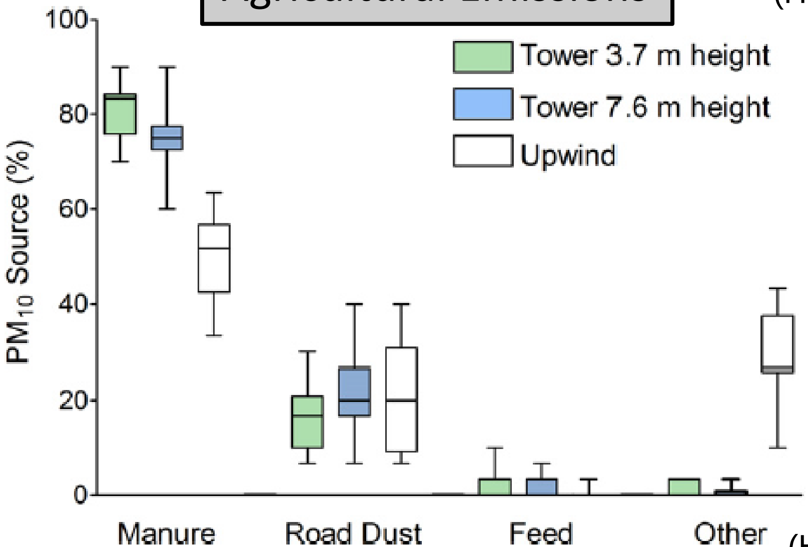
What is *coarse particulate matter* ($PM_{10\text{-}2.5}$)?



Vehicle- and road-wear dusts

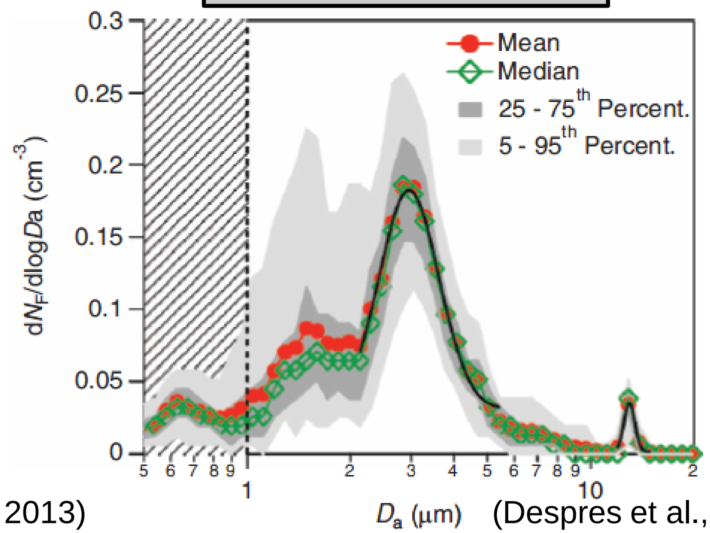
(Harrison et al., 2012)

Agricultural Emissions



(Huang et al., 2013)

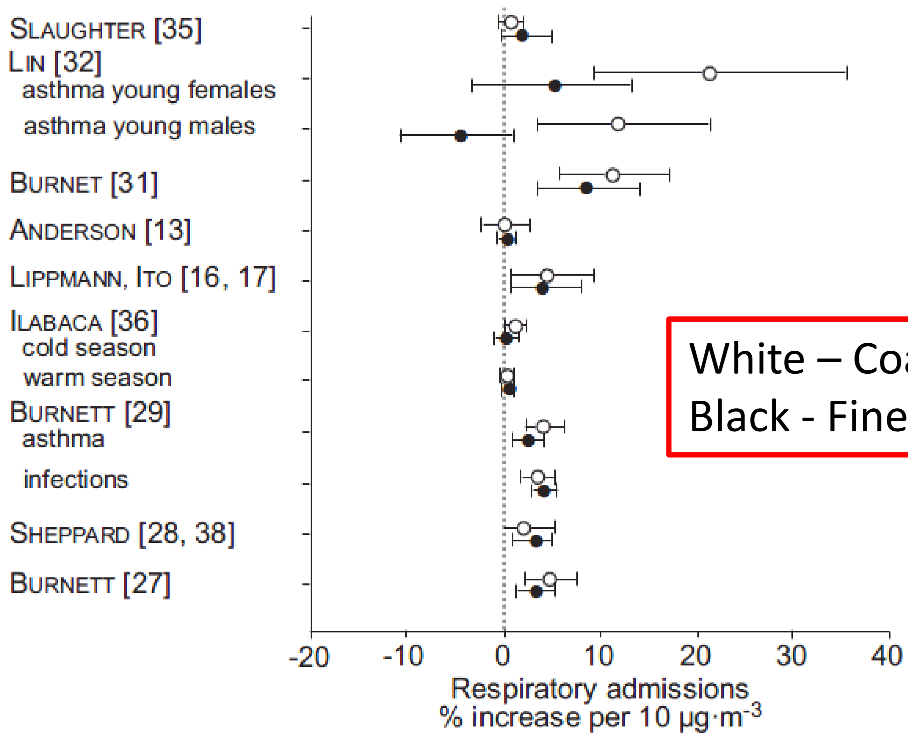
Biological Particles



(Despres et al., 2012)

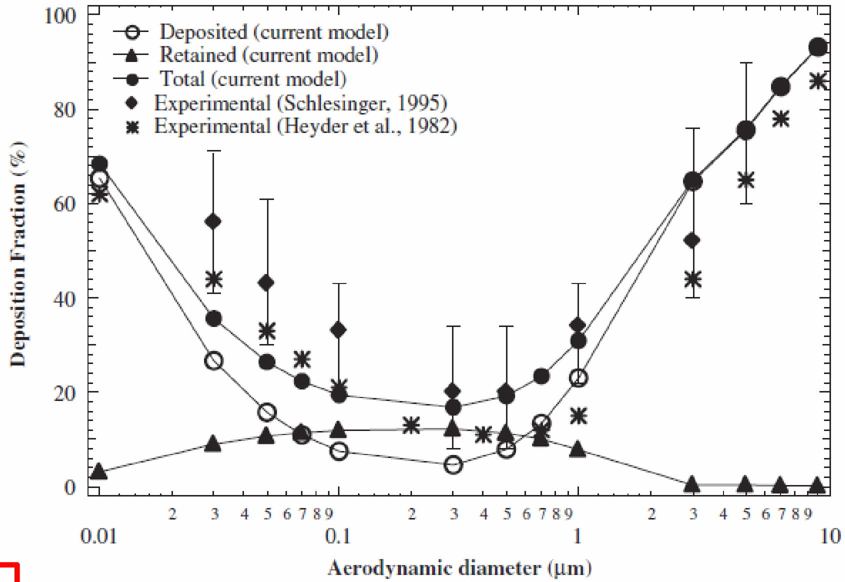
Why do we care about ***coarse particles***?

Epidemiological studies show exposure to both $PM_{2.5}$ and $PM_{10\text{-}2.5}$ are detrimental to human health!



(Brunekreef and Forsberg, 2005)

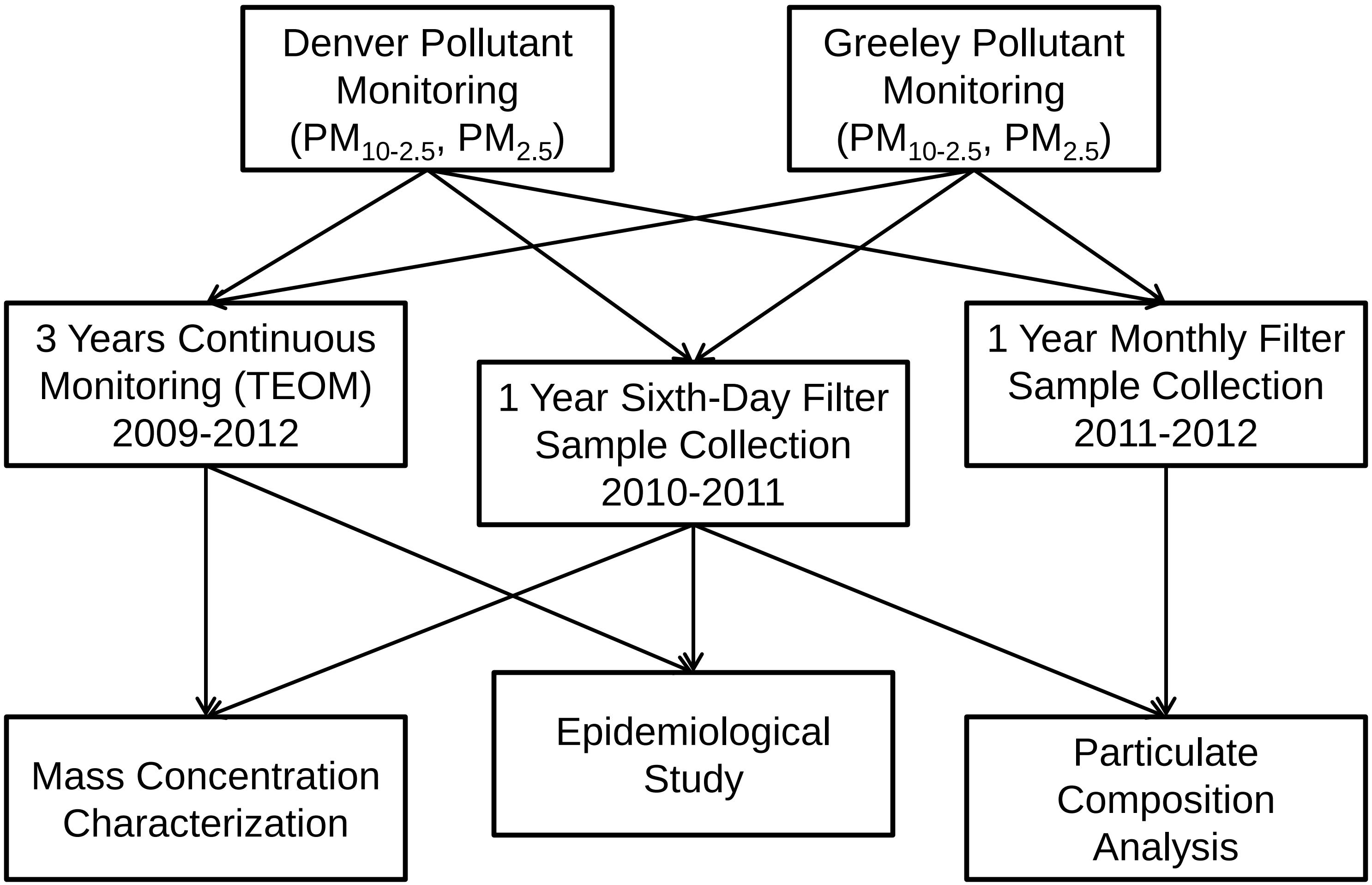
White – Coarse
Black - Fine



(Park and Wexler, 2008)

ALSO!
Cloud Formation
Microbe Transport
Carbon cycle
Mineral/dust cycles
Radiative Forcing

The Colorado Coarse Rural-Urban Sources and Health (CCRUSH) Study



How did we measure particulate matter?

Hourly Averages

Daily Averages

Total Mass Conc.

Semi-Volatile Mass Conc.

Elemental/Organic Carbon Conc.

Elemental Conc.

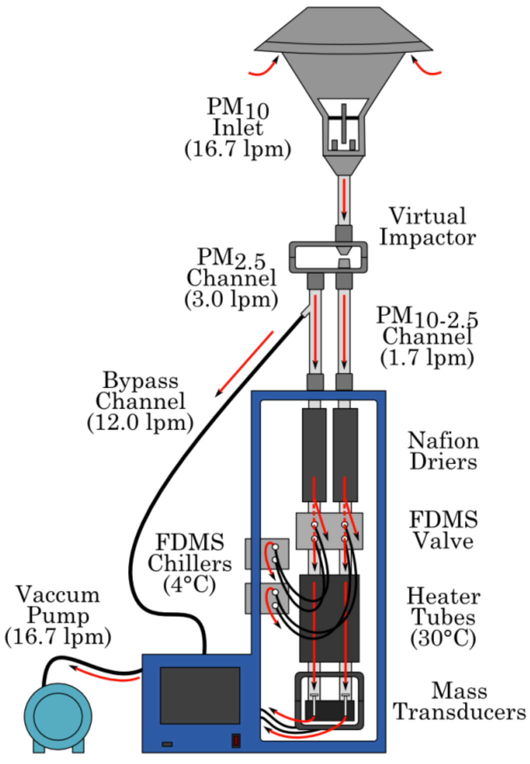
Endotoxin Content

Microbe DNA Speciation/Counts

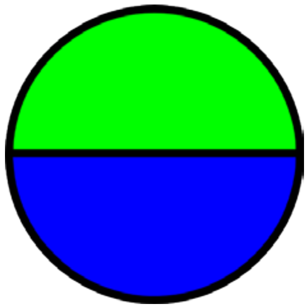
Toxicity (ROS macrophage assay)

Water-Soluble Carbon Characterization

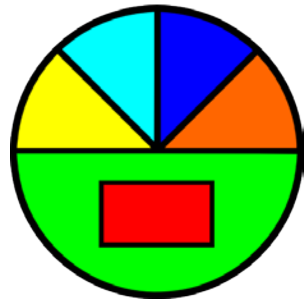
TEOM 1405-DF Flow Schematic



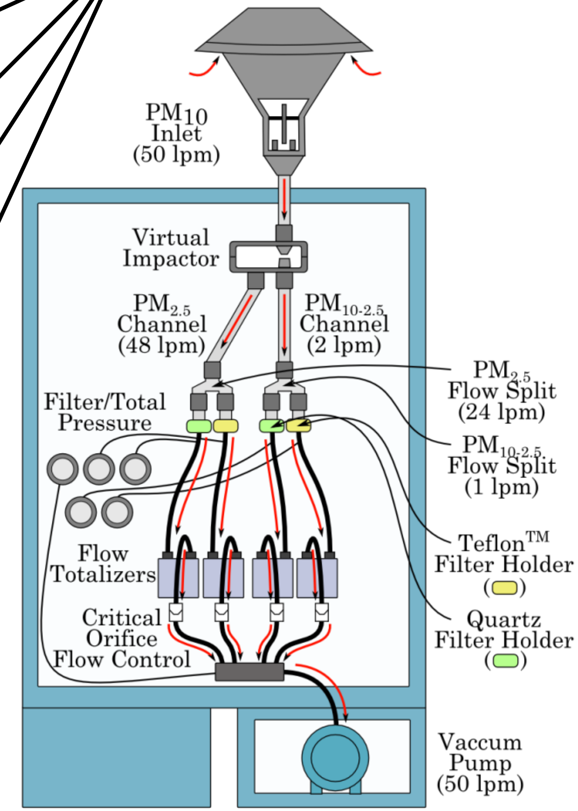
Teflon Filter



Quartz Filter



Filter Sampler Flow Schematic

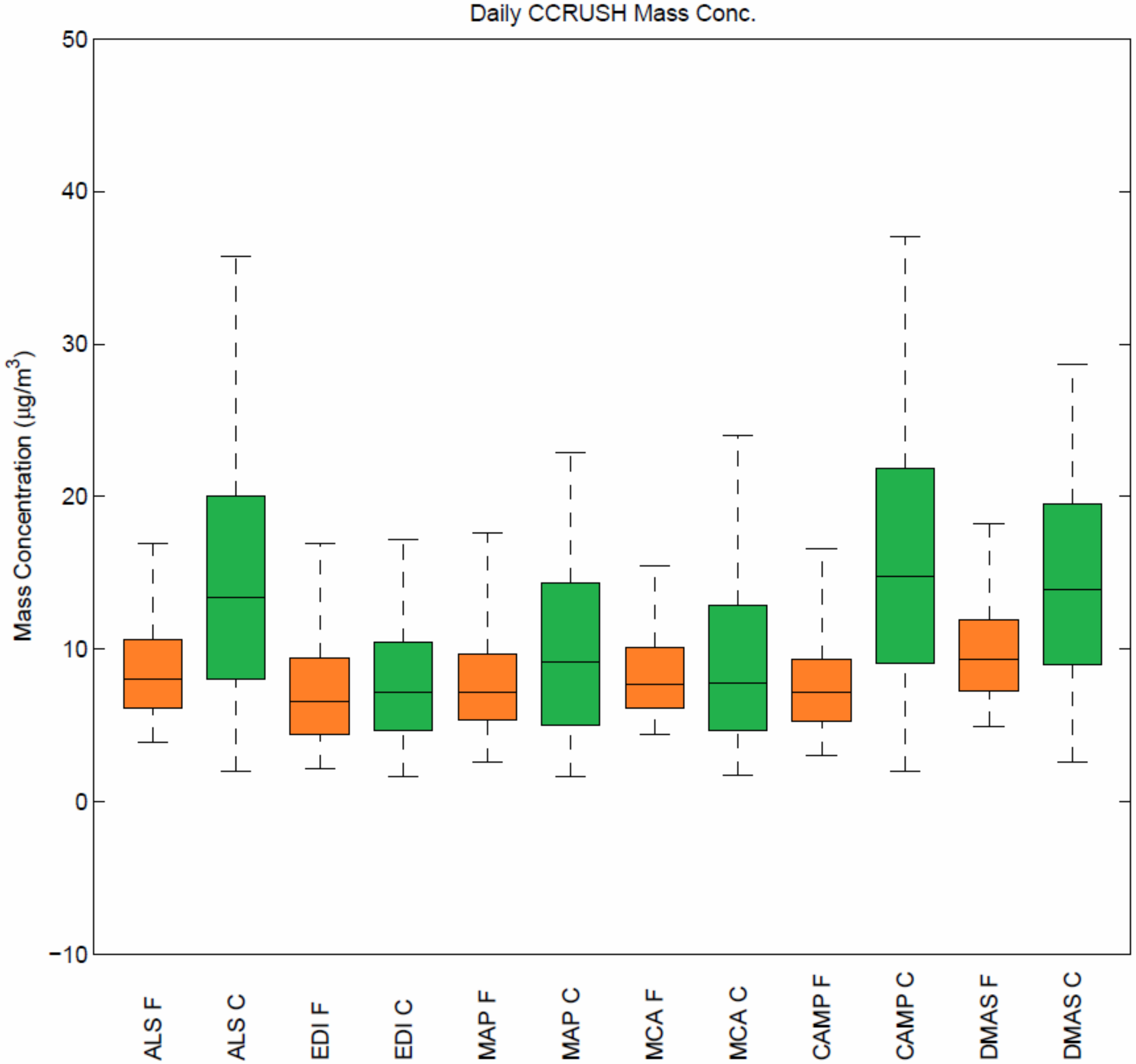


Where did we measure particulate matter?

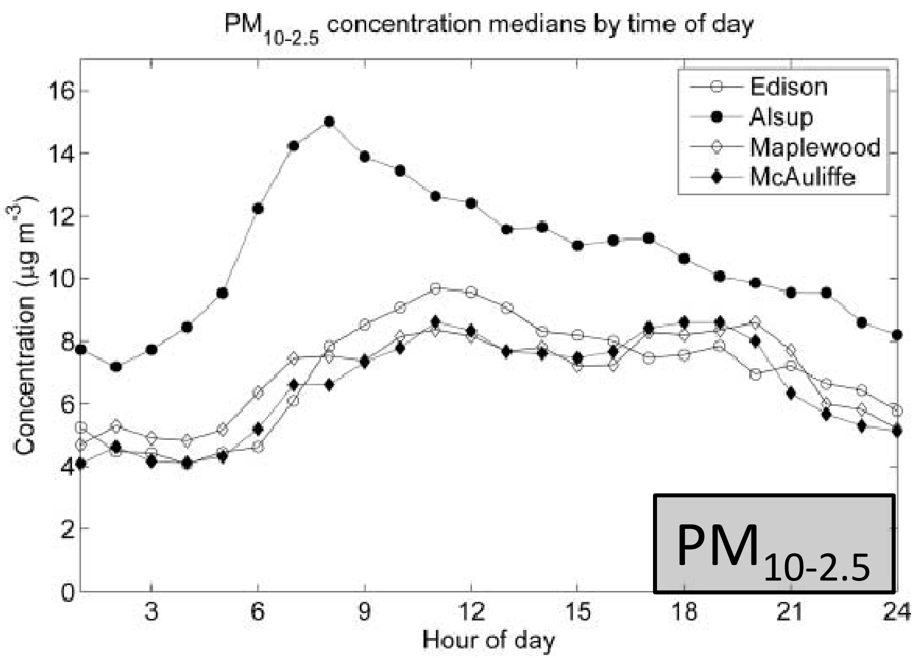
Greeley

Denver

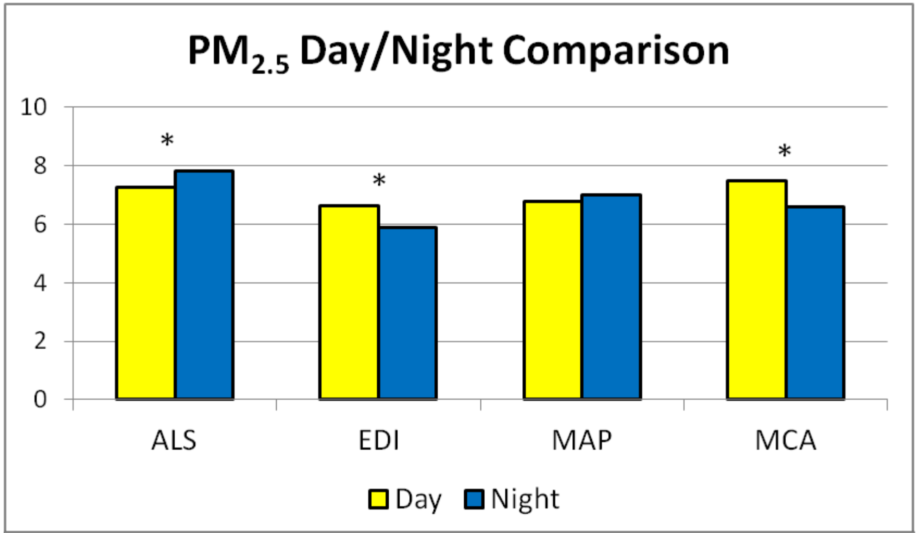
Mass Concentrations – Statistical Summary

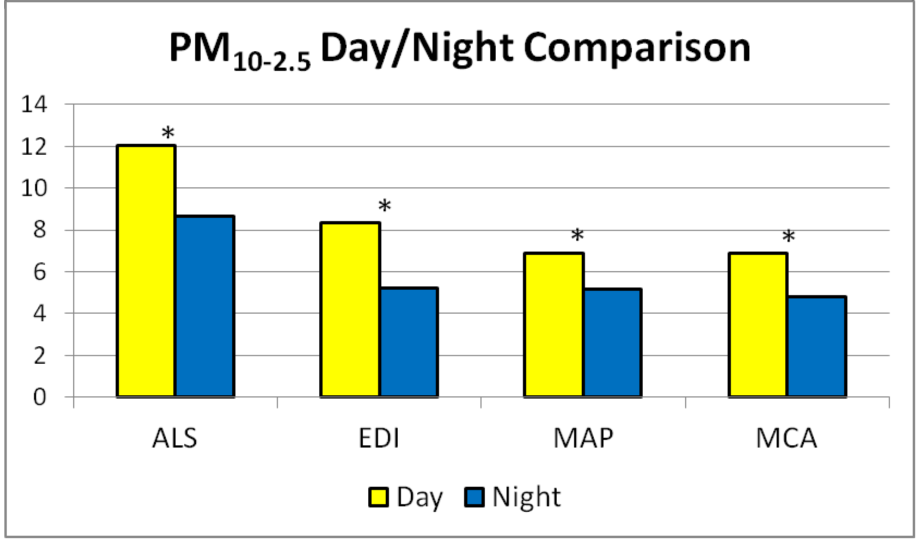


Mass Concentrations – Temporal Trends



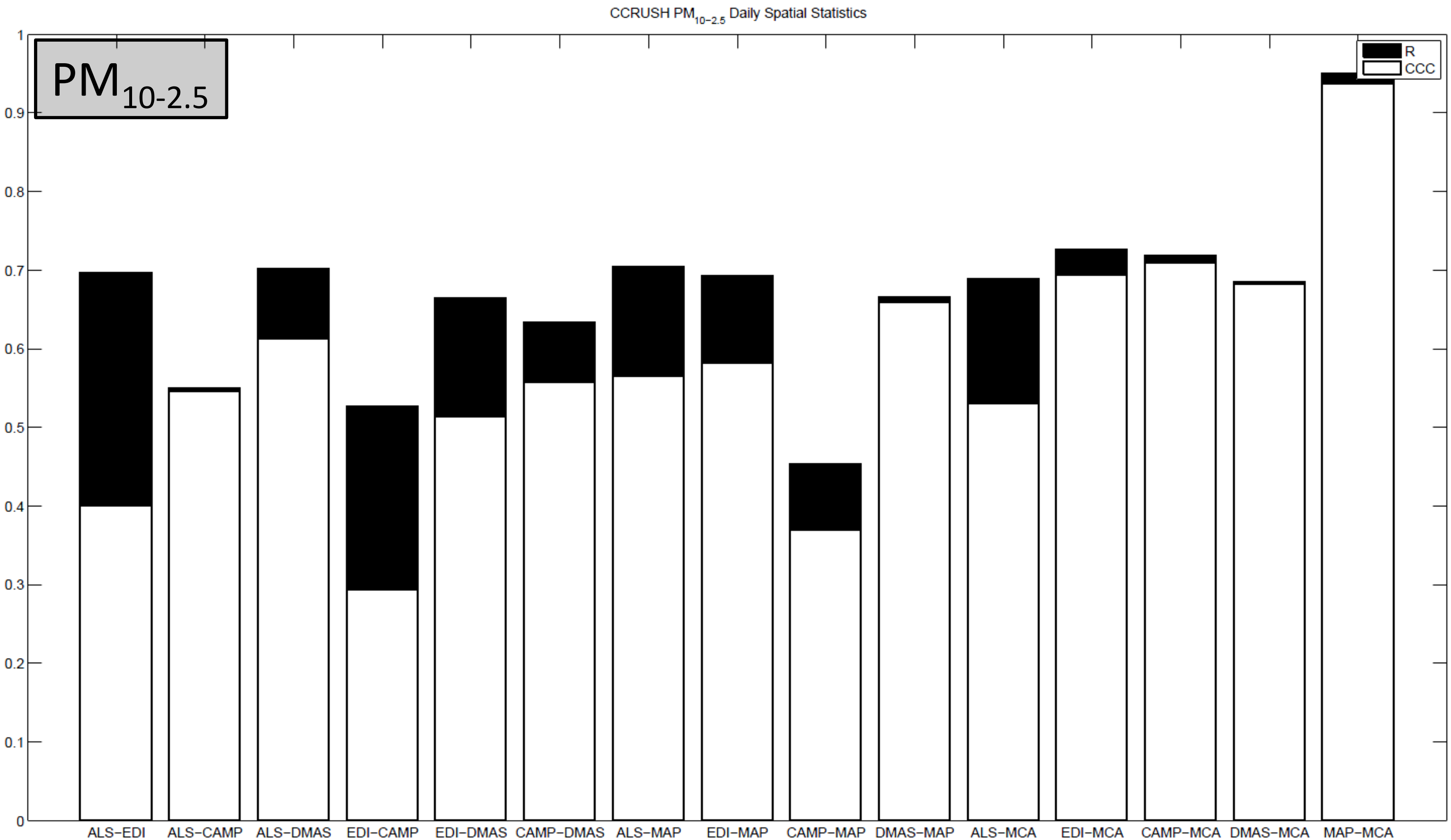
(Clements et al., 2012)





(* - significant difference)

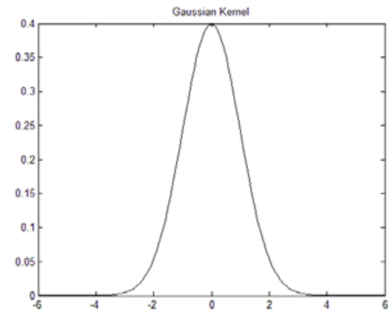
Mass Concentrations – Spatial Trends



Mass Concentrations – Meteorological Trends

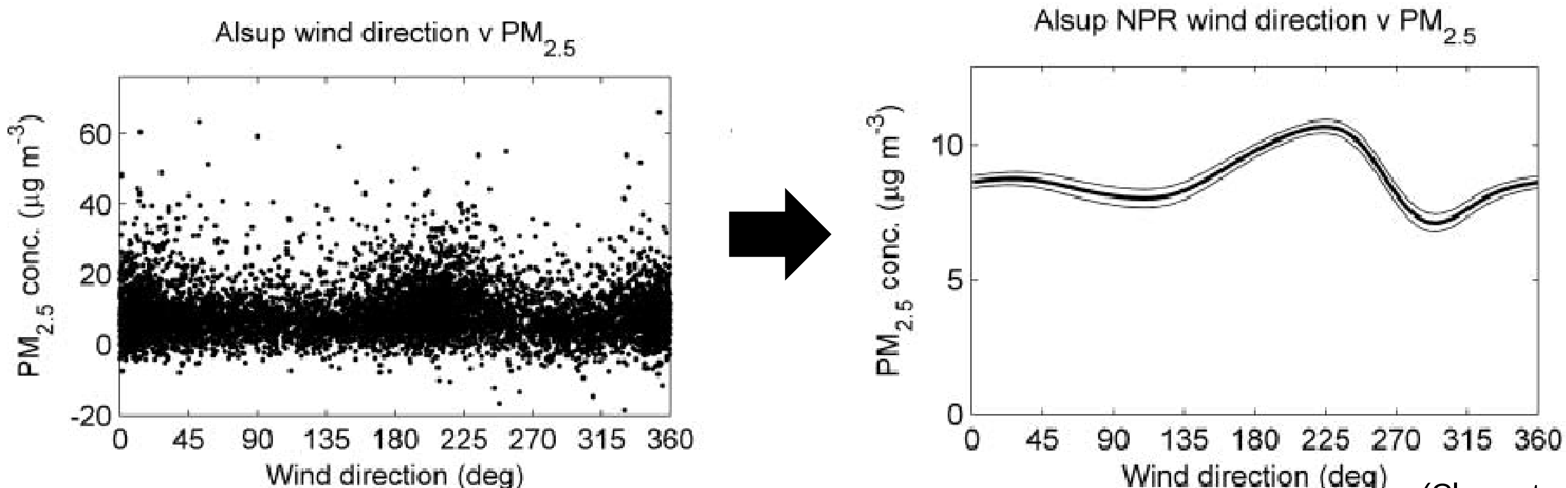
Nonparametric Regression

$$K(x) = (2\pi)^{-1/2} \exp\left(-0.5x^2\right)$$



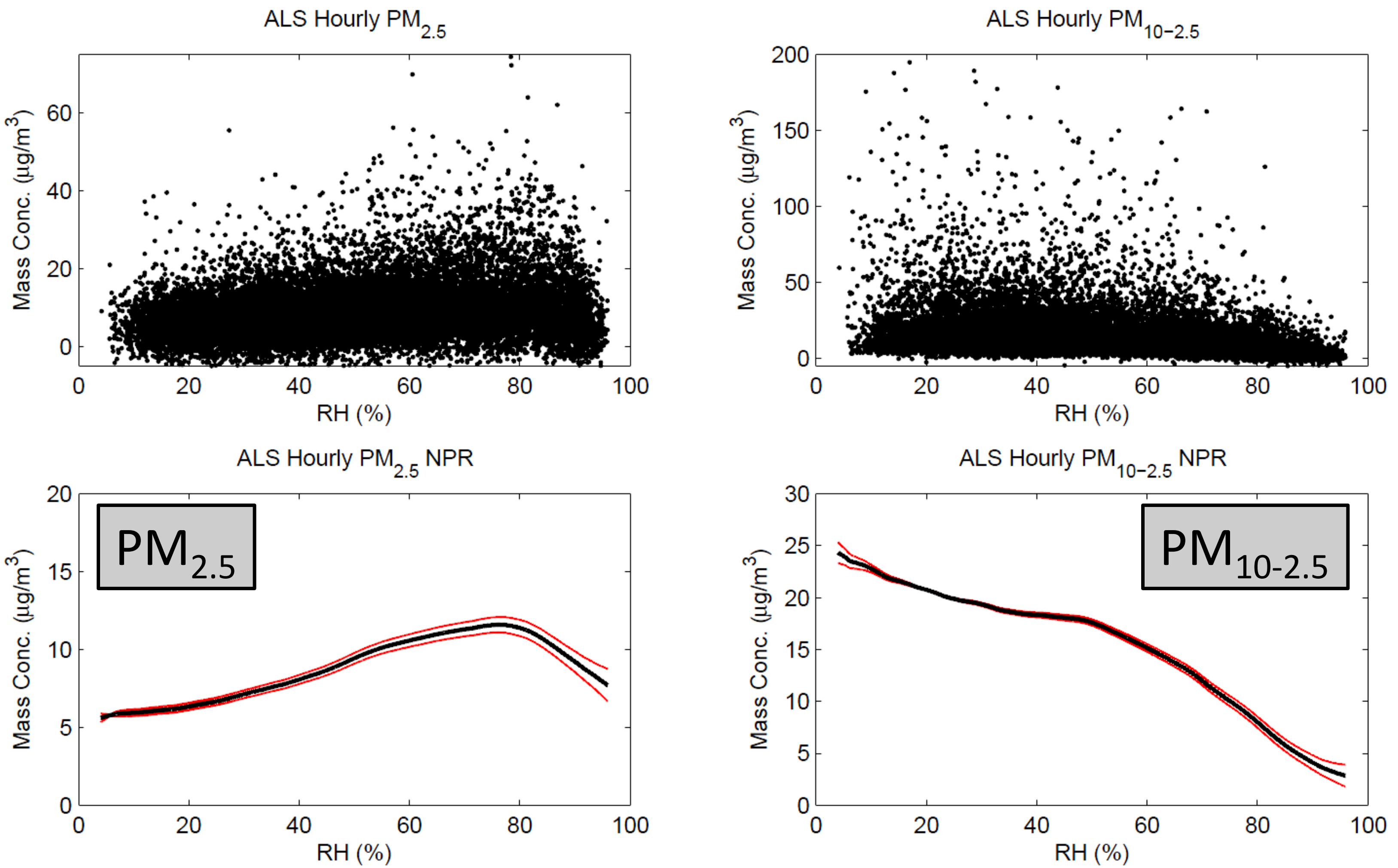
$$\bar{C}(\theta, \Delta\theta) = \frac{\sum_{i=1}^{n} K\left(\frac{\theta - W_i}{\Delta\theta}\right) C_i}{\sum_{i=1}^{n} K\left(\frac{\theta - W_i}{\Delta\theta}\right)}$$

(Henry et al., 2002)



(Clements et al., 2012)

Mass Concentrations – Meteorological Trends



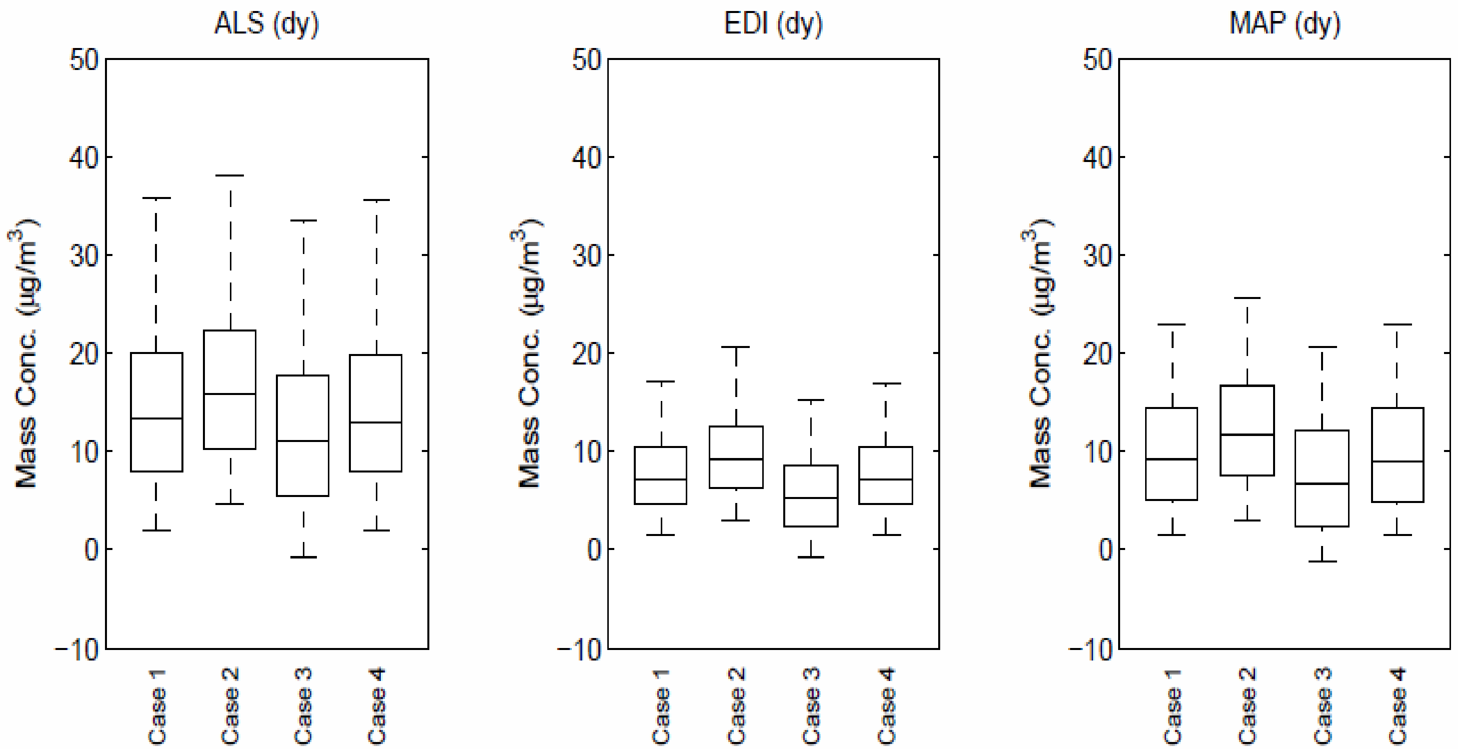
Mass Concentrations – Bias Analysis

$$PM_{10-2.5}\ Case\ 1 = PM_{10,FDMS} - PM_{2.5,FDMS} = PM_{10-2.5}NV + PM_{10-2.5}SV$$

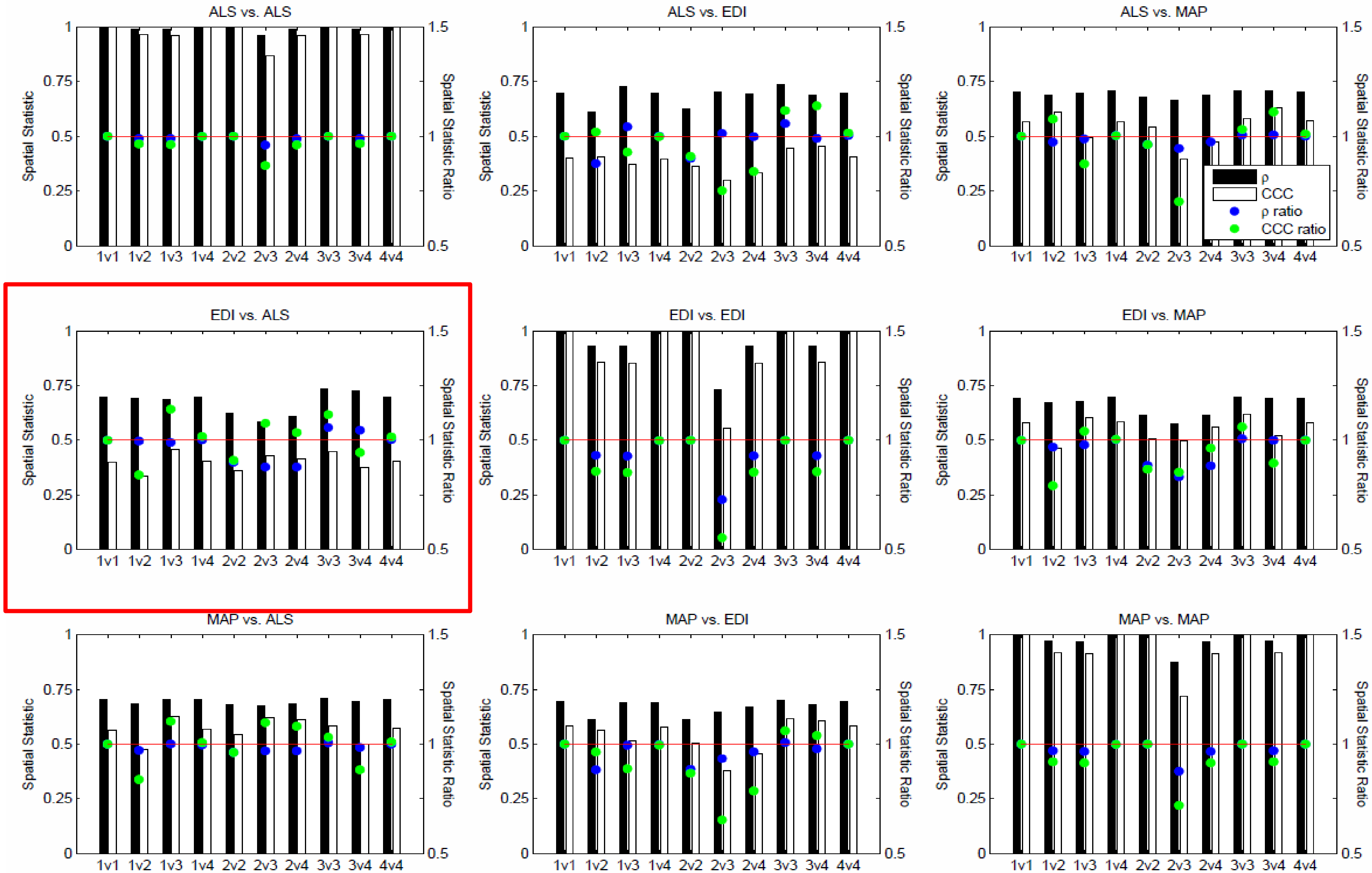
$$PM_{10-2.5}\ Case\ 2 = PM_{10,FDMS} - PM_{2.5} = PM_{10-2.5}NV + PM_{10}SV$$

$$PM_{10-2.5}\ Case\ 3 = PM_{10} - PM_{2.5,FDMS} = PM_{10-2.5}NV - PM_{2.5}SV$$

$$PM_{10-2.5}\ Case\ 4 = PM_{10} - PM_{2.5} = PM_{10-2.5}NV$$



Mass Concentrations – Bias Analysis



Mass Concentrations – Bias Analysis

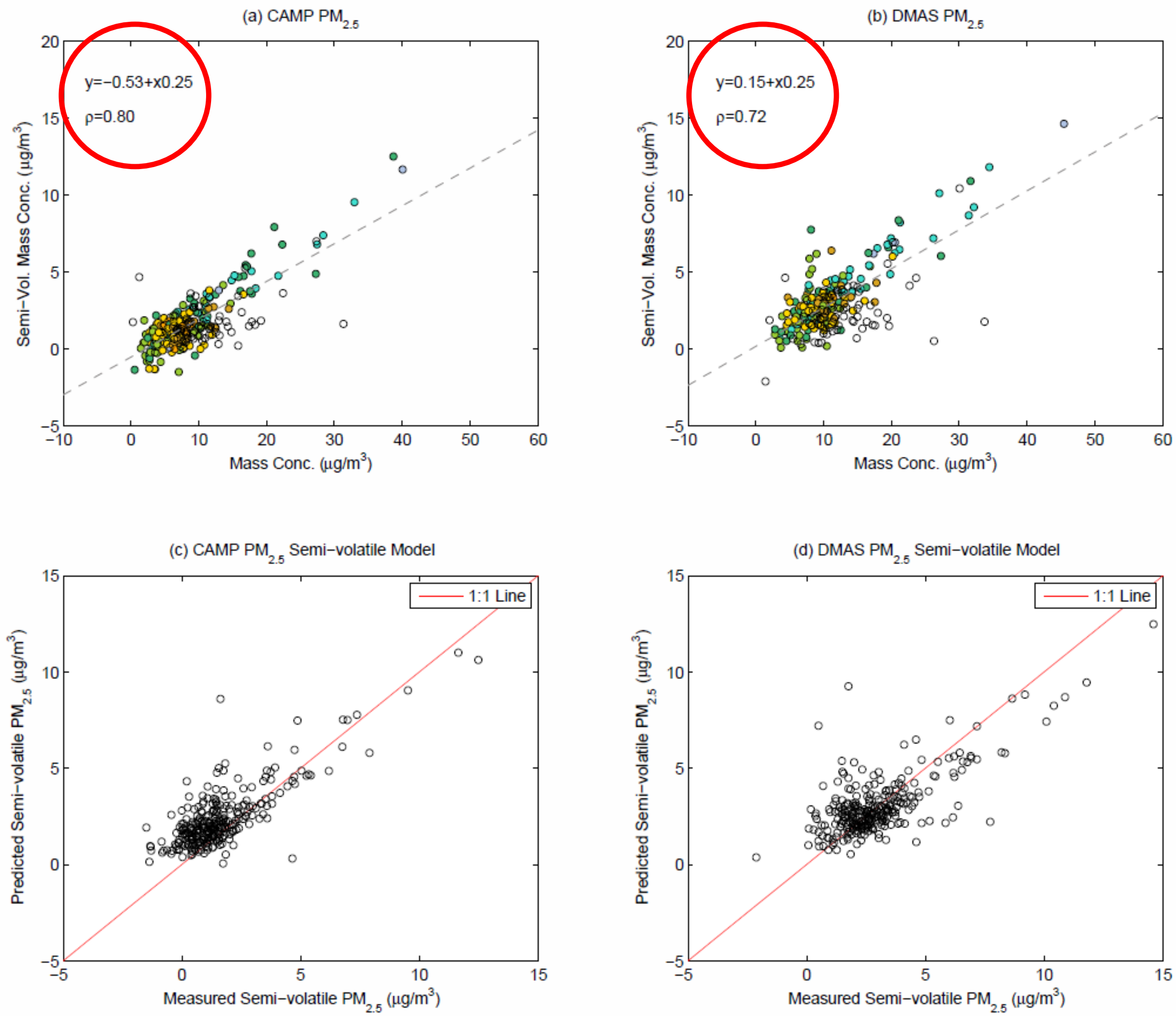
CPHE data is simulated by Case 3: PM_{10}(no-FDMS)-$PM_{2.5}$(FDMS)

- Case 3 underestimates $PM_{10\text{-}2.5}$ by the mass concentration of semi-volatile PM_{10}

Method for correcting CDPHE data:

- Model $PM_{2.5}$ semi-volatile concentrations based on the total $PM_{2.5}$
- Estimate the non-volatile fraction of PM2.5 by subtracting the modeled semi-volatile values from the total $PM_{2.5}$ concentrations
- Subtract the non-volatile $PM_{2.5}$ from the non-volatile PM_{10} concentrations to estimate $PM_{10\text{-}2.5}$ with Case 4
- Case 4 underestimates by the semi-volatile fraction of $PM_{10\text{-}2.5}$, which is very low (0.1 µg/m^3), so give a good approximation of Case 1
- Using non-volatile (or base) concentrations of TEOM instruments for estimating $PM_{10\text{-}2.5}$ seems like best low-cost option for monitoring in areas with low semi-volatile $PM_{10\text{-}2.5}$ concentrations

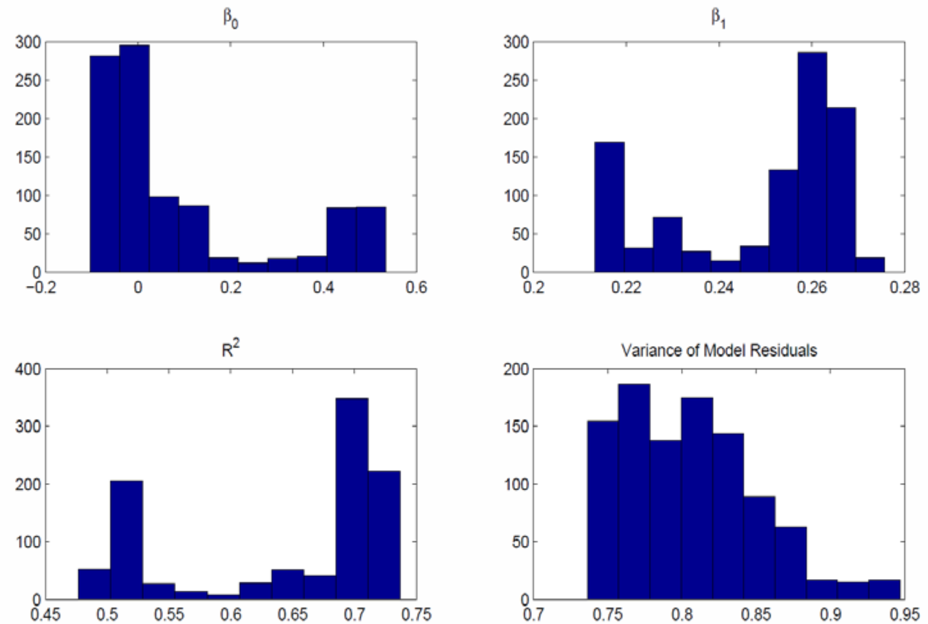
Mass Concentrations – Bias Analysis

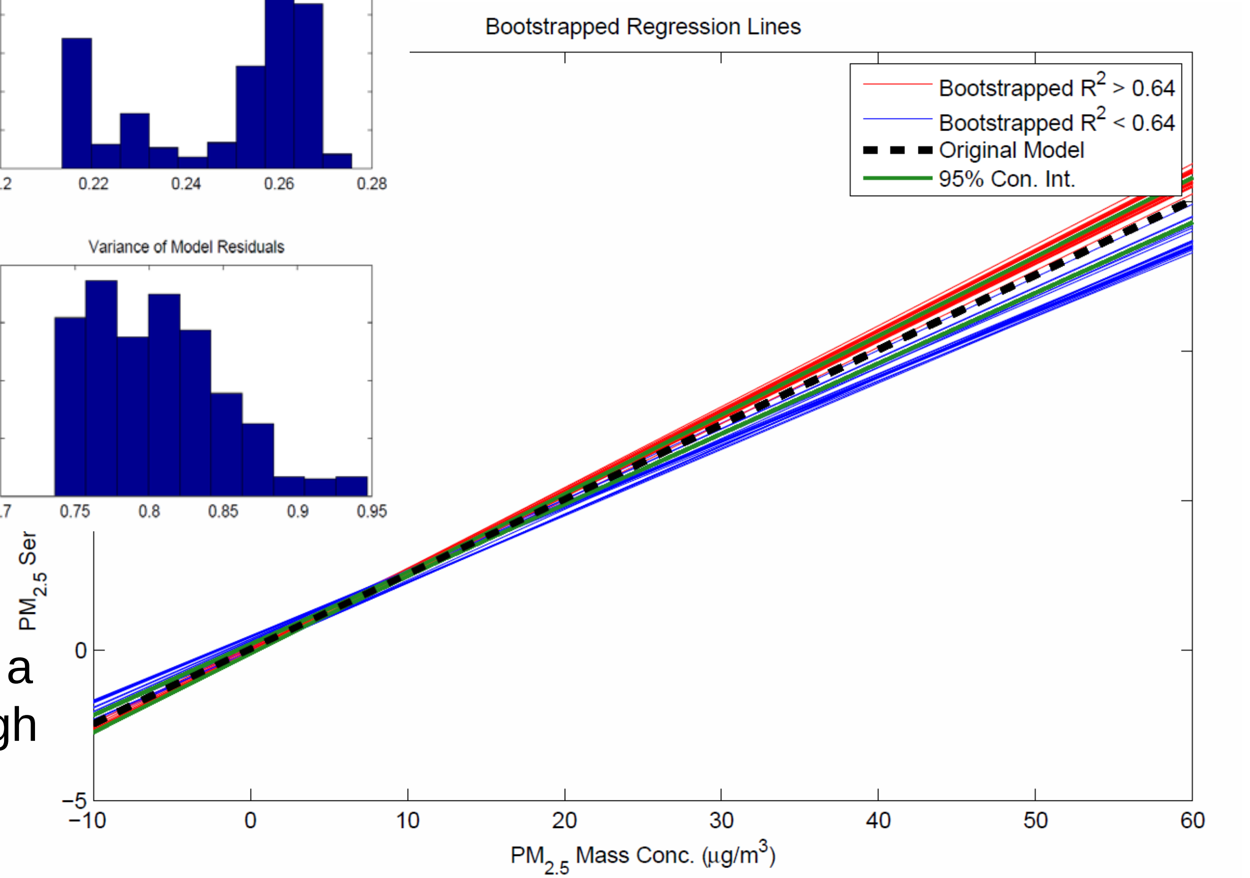


Model based on 10 months of data collected from Oct 2011 to July 2012, but how do we know it should apply to 3 years of CCRUSH data?

Mass Concentrations – Bias Analysis

Bootstrapped random 10 month segments of the ALS time series and performed regression between $PM_{2.5}$ and semi-volatile $PM_{2.5}$

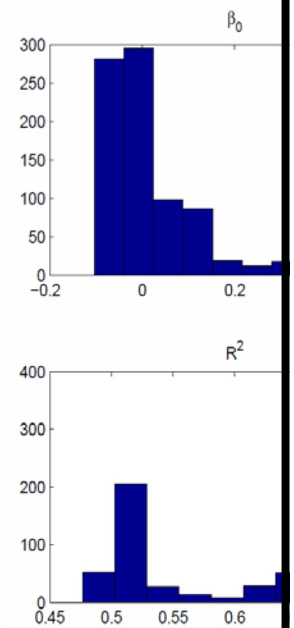


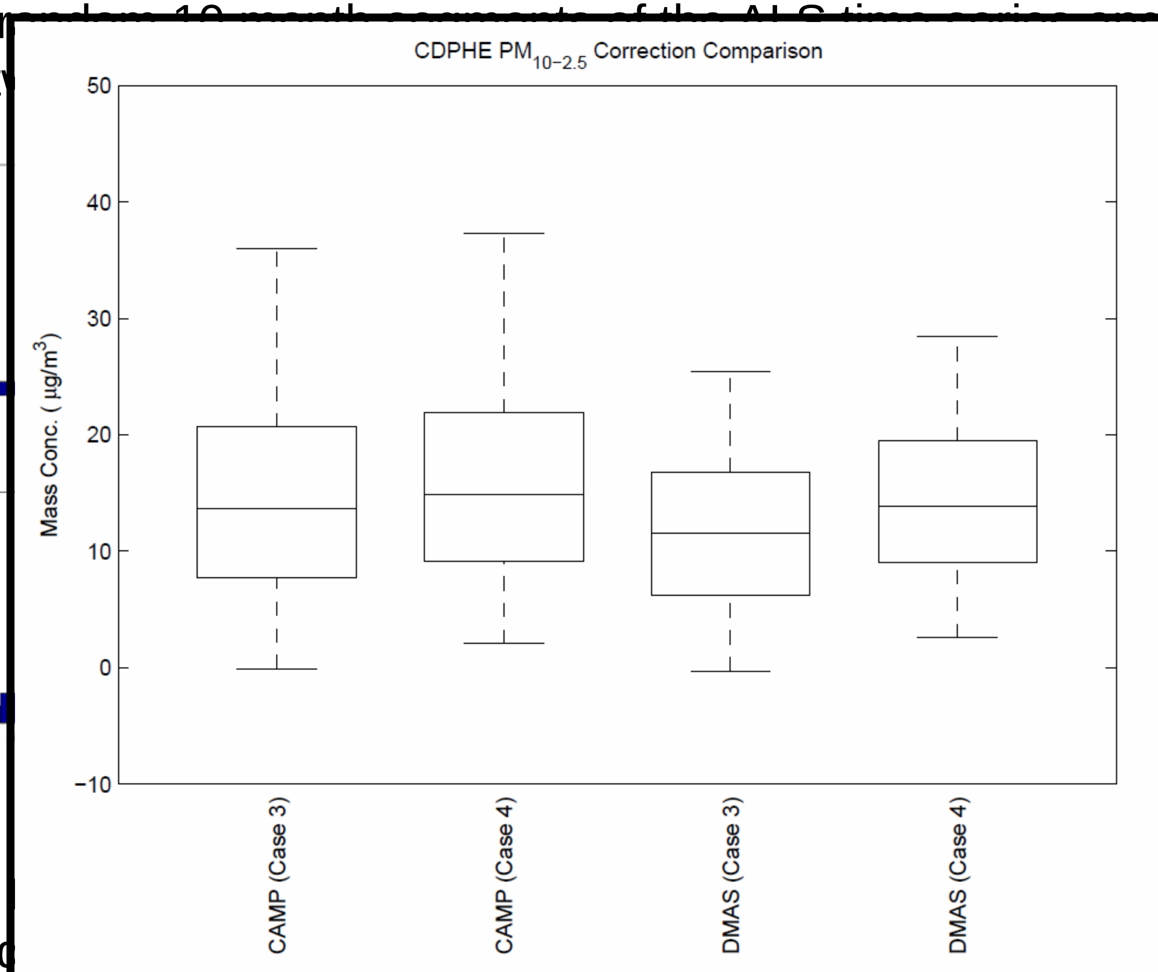


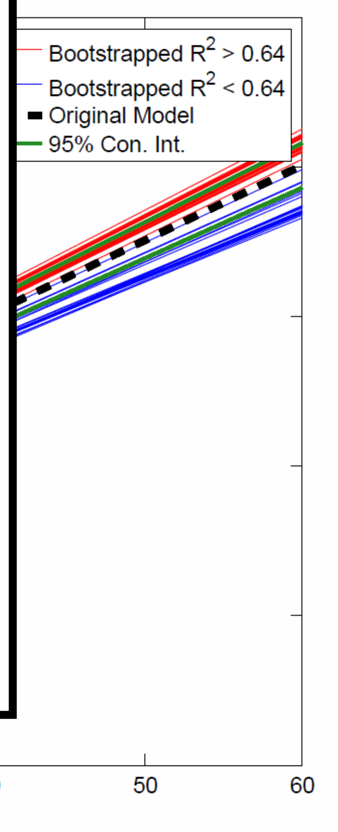
Bimodality due to sampling a low number of days with high $PM_{2.5}$, typically occurring during cold periods

Mass Concentrations – Bias Analysis

Bootstrapped r[...] performed regression bet[...]

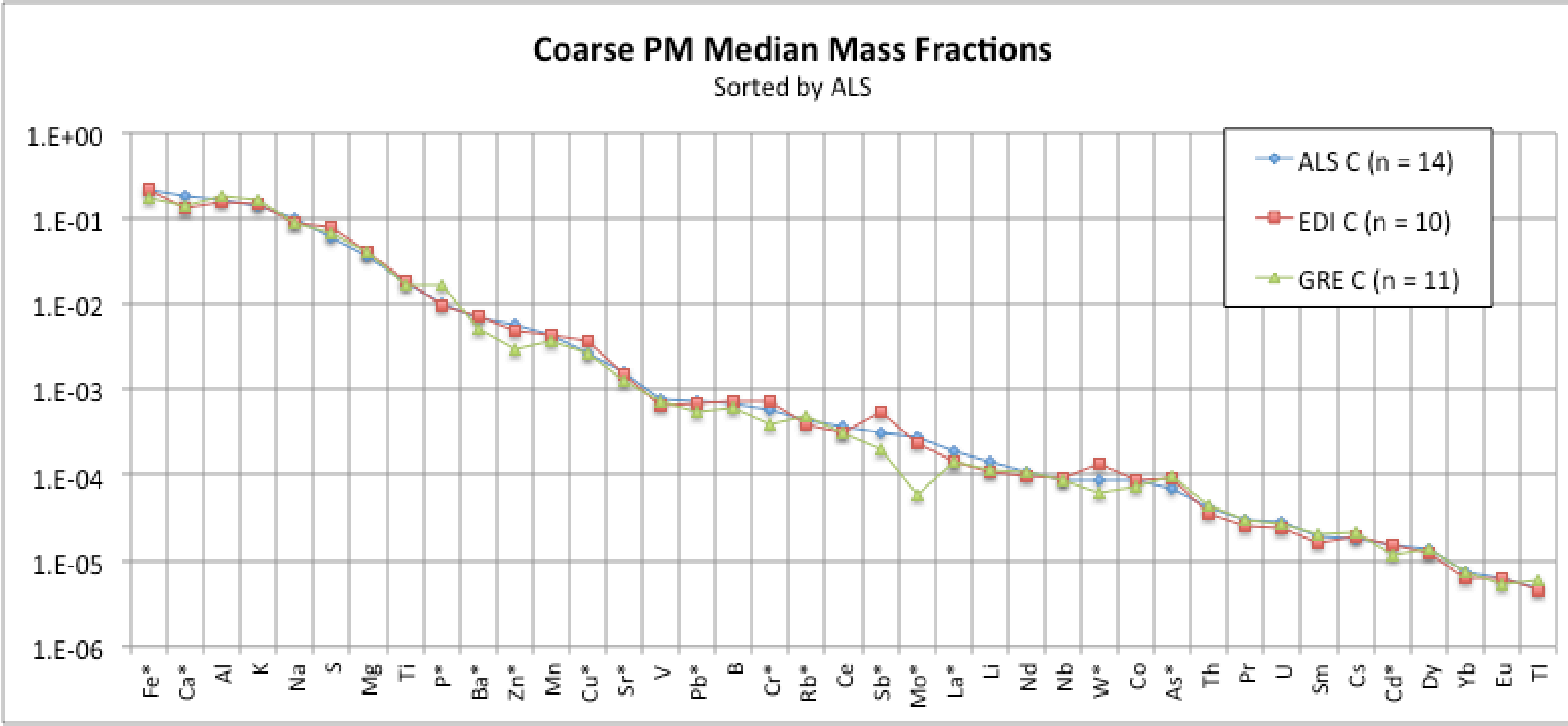




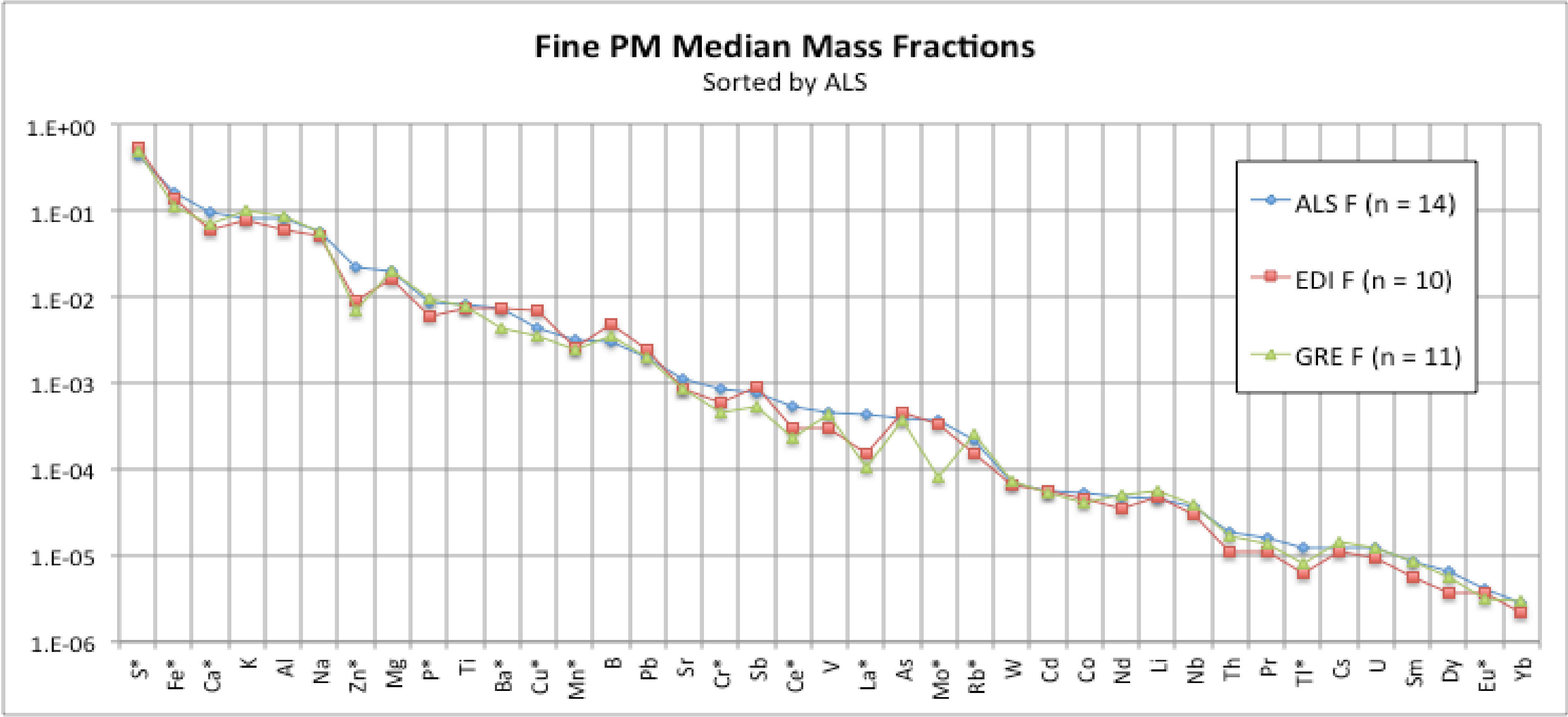


Bimodality due [...]
low number of [...]
$PM_{2.5}$, typically occurring
during cold periods

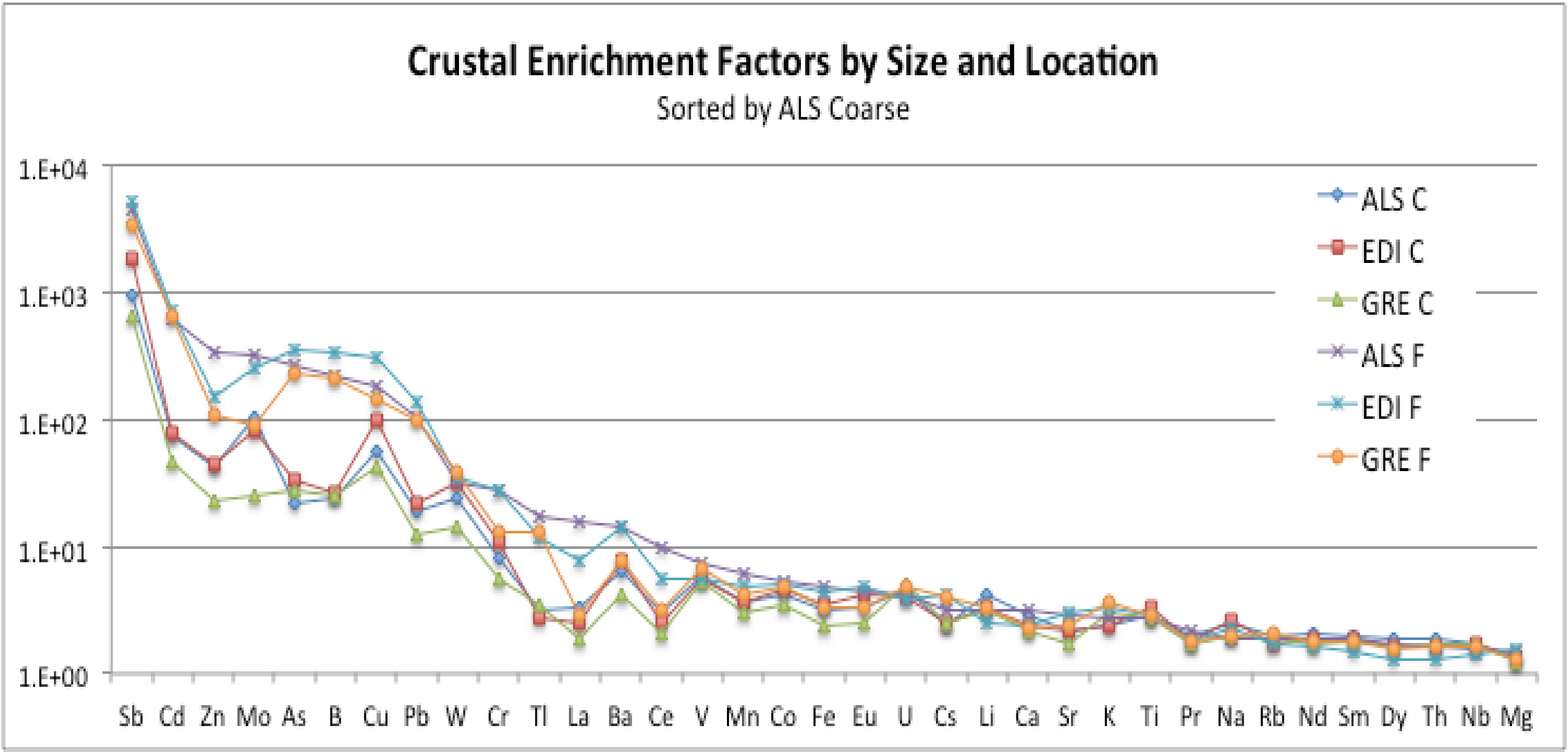
Elemental Concentrations - Concentrations and Enrichment



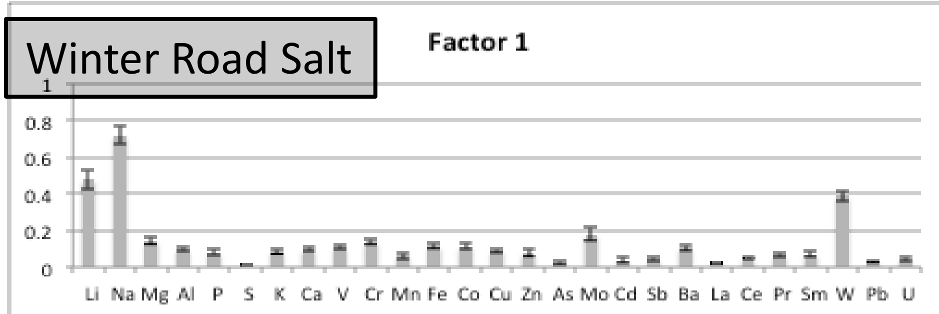
Elemental Concentrations - Concentrations and Enrichment

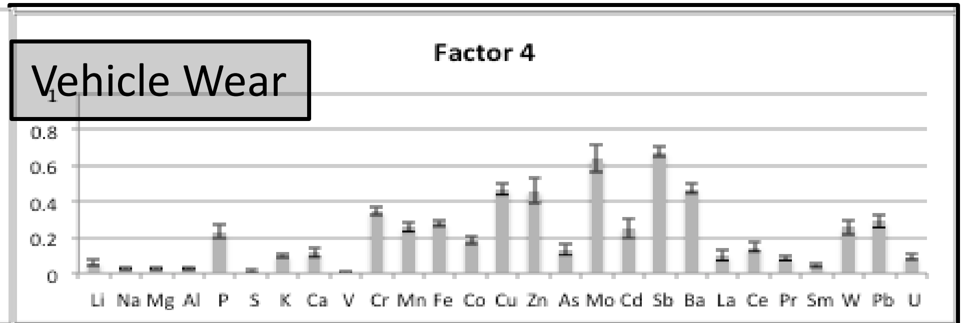


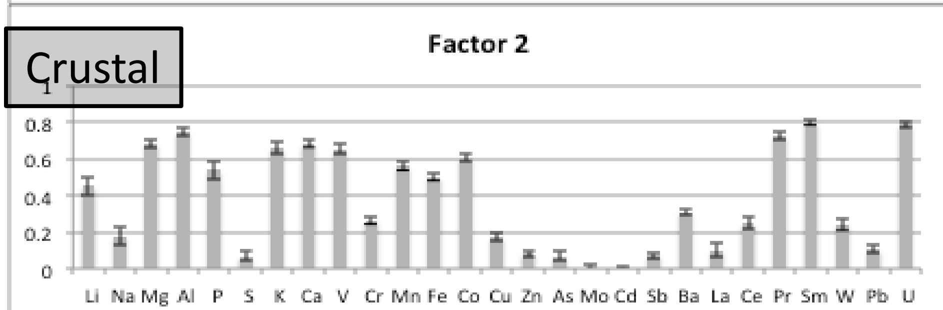
Elemental Concentrations - Concentrations and Enrichment

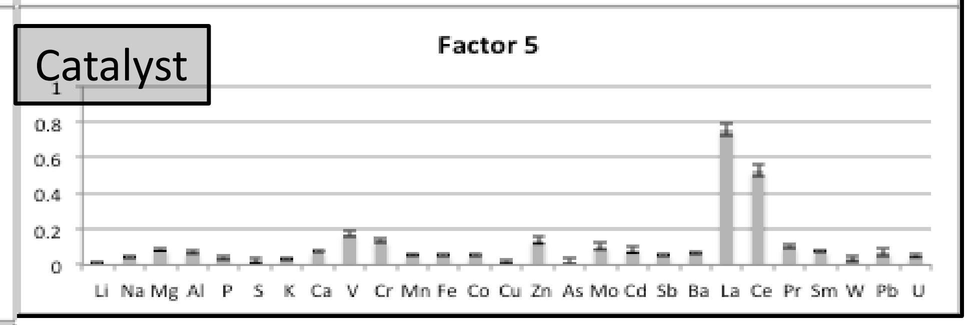


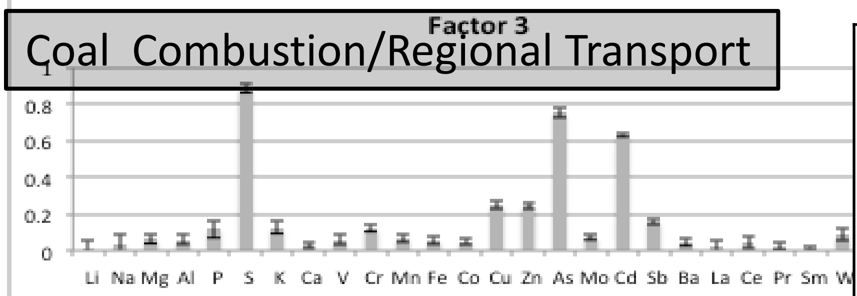
Elemental Concentrations – Source Apportionment









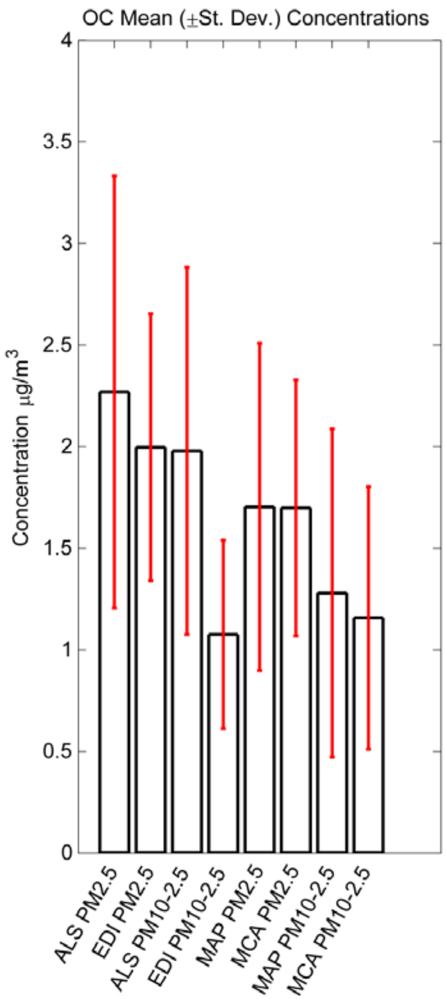


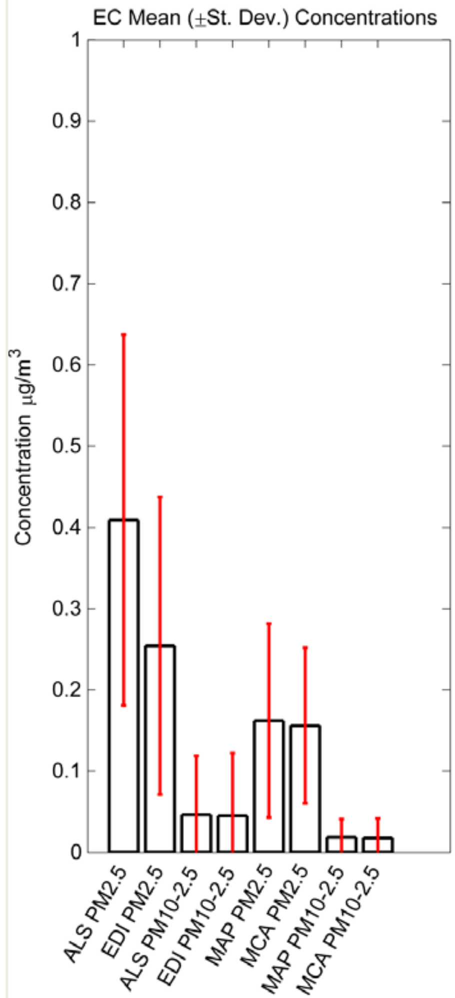
	Road Salt	Crustal	Coal combustion	Vehicle wear	Catalyst
			Fractional Element Contributions		
ALS F	0.07±0.06	0.18±0.15	0.46±0.14	0.15±0.11	0.15±0.15
EDI F	0.07±0.06	0.13±0.12	0.62±0.08	0.13±0.08	0.04±0.03
GRE F	0.08±0.04	0.28±0.18	0.57±0.16	0.06±0.04	0.02±0.01
ALS C	0.23±0.20	0.62±0.18	0.04±0.02	0.06±0.04	0.06±0.04
EDI C	0.26±0.23	0.52±0.19	0.06±0.03	0.13±0.08	0.03±0.01
GRE C	0.19±0.19	0.70±0.21	0.06±0.03	0.03±0.04	0.03±0.01

CCRUSH

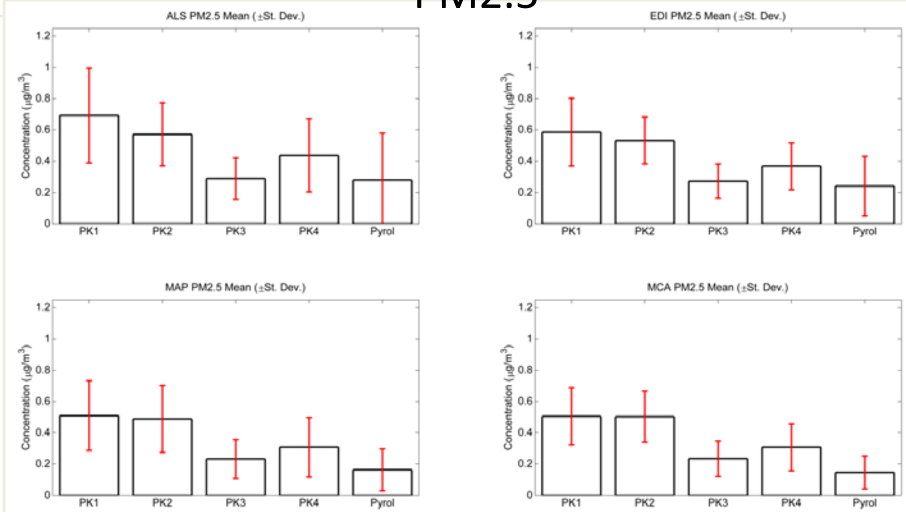
University of Colorado at Boulder
Department of Mechanical Engineering

Bulk ECOC – Summary

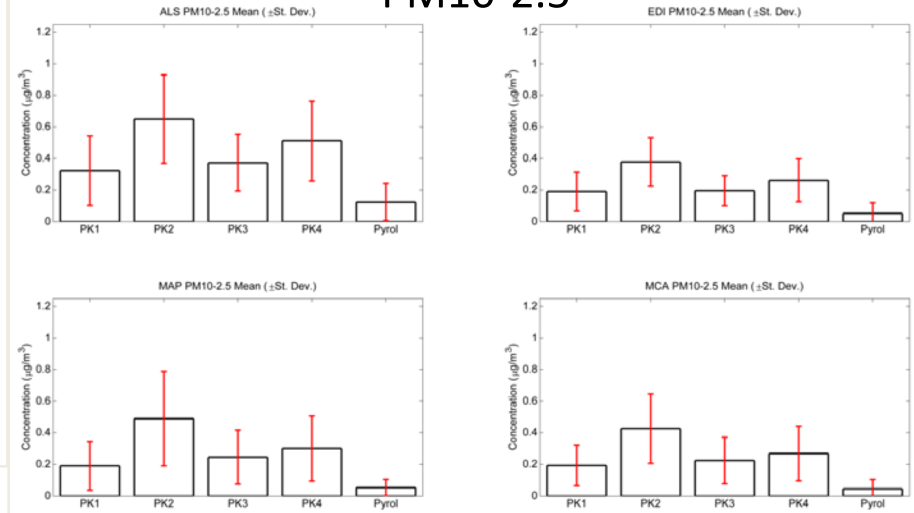




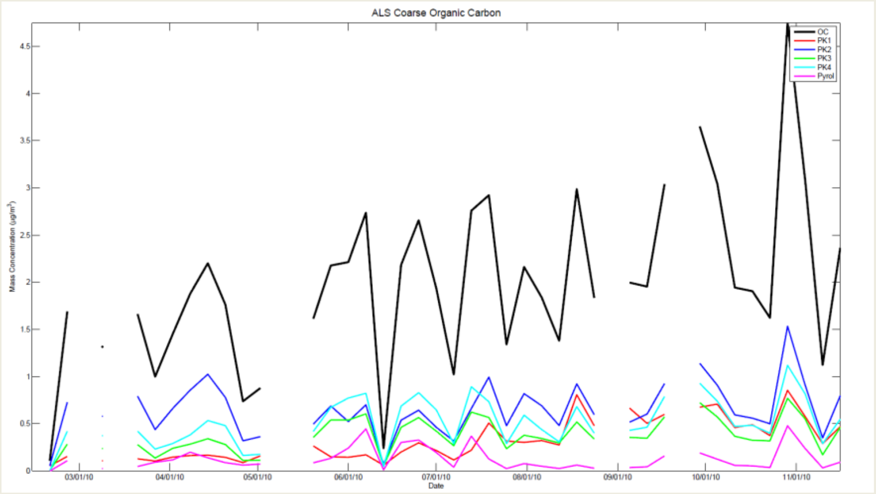
PM2.5

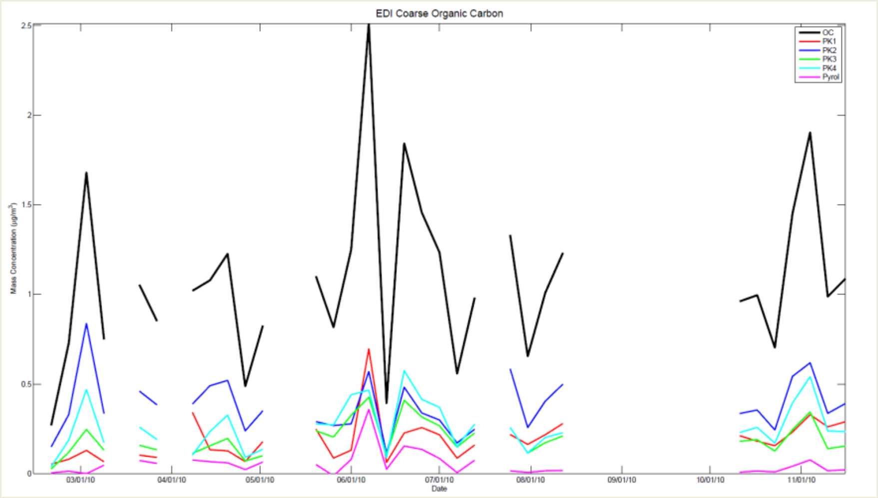


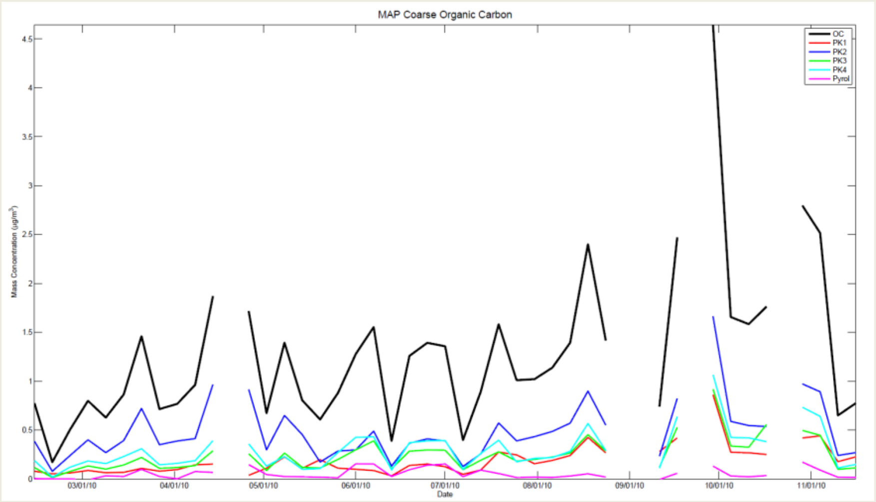
PM10-2.5

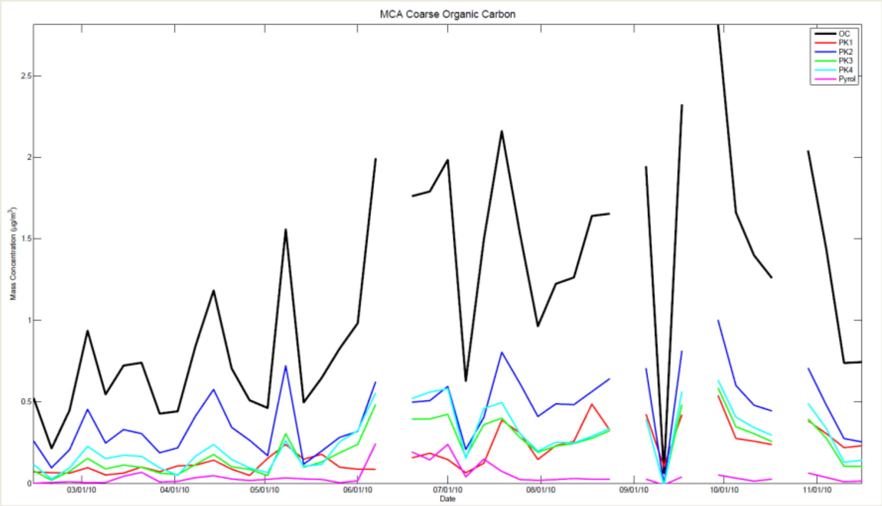


Bulk ECOC – Summer Peak 4 Shift

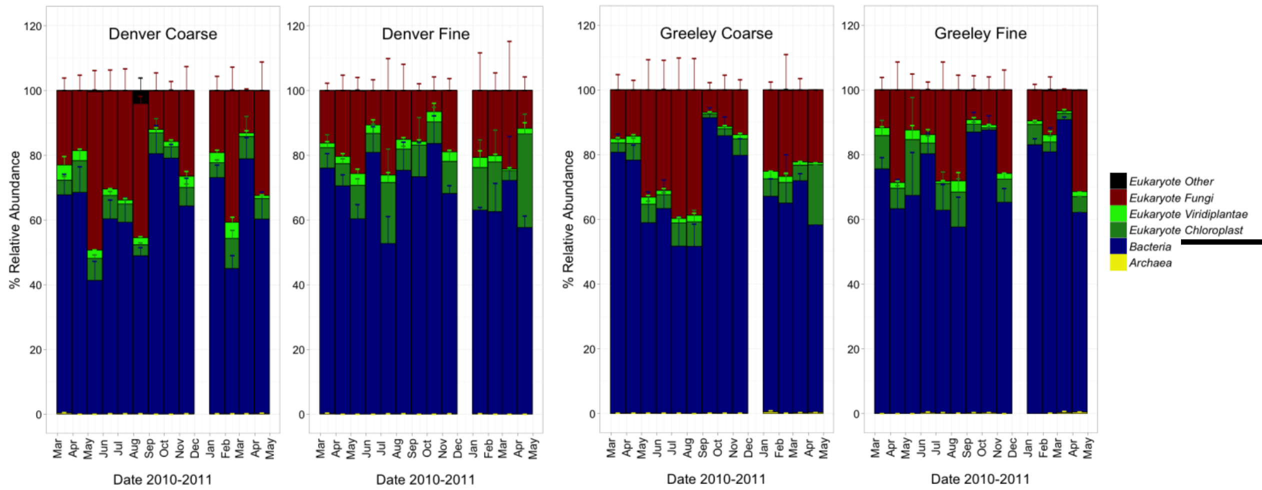


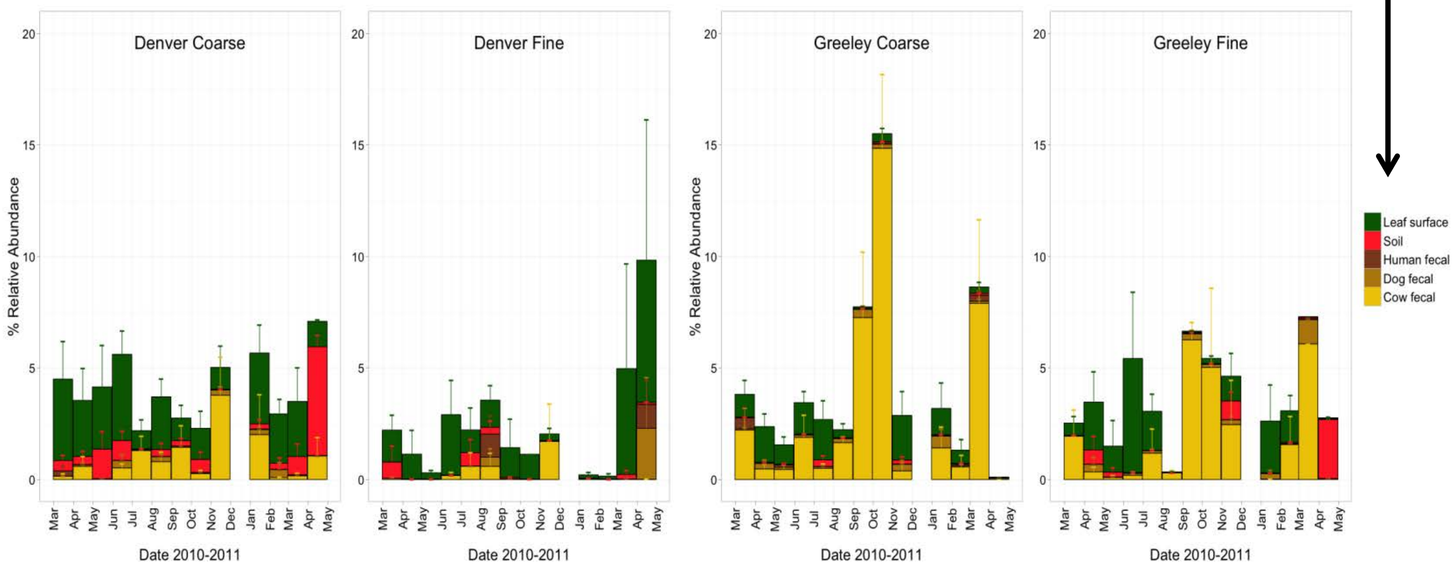




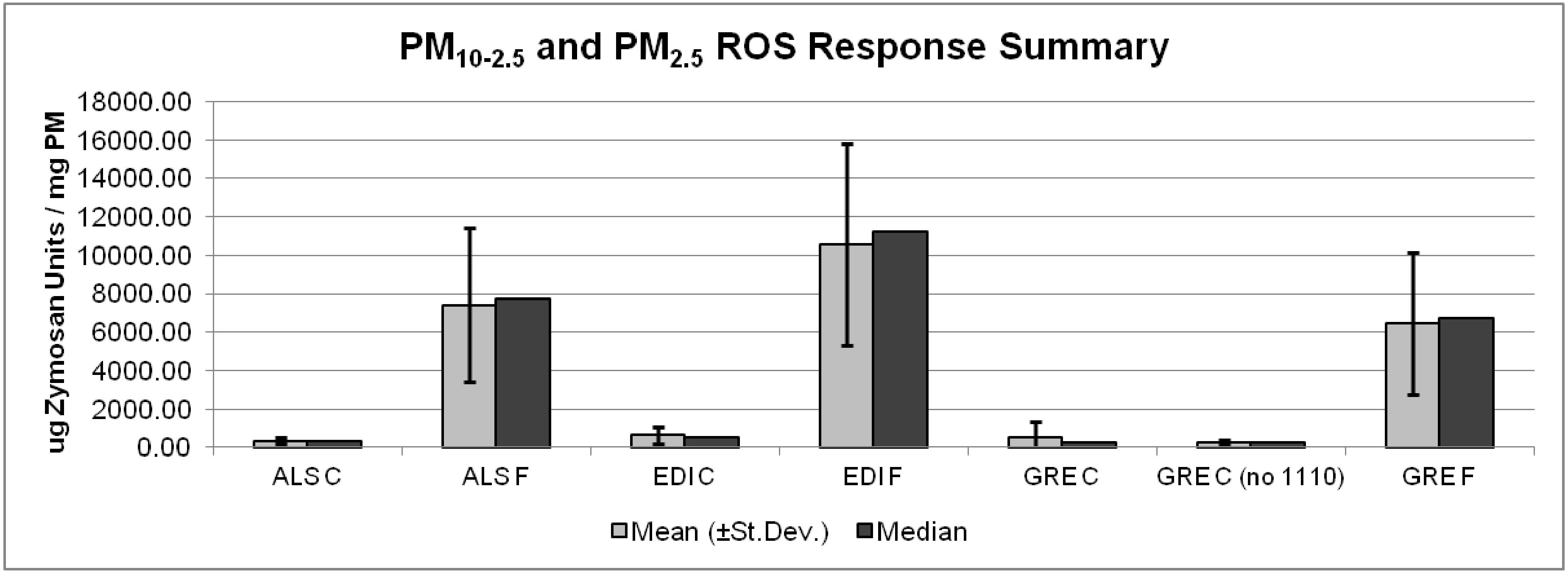


DNA Analysis - Microbe Species and Source Apportionment





ROS Assay - Summary



CCRUSH Study Results Summary

(1) Temporal trends are stronger for $PM_{10\text{-}2.5}$ and $PM_{2.5}$, related to increased rate of removal due to sedimentation

(2) $PM_{10\text{-}2.5}$ and $PM_{2.5}$ show opposite trends with wind speed and relative humidity, both fractions show the urban core of Denver as the most significant source region

(3) Biases from using various TEOM models were shown to significantly influence total concentration and spatial statistics

(4) Presented a method for removing biases from TEOM monitors in Denver

(5) Elemental concentrations revealed five factors explaining different sources of $PM_{10\text{-}2.5}$ and $PM_{2.5}$ in Denver and Greeley: road salt, crustal emissions, coal emissions, vehicle wear emissions, and a source related to catalysts found in vehicles and refineries

(6) OC peak fractions show a shift in dominant organic carbon type from Peak 2 to Peak 4 during the summer months at all sites

(7) Bacterial species identified leaf surfaces and soil to be dominant sources in Denver, and cow fecal matter as the dominant source in Greeley

(8) ROS assay results show an order of magnitude difference between $PM_{10\text{-}2.5}$ and $PM_{2.5}$ fractions, with the larger response seen for $PM_{2.5}$ samples

Future Work

(1) Finalize ECOC data and complete analysis of monthly TSP samples
(2) Perform endotoxin analysis
(3) Finish analyzing samples for total microbe counts via flow cytometry
(4) Characterize the water-soluble organic carbon fraction of collected particles
(5) Re-analyze the three-year time series of total and semi-volatile mass concentrations

Health Effects and Characterization of Urban and Rural Coarse Particulate Matter in Northeastern Colorado

Jennifer L. Peel, PhD, MPH

EPA STAR Meeting

March 18, 2013

Department of
Environmental and Radiological Health Sciences

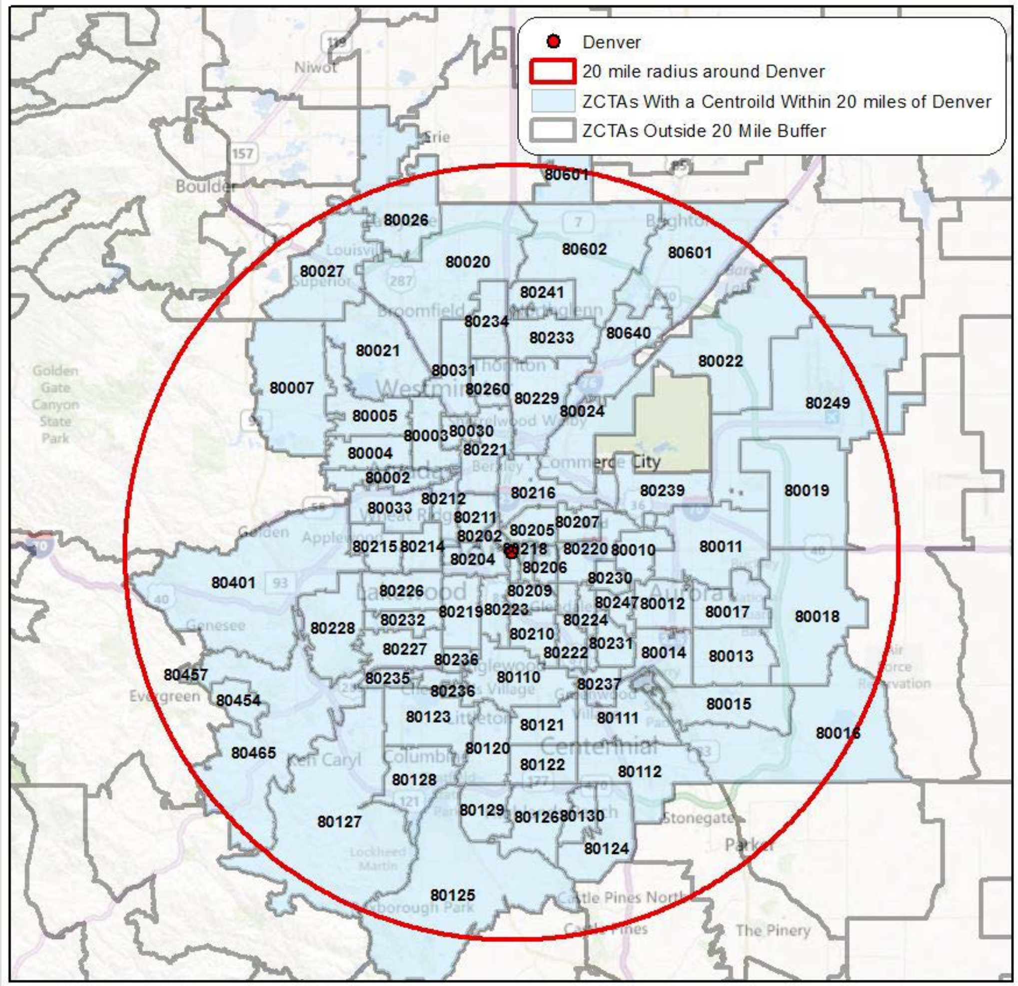
Colorado State University

CCRUSH – Health Effects Analysis

- Objective: Examine the association of short-term exposure coarse PM mass with respiratory and cardiovascular hospital visits in Denver and Greeley, CO

CCRUSH: Methods - Denver

- Daily non-elective hospital admissions, emergency department visits for all ages, 2009-2011
- 20 miles radius around the city Center

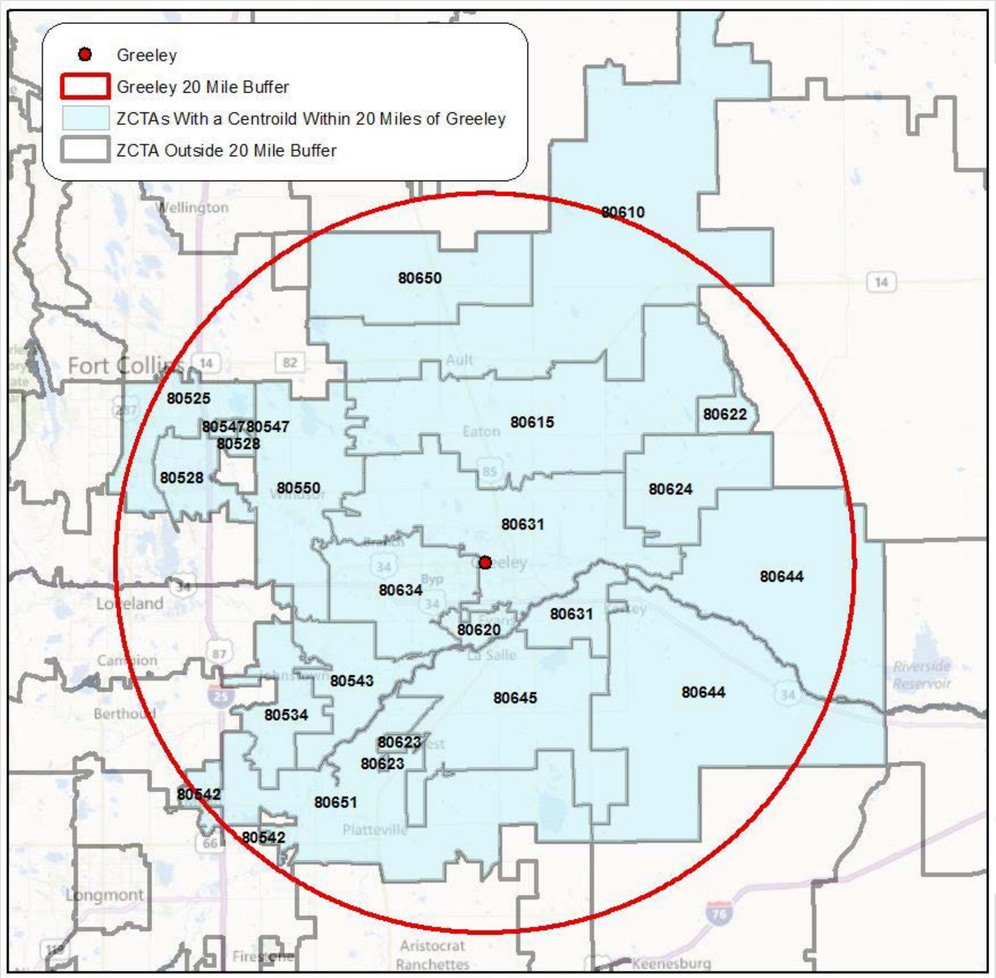


Department of
Environmental and Radiological Health Sciences

Colorado State University

CCRUSH: Methods - Greeley

- Daily non-elective hospital admissions, emergency department visits for all ages, 2009-2011
- 20 miles radius around the city Center



CCRUSH: Methods

- Cardiovascular, Respiratory
- COPD (ICD-9 490-492, 496)
- Asthma (493)
- Pneumonia (480-486)
- Upper Respiratory Infection (460-466, 477)
- Ischemic heart disease (410-414)

CCRUSH: Health models

- Poisson generalized additive models (GAMs)
  - Adjust for long term temporal trends (12 df per year), day of week, federal holidays, temperature (3 df), dewpoint (3 df)
- Lag 0 for CVD
- Lag 0, Distributed lag (0-1, 0-4) for respiratory outcomes
- RRs and 95% Cis per IQR increase
  - 9.9μg/m^3 for Denver
  - 9.0μg/m^3 for Greeley

CCRUSH: Preliminary Results

- Results primarily null
- Low daily counts, limited power, wide confidence intervals
- Suggestion of stronger effects for asthma, particularly for Greeley

CCRUSH: Ongoing Work

- Finalizing ED visit data for Denver
- Additional pollutants: PM_{10}, $PM_{2.5}$, ozone, CO, NO_2
- Alternative lag structures
- Additional health outcomes: adverse birth outcomes (preterm birth, low birth weight)
- Sensitivity analyses: alternate control for temporal trends, meteorology; case-crossover analyses

Thank you!

?

References

Brunekreef and Forsberg. European Respiratory Journal, 26: 309-318 (2005).
Clements et al. Aerosol Science and Technology, 46(1): 108-123 (2012).
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