Health Effects of Organic Aerosols:

Results from the Southeastern Center for Air Pollution & Epidemiology

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Air Pollution Health Effects

- Strong evidence for health effects of ambient air pollution, including PM, PM components, and criteria gases

Respiratory

Coughing, wheezing, reduced lung function

Exacerbation of asthma, COPD

Lung cancer

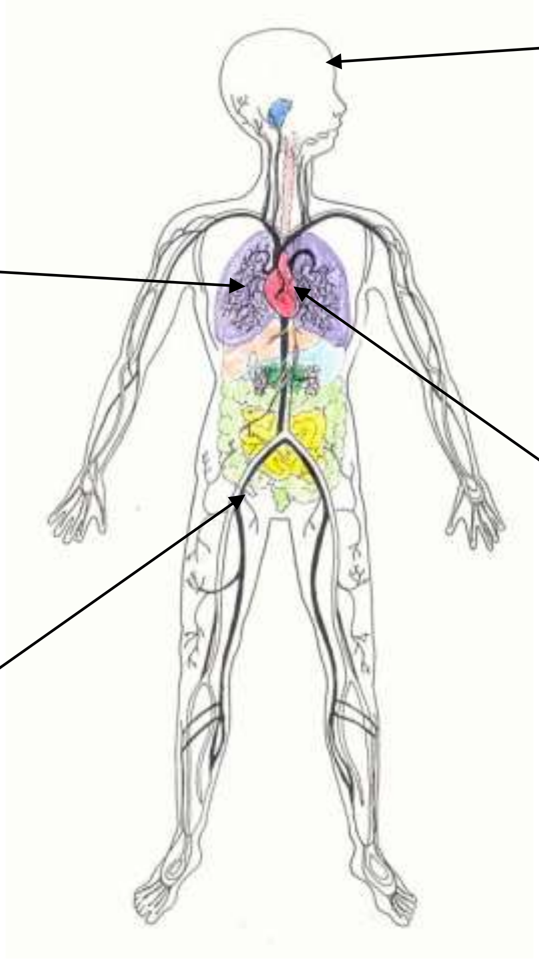
Respiratory mortality

Reproductive

Low birth weight

Preterm births and intrauterine growth retardation (?)

↑ Birth defects (?)



Central Nervous

Cerebrovascular impairment

↑ Stroke (?)

Cardiovascular

↑ Systemic inflammation

Autonomic system disorder (HRV reduction, HR increase dysrhythmias)

↑ Atherosclerosis

↑ Myocardial infarctions

CV mortality

Health Relevance of Organic Aerosols

- Increasing recognition of the health relevance of organic aerosol
- Particulate organic carbon (OC) comprises a substantial portion $PM_{2.5}$, and has been associated with adverse health effects
- Other organic aerosols, including OC species or volatile organic compounds (VOCs), have received less attention
- In general, data limitations have hindered their assessment
- Their assessment presents
  - Classic epidemiologic challenges: study design, model selection, co-pollutant confounding, exposure measurement error
  - Special considerations: different measurement methods; mixtures of gases and particles, many species, from primary and secondary sources

Organic Aerosol Data used in Health Studies

- Measurements at monitoring sites or on subjects, e.g.
  - Particle-phase total OC (e.g., filter samples analyzed via TOR/TOT)
  - Particle-phase non-polar organic compounds (e.g., filter samples analyzed via TD-GCMS)
  - Volatile organic compounds (e.g., air samples analyzed via GC-FID)
- Modeled indices of multi-pollutant mixtures containing organic aerosols, e.g.
  - $PM_{2.5}$ source apportionment → high OC content sources
  - $PM_{2.5}$ oxidative potential

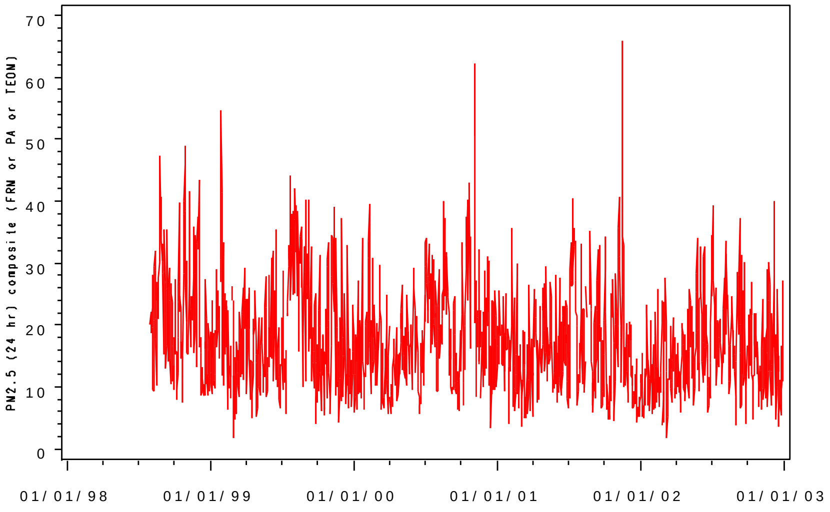
Health Study Design?

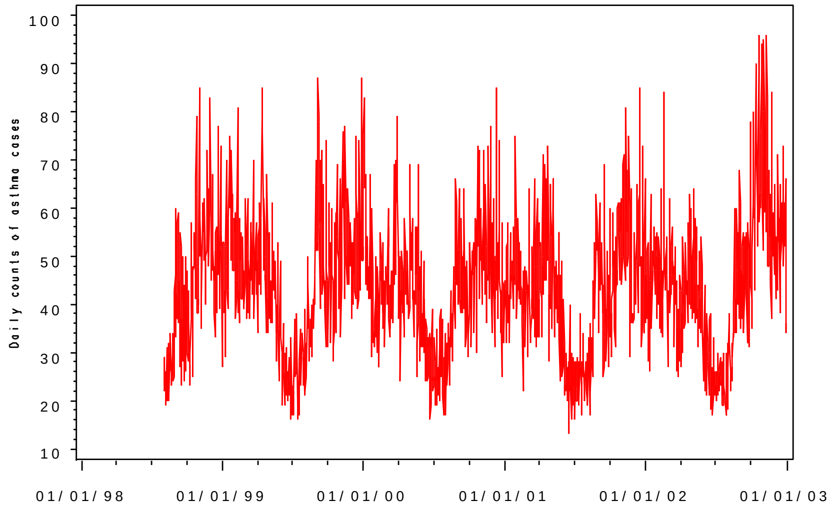
- Broadly depends on
  - Outcomes of concern (e.g., disease exacerbation vs. onset)
  - Exposure data availability
- Short-term (acute) effects studies
  - Consider short-term temporal variability in pollution (e.g., 1-5 days)
  - Outcomes and exposures compared over time
  - *Population-based time-series studies* of mortality, hospitalizations
  - *Small panel studies* of subjects followed repeatedly over short period
- Chronic effects studies
  - Consider long-term spatial/inter-individual variability in pollution (annual, multi-year)
  - Outcomes and exposures compared across communities or individuals
  - *Large cohort studies* of subjects followed over many years

Time-Series Studies

- Examine associations between daily air pollution concentrations and daily counts of health outcome (morbidity or mortality)

‘EXPOSURE’:
Daily ambient $PM_{2.5}$ concentrations → OUTCOME:
Daily counts of ED visits for asthma





CONFOUNDERS: time trend, day-of-week, holidays, hospital entry/exit, temperature, dew point

Southeastern Center for Air Pollution and Epidemiology (SCAPE)

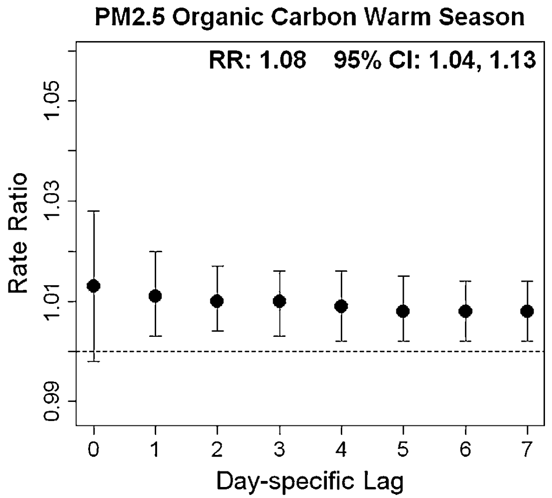
- USEPA Clean Air Research Center
- Co-directors: Paige Tolbert (Emory), Ted Russell (Georgia Tech)
- Objective: to improve our understanding of how air pollutant mixtures impact health, using field measurements, modeling and epidemiologic approaches
- Project 4: Multi-City Morbidity Study
  - Extends single-city work in Atlanta, Dallas, and St. Louis (initiated previous to SCAPE with funding from EPRI, USEPA, NIH) to 5 cities

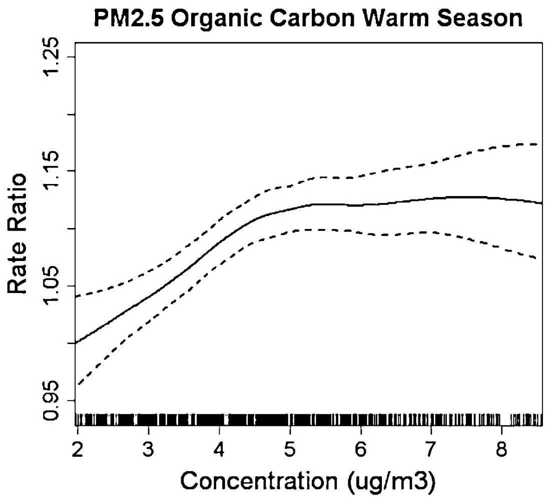
Model Selection: Lag Structure, Concentration-Response Shape?

- Long-term daily monitoring conducted at Atlanta Jefferson St. Site (1998-present)
- Previous analysis of 1998-2004 data
- Significant warm-season OC associations with pediatric asthma ED visits
- Suggestion of non-linearity and possibly longer lags important
- Attenuated with control for O_3

TABLE 2. RATE RATIOS AND 95% CONFIDENCE INTERVALS FROM POISSON GENERALIZED LINEAR MODELS FOR INTERQUARTILE RANGE INCREASES IN THREE-DAY MOVING AVERAGE POPULATION-WEIGHTED AMBIENT AIR POLLUTANT CONCENTRATIONS*

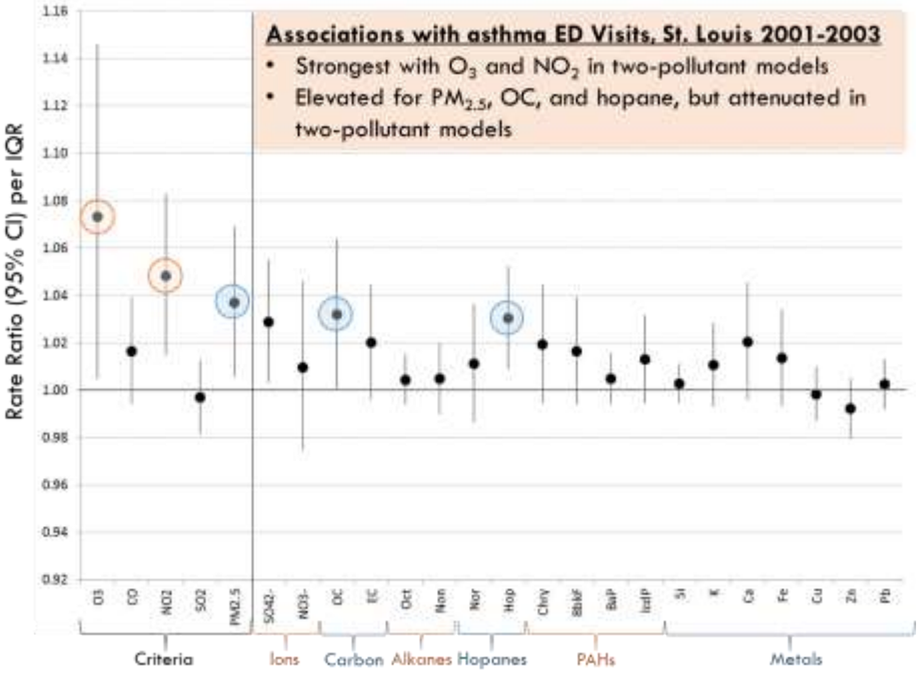
	Overall RR (95% CI) (Jan–Dec)	Warm Season RR (95% CI) (May–Oct)	Cold Season RR (95% CI) (Nov–Apr)
Ozone[†‡]	**1.062 (1.031–1.093)**	**1.082 (1.043–1.123)**	1.044 (0.992–1.098)
Nitrogen dioxide[†]	**1.036 (1.018–1.055)**	**1.066 (1.038–1.095)**	1.016 (0.992–1.040)
Carbon monoxide[†]	**1.023 (1.006–1.041)**	**1.068 (1.034–1.102)**	1.005 (0.985–1.025)
Sulfur dioxide[†]	1.012 (0.994–1.030)	**1.030 (1.002–1.058)**	1.001 (0.978–1.025)
PM_{10}[§]	**1.020 (1.003–1.038)**	**1.026 (1.001–1.051)**	1.018 (0.994–1.043)
$PM_{10\ 2.5}$[‖]	**1.034 (1.011–1.057)**	1.025 (0.991–1.059)	**1.041 (1.010–1.073)**
$PM_{2.5}$[‖]	**1.020 (1.002–1.039)**	**1.043 (1.016–1.070)**	1.005 (0.978–1.031)
$PM_{2.5}$ sulfate[‖]	1.014 (0.995–1.033)	**1.027 (1.004–1.049)**	0.991 (0.953–1.029)
$PM_{2.5}$ elemental carbon[‖]	1.015 (0.997–1.033)	**1.041 (1.010–1.072)**	1.003 (0.981–1.026)
$PM_{2.5}$ organic carbon[‖]	1.008 (0.994–1.021)	**1.034 (1.007–1.062)**	1.000 (0.985–1.016)
$PM_{2.5}$ water-soluble metals[‖]	**1.021 (1.000–1.042)**	**1.029 (1.003–1.055)**	1.005 (0.968–1.043)

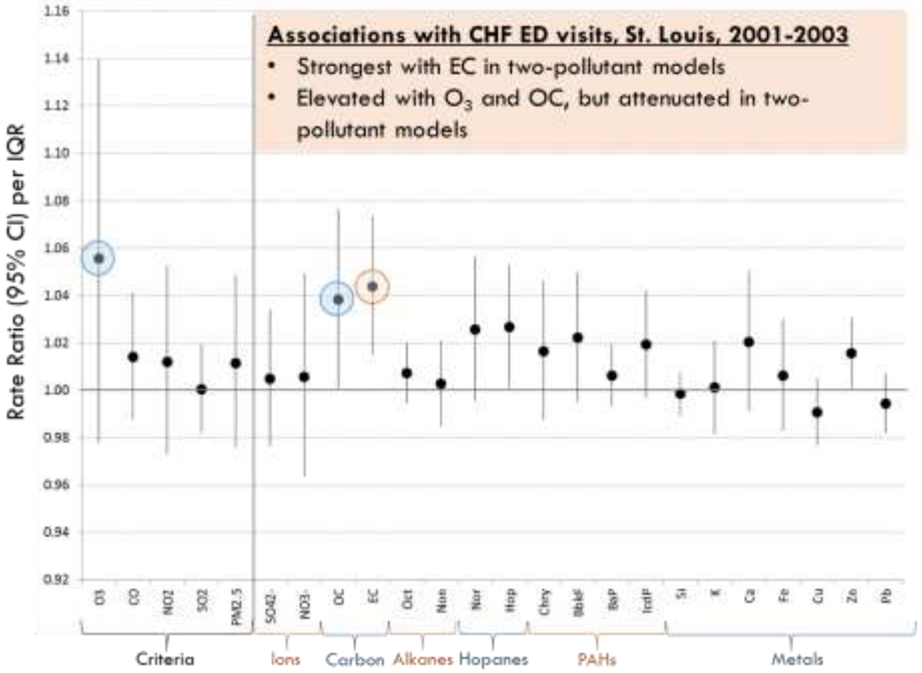




Strickland et al., *Am J Resp Crit Care Med* 182:307-316, 2010

Co-Pollutant Confounding?



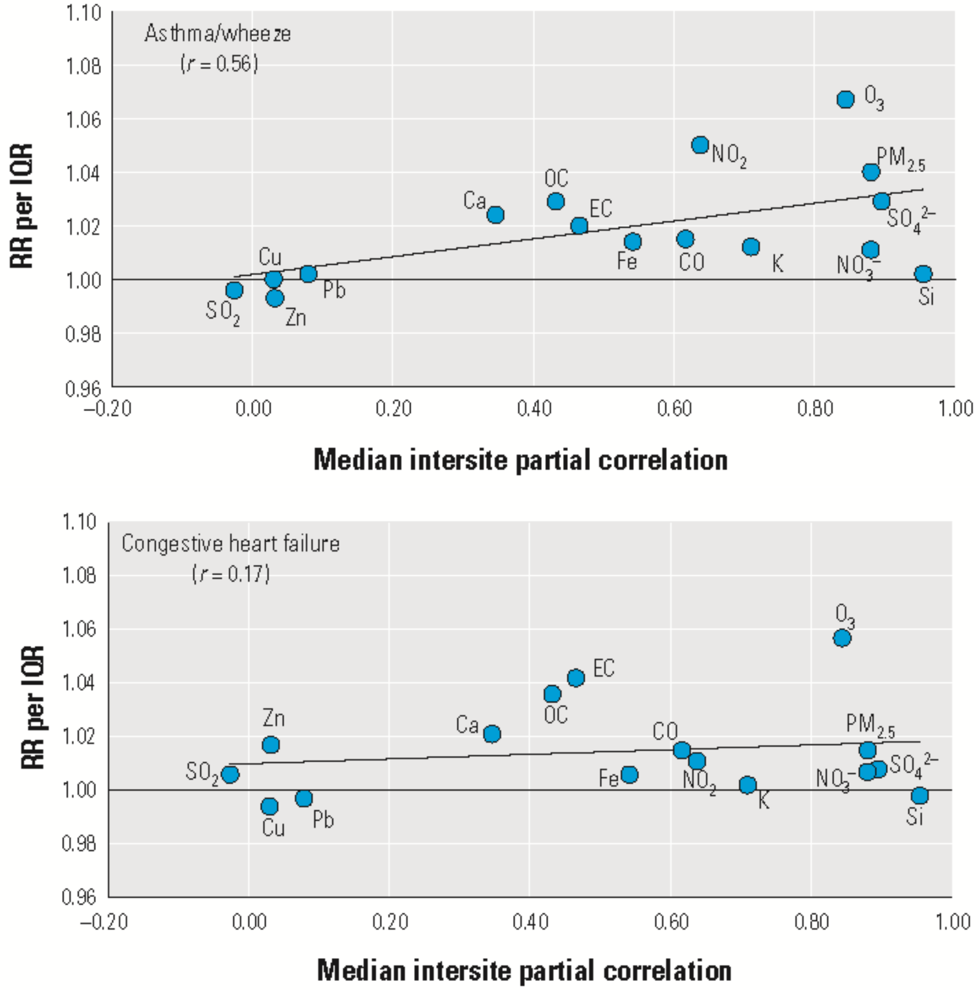


- Speciated $PM_{2.5}$ measurements collected at St. Louis Supersite at Tudor St., 2001-2003
- Epidemiologic results similar to those observed in Atlanta
- Carbon components more strongly associated with cardiovascular than respiratory outcomes

Sarnat et al., *Environ Health Perspect* 123:437–444, 2015

Exposure Measurement Error?

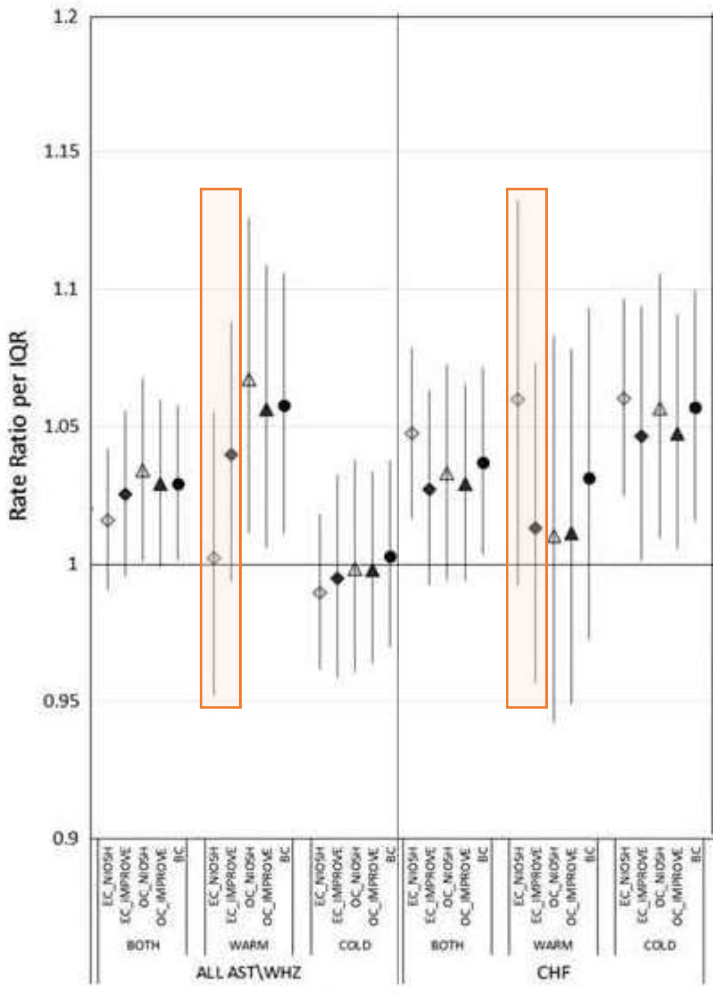
- Assessed correlations of pollutant data available at multiple monitoring sites in St. Louis to provide an indication of spatiotemporal heterogeneity
  - 4-14 sites, depending on pollutant
- Positive trends between the median inter-site correlations and observed RRs across pollutants for asthma outcome
- Suggests downward bias of observed RRs for pollutants with higher spatiotemporal variability
- Consistent with work in Atlanta
  - Simulation studies (Goldman et al., 2010, 2011, 2012)
  - Application of modeled spatially-resolved AQ data (Sarnat et al., 2013)



Sarnat et al., *Environ Health Perspect* 123:437–444, 2015

Impact of EC/OC Measurement Methods?

- Two common EC/OC measurement methods
  - Thermal optical transmittance (e.g., NIOSH method)
  - Thermal optical reflectance (e.g., IMPROVE method)
  - Differ in how carbon particles are apportioned to EC and OC
- Speciation Trends Network changed from NIOSH-like to IMPROVE method during 2007-2009
- Examined impact of measurement method on observed epidemiologic results in St. Louis
- Associations of ED visits and EC/OC from the two methods generally concordant
- But, differences in warm-season EC associations
  - May reflect differences in composition of PM assigned to EC and OC
  - EC from IMPROVE shown to include more biomass burning-related OC and secondary organic aerosols than EC from NIOSH



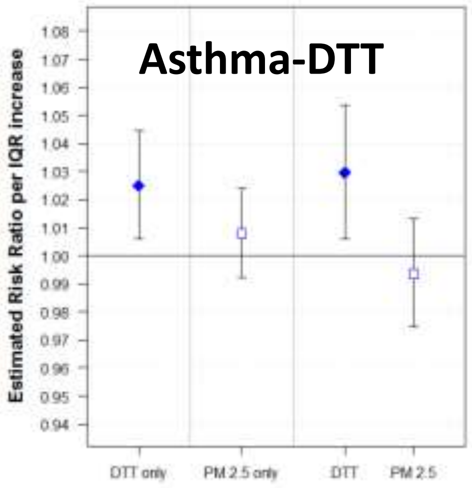
Winquist et al., *J Exposure Sci Environ Epidemiol* 25:215-221, 2015

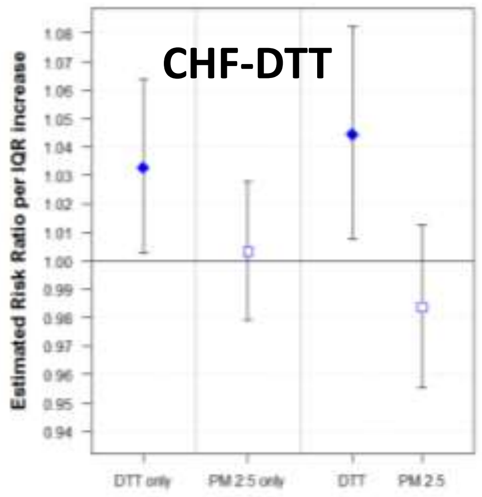
Modeled Indices of Mixtures that Contain Organic Aerosols: E.g., $PM_{2.5}$ Oxidative Potential

- Oxidative stress, an imbalance of antioxidants and oxidants in the body, is a mechanism through which $PM_{2.5}$ may adversely impact health
  - Due to oxidants carried to lungs, or
  - Due to potential for inhaled aerosol to generate reactive oxygen species (ROS)
- Weber group has worked on two different antioxidant assays that measure $PM_{2.5}$ OP via antioxidant depletion in vitro
  - Dithiothreitol (DTT), chemical surrogate of cellular reductants
  - Ascorbic acid (AA), a physiological antioxidant found in lung lining fluid
- During SCAPE, collected detailed aerosol measurements on ~200 days at Atlanta Jefferson St. site during 2012-2013, including DTT and AA
- For retrospective epidemiologic studies, develop prediction models for DTT and AA in order to back-estimate $PM_{2.5}$ OP
  - First approach developed such models based on $PM_{2.5}$ source apportionment data

Health Associations with Back-Casted Estimates, Atlanta 1998-2012

- DTT activity associated with asthma and CHF ED visits
- Associations with AA activity weaker or null
- DTT activity strongly correlated with multiple ROS-active pollutants (organic species, water-soluble metals) while AA primarily reflects copper
- DTT a promising integrated indicator for multipollutant ROS activity
- Results support hypothesis that oxidative stress derived from ambient air pollution is a pathway to adverse health outcomes
- Developing other approaches to predict and back-cast $PM_{2.5}$ OP in this study



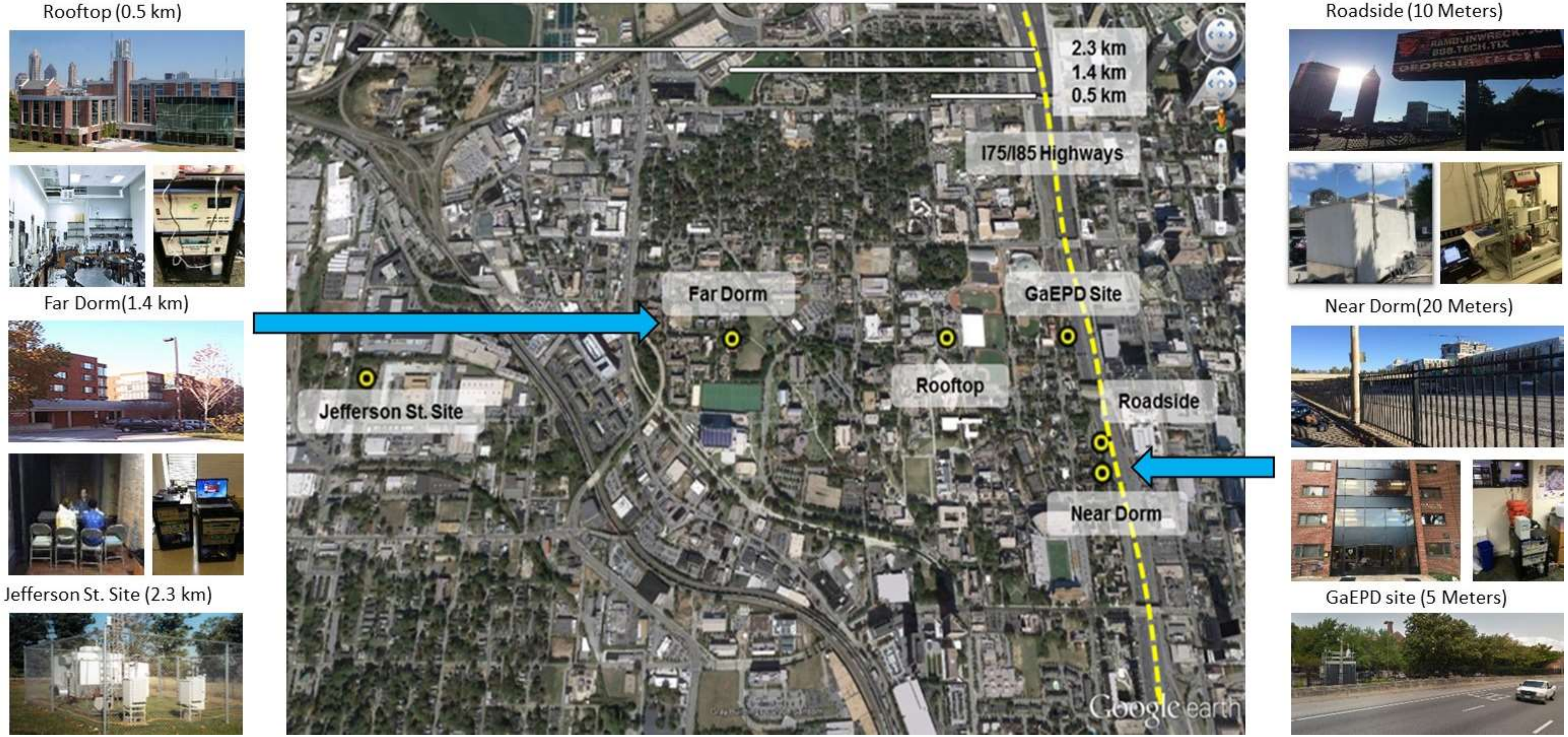


Bates et al., *Environ Sci & Technol* 49:13605-13612, 2015

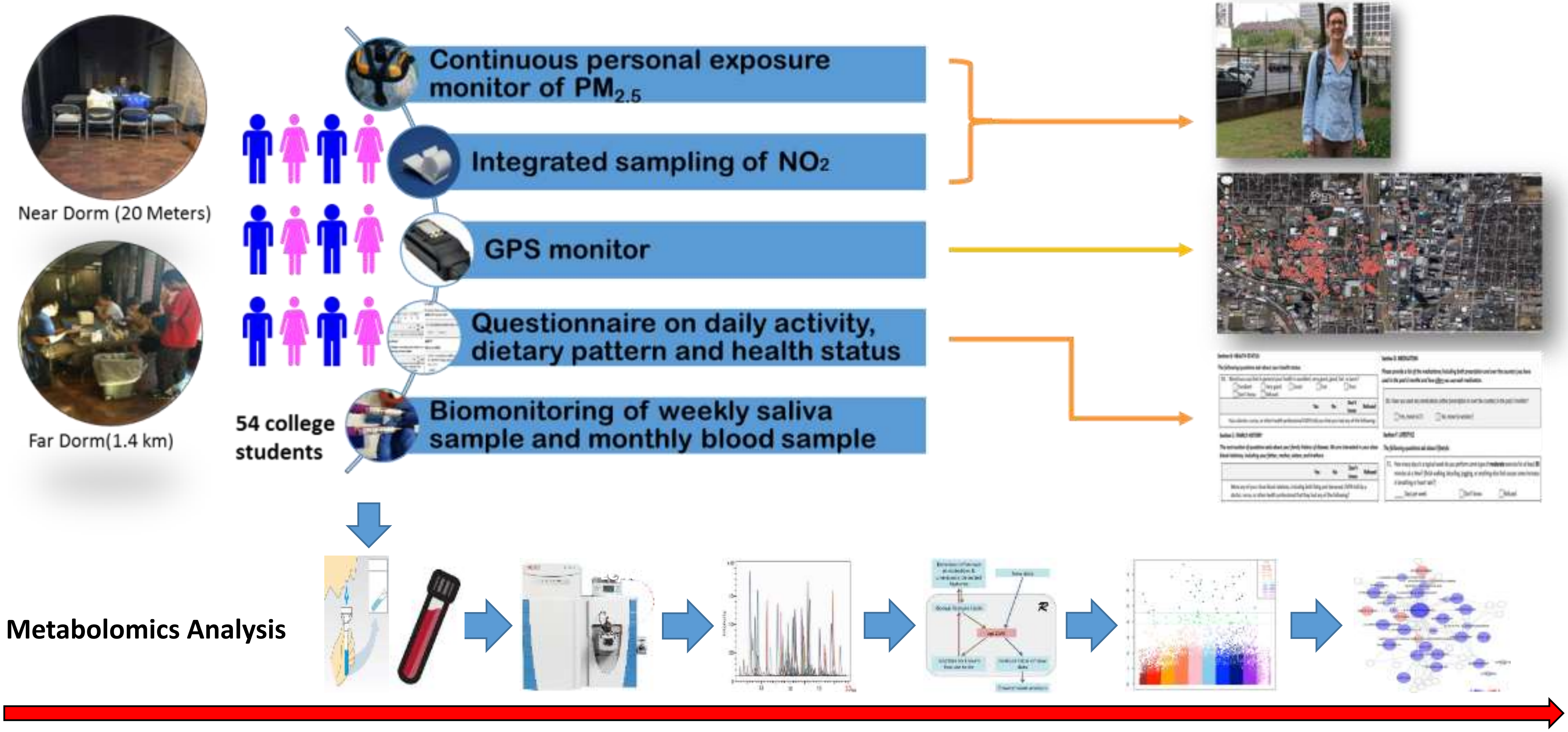
Fang et al., *Atmospheric Chemistry and Physics*, accepted

Other Study Designs for Targeted Questions

E.g., the *Dorm Room Inhalation To Vehicle Emissions (DRIVE)* study to develop multipollutant indicators of primary traffic pollution (Sarnat J, Russell; PIs); collect intensive data on CO, NO_2, NO, BC, OC, and WS-DTT outdoors and indoors at varying distances from traffic hotspot



Personal Sampling and Biomonitoring Opportunities



Summary and Considerations for Future Work

- Health studies increasingly assess acute effects of organic aerosols
  - Classic epidemiologic issues: model selection, co-pollutant confounding, exposure error
  - Special considerations: lack of detailed information on atmospheric chemistry, measurement method impacts, multi-pollutant mixtures
- Few if any long term studies of organic aerosols
- Future measurements for health studies should be designed to take advantage of temporal and/or spatial contrasts
  - For population-based acute effects setting, information on daily levels is critical
  - For panel-based setting, measurement methods that can be used in diverse microenvironments, with low detection limits given lower collected mass on personal samples
  - For long-term cohort studies, models that can accurately predict individual-level long-term concentrations at residences or where subjects spend time

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