

**Annual Center Progress Report**  
**Southeastern Center for Air Pollution and Epidemiology**  
**Georgia Tech/Emory EPA Clean Air Research Center**  
**August 1, 2014 – July 31, 2015**

This Progress Report covers the work of the Southeastern Center for Air Pollution and Epidemiology (SCAPE) from August 1, 2014 – July 31, 2015. Four Research Projects are supported by three Cores: an Administrative Core, an Air Quality Core and a Biostatistics Core. Additionally, funds are being used to support four collaborative projects. Summaries of the research conducted to date, results, and future activities for each Research Project and Research Core are provided below. More detailed information may be found in the Annual Research Project Summaries.

The Administrative Core provides overall oversight, coordination, and integration of the Center. Since initial funding of the Center, the Administrative Core developed a quality management structure, which is detailed in the EPA-approved Quality Management Plan. Functions of the quality management team over the past year are described below under Quality Assurance. In September 2014, SCAPE hosted the CLARC Annual Meeting at Georgia Tech, followed by a CLARC workshop entitled “State-of-the-Science Spatiotemporal Characterization of Ambient Air Pollution.” In November 2014, a productive fourth annual meeting for SCAPE’s ten member Science Advisory Committee took place at Emory. Multiple Center-wide and Project-specific meetings have been held throughout the year to ensure that research is coordinated and integrated among Projects and Cores.

### **1. Research Conducted and Results Generated**

#### Project 1: Development and Deployment of an Instrumentation Suite for Comprehensive Air Quality Characterization including Aerosol ROS

*Objective:* Develop method(s) for measuring ROS online and semi-continuously, acquire instrumentation, and organize measurement program. Undertake an extensive measurement campaign that will characterize spatial distributions of key air quality parameters to inform the SCAPE modeling and health studies.

#### *Research Conducted and Results Generated:*

1. Published seven papers, five more are in preparation.
2. Presented research results at conferences (15 presentations). Chaired a symposium (Chairs V. Verma and R. Weber) at AAAR Oct. 2014 on aerosol health effects.
3. Developed, constructed, and tested an online water-soluble DTT analytical instrument.
4. Performed experiments to quantify the stability of DTT on archived filters.

#### Project 2: Examining In-Vehicle Pollution and Oxidative Stress in a Cohort of Daily Commuters

*Objective:* Examine the effects of exposure to particulate mixtures occurring during automobile commuting and within indoor, non-commuting microenvironments and corresponding measures of oxidative stress-mediated response.

#### *Research Conducted and Results Generated:*

1. Completed initial sample analysis and features extractions on all ACE-2 metabolomics.
2. Completed draft of primary Project 2 epidemiology paper with a target submission date of October 2015. Findings showed elevated CRP and reduced lung function associated with highway commutes relative to controlled exposure scenarios.

3. Completed draft manuscript on comparison of ACE cytokine in dried blood spots (ELISA) vs. plasma electrochemiluminescence. Target submission date: November 2015.
4. Submitted three (3) abstracts to ISEE and two (2) to ISES.
5. Published asthma status modification paper (Mirabelli et al. 2015 *Epidemiology*) showing effect measure modification by asthma control status on eNO and lung function following highway commutes.
6. Conducted PMF on in-vehicle commutes and included output in source apportionment epidemiologic models. Results showed significant decrements in lung function and suggestive elevations in eNO most associated with a factor of in-vehicle PM that was highly enriched with transition metal species.

### Project 3: Novel Estimates of Pollutant Mixtures and Pediatric Health in Two Birth Cohorts

*Objective:* Explore the interplay between certain early life events, characterizations of air pollutant mixtures developed as part of the Center's Mixtures Characterization Toolkit, and a range of pediatric health outcomes using two large, population-based birth cohorts.

#### *Research Conducted and Results Generated:*

1. Published associations of ambient air pollution with several different types of respiratory emergency visits among children age 0-4 years in Atlanta (Darrow et al. 2014 *Am J Epidemiol*), which received the 2014 Society of Toxicology Occupational Public Health Specialty Section Paper of the Year award. Published a related manuscript describing the relationship between emergency visits for bronchiolitis during infancy and subsequent risk of emergency visits for asthma after age five in Georgia (Strickland et al. 2014 *Pediatr Perinat Epidemiol*).
2. Published joint effects estimates for NO<sub>2</sub>, ozone, and PM<sub>2.5</sub> using classification and regression trees for pediatric asthma emergency visits in a three-city study (Atlanta, Dallas, St. Louis) (Gass et al. 2015 *Environ Health*).
3. Published pediatric asthma emergency visits analyses using the Bayesian ensemble source apportionment estimates in Atlanta (Gass et al. 2015 *Am J Epidemiol*).
4. Georgia analyses of fused CMAQ estimated in relation to preterm birth accepted for publication at *Environ Health Perspect* on June 19, 2015.
5. Georgia analyses of satellite-derived PM<sub>2.5</sub> and emergency visits for pediatric respiratory disease accepted for publication at *Environ Health Perspect* on May 21, 2015.
6. Published Atlanta time-series analyses using mixtures estimated from self-organizing maps (Pearce et al. 2015 *Environ Health*).
7. A manuscript describing the fusion of observational data with chemical transport model simulations and a manuscript describing the link between reactive oxygen species and cardiorespiratory effects are under peer review.
8. Preliminary results generated for a Georgia-wide analysis of pediatric ED visits and fused CMAQ estimates and a first draft manuscript has been prepared.
9. Finalized the RLINE air quality model for estimating PM<sub>2.5</sub> from traffic emissions in Atlanta for use in the Kaiser Permanente analyses.
10. Presented preliminary results for associations between RLINE estimates and incidence of asthma in the Kaiser Permanente cohort at the 2015 Society for Epidemiologic Research annual meeting.

#### Project 4: A Multi-City Time-Series Study of Pollutant Mixtures and Acute Morbidity

*Objective:* Conduct a multi-city time-series study to clarify the impacts of air quality on acute cardiorespiratory morbidity in five US cities using novel mixture characterization metrics.

##### *Research Conducted and Results Generated:*

1. Continued efforts on application of spatially-refined modeled estimates of ambient concentrations in multi-city epidemiologic analyses, including satellite-derived air quality estimates and the SCAPE data fusion approach (Friberg et al., submitted to ES&T) in health effect analyses and compared results with use of traditional monitoring-based exposure assignment approaches (Chang et al., APHA 2014; Sarnat et al., ENV-VISION 2015; Sarnat et al., ISEE 2015).
2. Continued work on methods for detecting and analyzing air pollution mixtures using multi-pollutant monitoring data, including classification and regression trees (Gass et al., 2015), self-organizing maps (Pearce et al., 2014; Pearce et al., 2015; Pearce et al., ISEE 2015), joint effects and other approaches to estimating the effects of pollutant groups (Ye et al., ISEE 2015), examination of the effect of reactive oxygen species (ROS) on health using retrospectively predicted DTT activity (Bates et al., submitted to ES&T Bates et al., CMAS 2015 abstract pending; Bates et al. AAAR 2015), and estimating and comparing effects of sources of PM<sub>2.5</sub> across multiple cities (Krall et al., submitted to EHP; Krall et al. JSM 2015).
3. Continued work on examining detailed PM<sub>2.5</sub> components data in epidemiologic analyses (Sarnat et al., 2015; Ye et al., ISEE 2015; Krall et al., submitted to CEHR).
4. Conducted preliminary multi-city analyses examining the shape of concentration-response functions using categorical pollution indicators.
5. Assessed potential modifiers of the effects of ambient air pollution on health, including age (Alhanti et al., accepted at JESEE), neighborhood socioeconomic factors (O'Lenick et al., submitted to JECH; O'Lenick et al., SER 2015), air exchange rates, and season.

#### Core B: Air Quality Core

*Objective:* Provide SCAPE researchers with the methods and data to comprehensively characterize air pollutants relevant to the four projects and other cores. Project activities are supported by collecting and managing atmospheric data, developing a "Mixture Characterization Toolkit" (MC Toolkit) for further analyses specific to the projects, and providing the expertise and resources to facilitate the application of the various components of the toolkit. Comprehensive characterization of air pollutants is developed by analyses of the detailed chemical and physical measurements conducted by the Center, along with those available from ambient air quality monitoring networks and special field campaigns. Spatial and temporal characterization of the air pollutant mixtures and emission sources are determined by using extended receptor-oriented models, chemical transport models, regression approaches, hybrid methods, and remote sensing applied over multiple scales.

##### *Research Conducted and Results Generated:*

1. Hosted a workshop on Spatiotemporal Multipollutant Characterization Methods following the 2014 CLARC annual meeting in Atlanta.
2. Leading the preparation of a manuscript covering the various spatiotemporal pollutant modeling methods used by the CLARCs as part of their research.
3. The uniquely large data set of Reactive Oxygen Species (ROS), as measured using a dithiothreitol (DTT) assay and an advanced as part of Project 1, was modeled using the ensemble-trained chemical mass balance method to develop source-ROS relationships. Those relationships were used to simulate historical trends in ambient PM<sub>2.5</sub> DTT-activity. The modeled historical trend in

ROS was then used in an epidemiological analysis in Atlanta using a long term emergency department (ED) record to assess the association between ROS (as measured using the DTT assay) and various health outcomes.

4. An analysis similar to the above was carried out using ROS measured using the ascorbic acid assay and the results were provided to Emory as part of Project 4.
5. The OBS-CMAQ data fusion method (described last year) has been applied to the five Project 4 cities. The method was written up in manuscript form and was submitted for publication.
6. The same data fusion methodology was applied to North Carolina for comparison as part of the Harvard-Georgia Tech satellite method intercomparison. This work is still in progress.
7. Working with the Atlanta Regional Council (ARC) and the Environmental Protection Division (EPD) of the Georgia Dept. of Natural Resources, we have analyzed their RLINE dispersion modeling results using our CMB mobile source impacts at monitors in Atlanta, as well as the OBS-CMAQ data fusion/with IMSI to rescale the RLINE results to more closely follow observations.
8. Using the rescaled ARC/EPD RLINE results, mapped to 250 m resolution grids, we have explored various methods to provide researchers in Project 3 with 250 m resolution PM<sub>2.5</sub> fields. Methods examined include (a) use of Emory's statistical downscaler using satellite observations or CMAQ model results and the RLINE results and combining and (b) directly combining RLINE and the OBS-CMAQ fields.
9. Applied the CMAQ-DDM (Decoupled Direct Method) model, described last year in the progress report as well as in a publication, to additional years to determine the source impact for 40 PM<sub>2.5</sub> species from 20 source categories in the 36-km CONUS domain. We have also been investigating how to better correct source impacts for secondary aerosol formation and to improve source profiles.
10. Developed multipollutant CMAQ fields for the 2013 period when CCAR (UW) was conducting their collaborative measurements in Atlanta. The CMAQ fields were provided to CCAR. We (both teams) have compared CCAR's observations to our modeled results, as well as to our fixed site measurements.

#### Core C: Biostatistics Core

*Objective:* Provide statistical support to the Center and to the associated Projects.

#### *Research Conducted and Results Generated:*

As part of and in addition to their participation in SCAPE research projects, members of the Biostatistics Core participated in a number of peer-reviewed publications and presentations relating to development and application of advanced epidemiologic and statistical methods. Core contributions are detailed in the progress report below and include:

1. Ten new peer-reviewed publications, two additional publications accepted for publication, and multiple presentations at national conferences.
2. Postdoctoral researcher Jenna Krall and Project 3 PI Matthew Strickland presented their analyses of health effects of pollutant mixtures as part of an invitation-only workshop on mixture analysis by the National Institute of Environmental Health Sciences. Additional analyses by Core Director Lance Waller were also included as a poster.

## **2. Difficulties in Carrying out Mission of Center**

During this fifth reporting period, the work of the Center has progressed as planned without any major difficulties in carrying out the proposed mission. A request for a one-year no cost extension was submitted to EPA on December 16, 2014. This request details the reasons for delays in execution of the

original SCAPE research plan by project, including personnel changes and maternity leaves, human subject requirements, and slow receipt of data from subcontractors.

### **3. Absences or Changes in Key Personnel**

Key personnel on the Projects and Cores have remained, largely, the same since the initial grant funding. Prof. Bergin, the GIT PI on Project 2, moved to Duke. Given that the chemical analyses being conducted by GIT was largely done, and that he remains available for consultation, this is having a minor impact on the project. There have been minor changes in study staff as described by project below.

1. Air Quality Core: David Lavoue left the group this year. Josephine Bates, a graduate student who joined the group in August 2013, is assuming David's projects.
2. Biostatistics Core: Dr. John Pearce, a postdoctoral researcher supported on Core Director Waller's NIEHS T32 training grant in Environmental Biostatistics, obtained a K99/R00 grant from NIEHS, completed the K99 portion and initiated his R00 in a new position as a tenure-track assistant professor in Environmental Health at the Medical University of South Carolina. Dr. Jenna Krall joined the SCAPE research team as a postdoctoral researcher supported on the same training grant. Dr. Krall brings expertise in the development and application of statistical methods for linking source apportionment to epidemiologic outcomes and has already initiated collaborations with Drs. Stefanie Sarnat, Matthew Strickland, Lance Waller, and Howard Chang.
3. Project 1: PhD student Laura King has been completing her thesis and has not been working directly on the project. MS Student Dong Gao was added to the project.
4. Project 2: Roby Greenwald left Emory for a faculty position at Georgia State University. Mike Bergin left Georgia Tech for a faculty position at Duke University. Rachel Golan finished her post-doc position at Emory and returned to Israel for a faculty position. Drs. Greenwald, Bergin, and Golan are all still collaborating on Project 2. David Diaz-Sanchez from EPA is now also collaborating on Project 2 analyses.
5. Project 3: Due to drastic downsizing at Kaiser Permanente, Kaiser was no longer able to provide a PI to collaborate with Project 3 and the subcontract was terminated early. All Kaiser data have been received and the analyses are being done by the Emory research team.

### **4. Financial Report (removed)**

## 5. Quality Assurance

SCAPE's Quality Management Plan (QMP) was submitted to and approved by EPA in March 2011. No changes were made to the QMP during the 2015 annual review. Quality Assurance Project Plans (QAPPs) for all four Projects and the Air Quality Core were initially approved by the quality assurance team (Center Co-Directors, Quality Assurance Manager, and two Quality Advisors) in 2011 and are reviewed annually. All necessary Standard Operating Procedures have been drafted and approved.

The Quality Assurance Manager meets with the designated Quality Control Reviewer for each Project and the Air Quality Core on a semiannual basis to review all QA/QC procedures detailed in the Project QAPPs and data management plans and to conduct annual project audits during the first year of research. This reporting year, meetings were held in October 2014 and April 2015. The Quality Assurance Manager maintains detailed meeting records and works with the PIs and Quality Control Reviewers to resolve any issues.

The Quality Assurance Manager also works with the PIs and Quality Control Reviewers on a regular basis to ensure that data are stored securely. The Quality Assurance Manager maintains a data access log detailing user access to all restricted folders stored on network drives. The Quality Assurance Manager also works with the Quality Control Reviewers to maintain updated IRB approvals and inform the Project Officer of any amendments.

Finally, a new data management program is currently under development to ensure that all published analyses can easily be replicated should the authors leave Emory or Georgia Tech. Under this program, the first author is responsible for creating a single statistical program to replicate all tables or figures reported in SCAPE papers. These programs will be stored on secure network drives accessible to SCAPE researchers.

## 6. Planned Future Activities

### Project 1: Development and Deployment of an Instrumentation Suite for Comprehensive Air Quality Characterization including Aerosol ROS

1. Continue to analyze data, complete 6 manuscripts currently in progress, and present results at meetings.
2. Verify performance of online water-soluble DTT instrument.
3. Develop and verify method for measurement of total DTT on filter samples.

### Project 2: Examining In-Vehicle Pollution and Oxidative Stress in a Cohort of Daily Commuters

1. Complete analyses of all ACE-2 pollutant and health endpoints.
2. Complete and submit draft manuscripts currently in preparation of ACE-1 and initial ACE-2 data. The manuscripts include analyses of:
  - a. Correlations between noise and in-vehicle particulate pollution in ACE-1 (Ladva et al.);
  - b. Frequency of traffic pollution events and corresponding health response in ACE-2 (Greenwald et al.);
  - c. Associations between salivary cortisol and perceived stress in ACE-1 and ACE-2 (Raysoni et al.);
  - d. Associations between breath and blood MDA in ACE-1 (Golan et al.);
  - e. Associations between exposures and acute response in ACE-2 (Golan et al.);
  - f. Conduct ACE-2 epidemiologic analyses on changes in metabolomic profiles.

### Project 3: Novel Estimates of Pollutant Mixtures and Pediatric Health in Two Birth Cohorts

1. Ensure all manuscripts currently in peer review process are published.
2. Finalize analyses and submit manuscript for statewide pediatric ED visit and fused CMAQ analysis.
3. Finalize analyses and submit manuscript for statewide birth weight analyses.
4. Prepare and submit a manuscript describing the RLINE model estimates in Atlanta.
5. Prepare and submit a manuscript on the Kaiser Permanente asthma incidence analyses.
6. Examine associations between pregnancy exposures to PM<sub>2.5</sub> from traffic and asthma in the Kaiser Permanente cohort.
7. Further sub-analyses of both cohorts.

### Project 4: A Multi-City Time-Series Study of Pollutant Mixtures and Acute Morbidity

1. Incorporate Pittsburgh data in multi-city epidemiologic analyses.
2. Ensure currently submitted manuscripts are published.
3. Submit 3-5 manuscripts currently in preparation and planned.
4. Continue several analyses focused on assessment of mixtures and effect modification in the single- and multi-city context.

### Core B: Air Quality Core

1. Complete application of the CMAQ-CMB hybrid method to the entire 10 year period (2002-2012) to provide source-specific impact fields for the CONUS.
2. Use the CMAQ-Hybrid results and the ROS observations, both using the DTT and AA assays from Project 1, to develop source specific ROS impacts. The resulting associations will then be used to develop long term, national trends in ROS for use in an acute health association analysis as part of Project 4.
3. Finish the application of the OBS-CMAQ fusion approach to the NC area as part of the Harvard-GIT-EPA collaboration. Apply to EC, NO<sub>2</sub> and CO. Use the EC, CO and NO<sub>2</sub> results to estimate mobile source impacts using the IMSI approach. Conduct more thorough evaluation of the method and further comparison to the satellite-based approaches.
4. Provide further support to Project 3 in terms of using CMAQ, satellite observations and RLINE to develop fine scale fields.
5. Provide further support to Project 4 to estimate source impacts at the five SCAPE cities.
6. Provide further support to Project 1 to analyze their observational results.
7. Continue working with CCAR on the collaborative. We will apply RLINE at a fine scale to provide more detailed multipollutant data for comparison to their observations and to CMAQ.

### Core C: Biostatistics Core

1. Continue to work very closely with all SCAPE Projects. High priority efforts include:
  - a. Linking Air Quality Core and Project 1 exposure measures to the epidemiologic Projects 3 and 4.
  - b. Evaluating quantitative summaries of physiologic responses to scripted commutes in Project 2.
2. Provide statistical support for ongoing epidemiologic analyses of ambient air pollution and preterm birth, pediatric emergency department visits, and birth weight (part of the measurement error collaboration with CCAR).
3. Lead development of methodological projects, including a manuscript concerning partial reduction of unmeasured confounding (by using the future exposure indicator approach originally

proposed by members of the Core, Klein and Flanders, and featured in a series of publications by the group).

## 7. Collaborations

### **Collaborative Project 1: Characterization of primary and secondary traffic related particles (Collaborators: Harvard and SCAPE)**

The objective of this collaborative project is to characterize the composition of tunnel primary, secondary, and aged primary plus secondary aerosols generated for exposures in Harvard's toxicology study (Project 1). Dr. Sally Ng from Georgia Institute of Technology and doctoral student Matt Kollman collaborated with Harvard CLARC researchers on this effort, using an Aerosol Chemical Speciation Monitor (ACSM) provided by Aerodyne Inc. The ACSM provides quantitative measurement of non-refractory submicron aerosol composition, including mass spectra, with a time resolution on the order of 15 to 30 min. The ACSM measures organics, nitrate, sulfate, ammonium, and chloride. The extent of oxidation of chamber aerosols can also be determined semi-continuously from the mass fraction  $m/z$  44 ( $\text{CO}_2^+$ ), allowing measurement of the evolution of O/C over the course of each experiment.

For exposures conducted during the collaboration, the ACSM was operated continuously. The goal was to provide complementary chemical data including near real-time determination of the contribution of primary and secondary aerosols, as well as the extent of oxidation over the course of each experiment. An additional goal of the collaboration was to provide information about the atmosphere inside the photochemical chamber and how the secondary products relate to those found in the atmosphere. To do this, the ACSM was operated through the normal startup procedures of the photochemical chamber during the primary plus secondary organic aerosol (P+SOA) and SOA only atmospheres, as well as with the primary tunnel particles (P), to evaluate the changes observed in aerosol evolution as the photochemical chamber output stabilized prior to exposures. During this portion of the study, additional measurements collocated with the ACSM were made, including integrated particle mass, EC/OC, and trace elemental concentrations, as well as continuous particle size distribution using a Scanning Mobility Particle Sizer (SMPS).

During animal exposures, measurements were made at the point of exposure, including integrated particle mass, EC/OC, and trace elemental concentrations, as well as continuous particle size distribution using a Scanning Mobility Particle Sizer (SMPS). During the hours where animals were not being exposed, a collocated SMPS along with the ACSM were operated, but the remaining chamber output was utilized for collecting samples for analysis for reactive oxygen species.

The data analysis has been completed. We are preparing a manuscript. Below is a summary of the main findings from this study:

1. There are some variations in the organic aerosol loading in each exposure environment. The loadings are fairly constant for P only ( $9.4 \mu\text{g}/\text{m}^3$ ) and P+SOA ( $2.1 \mu\text{g}/\text{m}^3$ ). However, for the SOA only atmosphere, there is a clear diurnal cycle in the organic aerosol loading (highest around mid-night). The average organic loading for the SOA only system is also the highest among the three systems, at  $13 \mu\text{g}/\text{m}^3$ .



2. Results from Positive Matrix Factorization (PMF) analysis of each system reveal the presence of highly oxygenated organic aerosols (OOA) in all exposure environments. Surprisingly, even the P only system contains a fair amount of OOA. This could result from the mixing of ambient air with the tunnel air, prior to entering the chamber. We resolve an aromatic-type OOA factor, which has not been resolved in prior studies. The high levels of aromatic hydrocarbons under these exposure environments and the lack of biogenic influences likely make the aromatic OOA more distinctive in this study. Hydrocarbon-like OA (HOA) is only resolved in the P only system and P+SOA system, which is expected.
3. The total DTT activity of the aerosols increases with the OC content of the sample.
4. The intrinsic DTT activity of the aerosols formed in the three test environments are comparable. While the SOA system has the highest intrinsic DTT activity, it also has the largest variation, which could be a result of the more diverse source of SOA.
5. The intrinsic DTT activity of traffic aerosols in this study is comparable to ambient PM and oxidized OOA in Atlanta.
6. Results from this study clearly demonstrate that organic aerosols alone can generate reactive oxygen species. Many prior studies attributed DTT activity of ambient aerosols to metals. In this study, the SOA system does not contain any metals but still exhibits a similar level of DTT activity compared to the other two systems.

### **Collaborative Project 2: Mobile and Fixed Site Characterization of Vehicle Emission Impacts in Atlanta** **(Collaborators: SCAPE, CCAR, and EPA)**

The goals of this collaborative project are to compare instruments and methods for characterizing vehicle emissions, personal exposures and spatial distributions by deploying the CCAR measurement platform and sampling protocols in Atlanta for a 16-day period and to compare a limited set of spatially intensive mobile and fixed site measurements of selected pollutants with downscaled CMAQ predictions in Atlanta, Georgia.

We have been working with our CCAR collaborators to evaluate how well the ambient monitoring network and emissions-based regional scale (CMAQ chemical transport model) and local scale (RLINE dispersion model) compare with mobile platform measurements of air pollutant concentration gradients in metropolitan Atlanta. The CCAR mobile platform measurements taken in September, 2013 included “fuzzy point” characterizations and three trips originating and ending at an Atlanta central monitor location (Jefferson St, SEARCH monitor). One trip included a southeastern segment of the Atlanta perimeter highway from the airport to a CSN monitoring site. A second route included taking the I-75/I-85 connector to a large highway intersection (“spaghetti junction”) in northeastern Atlanta. A third route extended 60 km west to the rural SEARCH monitor at Yorkville.

Fuzzy point medians were compared with ambient monitor measurements and 4-km, 1-hr CMAQ predictions for NO<sub>2</sub>, NO<sub>x</sub>, ozone, black carbon, and nephelometer measurements. Pearson R-squared values for fuzzy point assessments with ambient measurements ranged from 0.37 to 0.89. R-squared values were lower when compared with CMAQ predictions due to the lack of spatial and temporal resolution of the CMAQ predictions as well as model limitations. Comparison of trip measurements with RLINE predictions and with roadside stationary measurements is ongoing. Passive badge data will also be evaluated to assess pollutant gradients.

An abstract has been submitted for presentation at the AAAR 2015 Annual Conference in Minneapolis in October, 2015.

**Collaborative Project 3: Inter-comparison of ambient PM2.5 estimation models in NC (Collaborators: SCAPE, Harvard, CCAR, and EPA)**

The goal of this effort is to summarize the strengths and limitations of current satellite-driven PM2.5 exposure models and CMAQ PM2.5 simulations, and to identify directions for future model development and applications in various population-based health effects studies. There are six candidate models to be evaluated: (1) Koutrakis group's mixed effects model, (2) Chang's spatial downscaler, (3) Liu group's mixed effects model, (4) UW/CCAR group's spatiotemporal model, and (5) Russell group's CMAQ PM2.5 simulation. We have designed a modeling domain centered in North Carolina for the 2006 – 2008 time period. To facilitate model cross-comparison, a common input dataset was compiled by Liu group, including MODIS total AOD values, derived meteorological parameters and, from the UW database, GIS-based spatial covariates. This was distributed to all participating research teams. A common master modeling grid at 10-km resolution was developed by Liu group and shared by all teams. A set of common procedures and statistics will be jointly developed by all participating teams to evaluate model performance. After preliminary results are generated, each team will document their model development in sufficient detail for other teams to reproduce their results. The estimated deliverable of this project will be a manuscript to report evaluation results.

As of June 2015, the Emory team has worked with the Harvard team to generate the final model development and prediction datasets using MODIS collection 6 AOD data at 10 km resolution over North Carolina for the proposed study period. Quality flags are included to mark potential outliers. The Emory team has completed model development with the updated dataset using Chang's spatial downscaler and Liu group's mixed effects model. The Harvard and UW teams will complete their model runs in August. National scale evaluation of the quality of various MODIS collection 6 AOD parameters are underway. In addition, Air Quality Core personnel have applied the OBS-CMAQ fusion approach to the domain, conducted data withholding cross validation, and compared the results to the Emory AOD-based method. The Emory team is working to process Georgia Tech's CMAQ output.

**Collaborative Project 4: Measurement Error for Air Pollution Cohort Studies: Application and Comparison of Several Statistical Methods to Georgia Birth Cohort Data (Collaborators: CCAR and SCAPE, possibly Harvard in the future)**

The project will consider three statistical approaches to account for measurement error arising from spatio-temporal exposure prediction models. These statistical approaches will be developed and applied to examine linear associations between ambient PM2.5 concentrations and birth weight among full-term births using Georgia state-wide geocoded birth records.

Emory investigators have successfully applied UW's spatio-temporal exposure model to predict ambient PM2.5 concentrations across the state of Georgia. The exposures were linked to individual birth records at the Census blockgroup level. Preliminary health analyses were conducted and the results were discussed among collaborators across CLARC centers during the Annual Meeting. Pending final sensitivity studies by Emory investigators, this component of the health analysis is complete and development of Bayesian measurement error methods will begin. UW has begun replicating Emory's analysis and has put in place software and procedure for applying the parameter bootstrap to assess bias and/or inflated standard errors from measurement error.

**Date of Report:** July 31, 2015

**EPA Agreement Number:** R834799

**Center Name & Internal Number:** Southeastern Center for Air Pollution and Epidemiology  
(R834799C001)

**Project Title:** Development and Deployment of an Instrumentation Suite for Comprehensive Air Quality Characterization including Aerosol ROS (Project 1)

**Investigator(s):** PI -- Rodney Weber, PhD<sup>1</sup> ([rweber@eas.gatech.edu](mailto:rweber@eas.gatech.edu)); Michael Bergin, PhD<sup>3</sup> ([mike.bergin@ce.gatech.edu](mailto:mike.bergin@ce.gatech.edu)); James Mulholland, PhD<sup>1</sup> ([james.mulholland@ce.gatech.edu](mailto:james.mulholland@ce.gatech.edu)); Athanasios Nenes, PhD<sup>2</sup> ([nenes@eas.gatech.edu](mailto:nenes@eas.gatech.edu)); Jeremy Sarnat, ScD<sup>2</sup> ([jsarnat@emory.edu](mailto:jsarnat@emory.edu)); Stefanie Sarnat, ScD<sup>2</sup> ([sebelt@sph.emory.edu](mailto:sebelt@sph.emory.edu)); Matthew Strickland, PhD<sup>2</sup> ([mjstric@emory.edu](mailto:mjstric@emory.edu))

**Institution(s) of PI(s):** <sup>1</sup>Georgia Institute of Technology and <sup>2</sup>Emory University, Atlanta, Georgia; <sup>3</sup>Duke University, Durham, North Carolina

**Research Category:** Air Quality and Air Toxics

**Project Period:** 08/01/2014 – 7/31/2015

**Objective of Research:** To provide a chemically comprehensive data set on ambient particle composition at various sites relative to roadway emissions that will be used by other SCAPE Projects. As a part of this effort, our goal is to develop new instruments and analytical methods to quantify concentrations of particle-bound reactive oxygen species (ROS) and associated aerosol components. These techniques were deployed during SCAPE and data sets have been generated for investigating ROS sources, atmospheric processing and health impacts.

#### **Progress Summary/Accomplishments:**

During this reporting period, work has focused on data analyses, publishing papers and two laboratory projects. Papers published during this performance period are listed below. In addition, the following papers are in progress:

- Xu L, Suresh S, Guo H, Weber RJ, Ng NL. Aerosol characterization over the southeastern United States using high resolution aerosol mass spectrometry: spatial and seasonal variation of aerosol composition, sources, and organic nitrates. *Atmospheric Chemistry and Physics Discussions* 15:10479-10552, 2015a. (Project 1)
- Bates JT, Weber RJ, Abrams J, Verma V, Fang T, Klein M, Strckland MJ, Sarnat SE, Chang H, Mulholland JA, Tolbert PE, Russell AG. Reactive oxygen species in atmospheric particulate matter suggest a link to cardiorespiratory effects, *in preparation* 2015. (Core B, Project 1)
- Fang T, Guo H, Verma V, Peltier RE, Weber RJ. PM2.5 Water-Soluble Elements in the Southeastern United States: Automated analytical method development, spatiotemporal distributions, source apportionment, and implications for health studies. *Atmospheric Chemistry and Physics Discussions* 15:17189-17227, 2015b. (Project 1)
- Fang T, Verma V, Bates JT, Mulholland JA, Russell AG, Weber RJ. Contrasting oxidative potential of ambient water-soluble PM2.5 measured by dithiothreitol (DTT) and ascorbic acid (AA) assays: spatiotemporal distribution, source apportionment, and health impacts, *in progress* 2015. (Project 1)
- Verma V, Wang Y, El-Afifi R, Fang T, Rowland J, Russell AG, Weber RJ. Fractionating ambient humic-like substances (HULIS) for their reactive oxygen species activity - Assessing the importance of quinones and atmospheric aging on particulate matter toxicity, *in review* 2015. (Project 1)

Laboratory work was undertaken in two areas: The development of an online ROS measurement system and analysis of the stability of ROS on archived filters.

Online ROS system: Although the filter-based system has provided major new insights, it is recognized that online measurements of ROS by acellular assays, such as DTT, could provide substantially greater insights into sources, atmospheric processing and health impacts of aerosols. An online system provides much larger data sets, allows better integration with state-of-the art online aerosol chemical speciation instrumentation, a better assessment of variability in ROS and what drives it, and an assessment of possible artifacts associated with filter-based methods. In the past year progress has been made on developing the method. First, an analysis was made to determine how to improve the sensitivity of the filter DTT-protocol for the much lower concentrations associated with an online particle collection system. Based on these results a method was developed involving a Particle Into Liquid Sample and flow injection system. The instrument was constructed and deployed for over 2 months of ambient sampling. Filter samples were collected at the same time, extracted in water and DTT measured. Overall, poor comparison was found between the online and filter results. Our hypothesis is that the online system is measuring closer to total DTT, whereas the filter system is only measuring the water-soluble fraction of DTT. To assess this we plan to develop a method to measure total DTT of particles collected on filters and rerun the comparison (see future plans).

Stability of ROS on Filters: Linking ROS to health-endpoints through epidemiological analysis requires knowledge of ROS over an extended period of time. Since our approach is a retrospective analysis, ROS (DTT) data from the JST site was estimated based on a source apportionment analyses. To verify predicted ROS and assess uncertainty we proposed to measure ROS on archived filters. This approach is based on the assumption that DTT is stable on frozen filters for extended time periods. To assess this, we performed experiments on filters collected by SEARCH at JST during the period when ROS was measured at JST as part of this project. These filters have been stored for over two years. We found that the DTT on archived filters was highly correlated to DTT measured immediately after filters were deployed, but lower by roughly 60%. Chemical speciation analysis suggests that this is due to loss of DTT activity of the organic fraction contributing to DTT (hydrophobic fraction), whereas the redox metals contributing to DTT activity were more stable (hydrophilic fraction). A manuscript on this work is currently in progress.

#### **Publications:**

1. Fang T, Verma V, Guo H, King LE, Edgerton ES, Weber RJ. A semi-automated system for quantifying the oxidative potential of ambient particles in aqueous extracts using the dithiothreitol (DTT) assay: results from the Southeastern Center for Air Pollution and Epidemiology (SCAPE). *Atmospheric Measurement Techniques* 8:471-82, 2015. (Project 1)
2. Guo H, Xu L, Bougiatioti A, Cerully KM, Capps SL, Hite JR, Carlton AG, Lee S-H, Bergin MH, Ng NL, Nenes A, Weber RJ. Fine-particle water and pH in the southeastern United States. *Atmospheric Chemistry and Physics* 15:5211–5228, 2015. (Project 1)
3. Verma V, Fang T, Lu X, Peltier RE, Russell AG, Ng NL, Weber RJ. Organic aerosols associated with the generation of reactive oxygen species (ROS) by water-soluble PM<sub>2.5</sub>. *Environmental Science and Technology* 49(7):4646-4656, 2015. (Project 1)
4. Xu L, Guo H, Boyd CM, Klein M, Bougiatioti A, Cerully KM, Hite JR, Isaacman-VanWertz G, Kreisberg NM, Knot C, Olson K, Koss A, Goldstein AH, Hering SV, de Gouw J, Baumann K, Lee SH, Nenes A, Weber RJ, Ng NL. Effects of anthropogenic emissions on aerosol formation from isoprene and monoterpenes in the southeastern United States. *Proceedings of the National Academy of Sciences USA* 112(1):37-42, 2015 (Core B, Core C, Project 1)
5. Budisulistiorini SH, Canagaratna MR, Croteau PL, Baumann K, Edgerton ES, Kollman MS, Ng NL, Verma V, Shaw SL, Knipping EM, Worsnop DR, Jayne JT, Weber RJ, Surratt JD. Intercomparison

**of an Aerosol Chemical Speciation Monitor (ACSM) with ambient fine aerosol measurements in downtown Atlanta, Georgia. *Atmospheric Measurement Techniques* 7: 1929-1941, 2014. (Project 1)**

6. Liu J, Scheuer E, Dibb JE, Ziemba LD, Thornhill KL, Anderson BE, Wisthaler A, Mikoviny T, Devi JJ, Bergin M, Weber RJ. Brown carbon in the continental troposphere. *Geophysical Research Letters* 41:2191–2195, 2014, doi:2110.1002/2013GL058976. (Project 1)
7. Verma V, Fang T, Guo H, King L, Bates JT, Peltier RE, Edgerton E, Russell AJ, Weber RJ. Reactive oxygen species associated with water-soluble PM<sub>2.5</sub> in the southeastern United States: spatiotemporal trends and source apportionment. *Atmospheric Chemistry and Physics* 14:12915-30, 2014. (Project 1, Core B)
8. Xu L, Guo H, Boyd CM, Klein M, Bougiatioti A, Cerully KM, Hite JR, Isaacman-VanWertz G, Kreisberg NM, Knote C, Olson K, Koss A, Goldstein AH, Hering SV, de Gouw J, Baumann K, Lee S-H, Nenes A, Weber RJ, Ng NL. Effects of anthropogenic emissions on aerosol formation from isoprene and monoterpenes in the southeastern United States. *Proceedings of the National Academy of Sciences* 112(1):37-42, 2014. (Project 1)
9. King LE, Weber RJ. Development and testing of an online method to measure ambient fine particulate reactive oxygen species (ROS) based on the 2',7'-dichlorofluorescein (DCFH) assay. *Atmospheric Measurement Techniques* 6:1647-1658, 2013. (Project 1)
10. Liu J, Bergin M, Guo H, King L, Kotra N, Edgerton E, Weber RJ. Size-resolved measurements of brown carbon in water and methanol extracts and estimates of their contribution to ambient fine-particle light absorption. *Atmospheric Chemistry and Physics* 13:12389-12404, 2013. (Project 1)
11. Verma V, Rico-Martinez R, Kotra N, Rennolds C, King L, Liu J, Snell T, Weber J. Estimating the toxicity of ambient fine aerosols using freshwater rotifer *Brachionus calyciflorus* (Rotifera: Monogononta). *Environmental Pollution* 182:379-384, 2013. (Project 1)
12. Verma V, Rico-Martinez R, Kotra N, King L, Liu J, Snell TW, Weber RJ. Contribution of water-soluble and insoluble components and their hydrophobic/hydrophilic subfractions to the reactive oxygen species-generating potential of fine ambient aerosols. *Environmental Science and Technology* 46:11384-11392, 2012. (Project 1)

**Presentations:**

1. Verma V, Fang T, Bates JT, Russell AG, Weber RJ. Oxidative potential of ambient particulate matter in southeastern United States and the generation of reactive oxygen species. Poster presentation at the Society of Environmental Toxicology and Chemistry North America 36<sup>th</sup> Annual Meeting. Salt Lake City, Utah, November 2015.
2. Bates J, Weber RJ, Verma V, Fang T, Klein M, Strickland M, Sarnat SE, Chang H, Mulholland J, Tolbert P, Russell AG. "Source impacts on reactive oxygen species generated by water-soluble PM<sub>2.5</sub> in Atlanta and associations with cardiorespiratory effects." Oral presentation at American Association for Aerosol Research Annual Conference. Minneapolis, MN, October 12-16, 2015.
3. Fang T, Verma V, Bates JT, Mulholland JA, Russell AG, Weber RJ. "Contrasting oxidative potential of ambient water-soluble PM<sub>2.5</sub> measured by dithiothreitol (DTT) and ascorbic acid (AA) assays: spatiotemporal distribution, source apportionment, and health impacts." Poster presentation at American Association for Aerosol Research Annual Conference. Minneapolis, MN, October 12-16, 2015.
4. Verma V, Fang T, Bates JT, Russell AJ, Devlin R, Weber RJ. "Reactive oxygen species (ROS) associated with ambient particulate matter – insights from Southeastern Center for Air

- Pollution and Epidemiology (SCAPE) study.” Platform presentation at American Association for Aerosol Research Annual Conference. Minneapolis, MN, October 12-16, 2015.
5. Verma V, Fang T, Xu L, Gao H, Bates JT, Russell AG, Peltier R, Lee N, Weber RJ. “Reactive oxygen species associated with water-soluble PM<sub>2.5</sub> in the southeastern United States – implications for health effects of ambient atmospheric aerosols.” Platform presentation at the International Society for Exposure Science Annual Meeting. Henderson, Nevada, October 2015.
  6. Ng NL, Xu L, Suresh S, Weber RJ, Baumann K, Edgerton ES. “Characterization of aerosol composition and sources in the greater Atlanta area by aerosol mass spectrometry.” Poster presentation at the AGU 47th Annual Fall Meeting. San Francisco, California, December 2014.
  7. Xu L, Middlebrook AM, Liao J, Welti A, Guo H, Lin JL, Bougiatioti A, Weber RJ, Nenes A, Holloway JS, Gilman J, Lerner BM, Graus M, Warneke C, Trainer M, de Gouw JA, Ng NL. “Aircraft Measurement of Isoprene-derived Organic Aerosol during the Southeast Nexus (SENEX) Campaign Using an Aerosol Mass Spectrometer.” Poster presentation at the AGU 47th Annual Fall Meeting. San Francisco, California, December 2014.
  8. Verma V, Fang T, Bates J, Lu X, Ng NL, Russell AG, Weber RJ. “Biomass burning as an important source of reactive oxygen species associated with the atmospheric aerosols in southeastern United States – implications for health effects of ambient particulate matter.” Poster presentation at the AGU 47th Annual Fall Meeting. San Francisco, California, December 2014.
  9. Tuet Wing-Yin, Verma V, Champion J, Ng NL. “Composition and oxidative properties of particulate matter (PM) mixtures.” Oral presentation at the American Institute of Chemical Engineers Conference. Atlanta, Georgia, November 2014.
  10. Fang T, Verma V, Peltier RE, Guo H, King LE, Weber RJ. “Distribution of ambient atmospheric water-soluble metals in the southeastern United States and insights into their complexation states.” Poster presentation at the American Association for Aerosol Research Annual Conference. Orlando, Florida, October 2014.
  11. Fang T, Verma V, Weber RJ. “Online determination of aerosol oxidative potential with particle-into-liquid sampler (PILS) using DTT (Dithiothreitol) assay.” Poster presentation at the American Association for Aerosol Research Annual Conference. Orlando, Florida, October 2014.
  12. Guo H, Xu L, Bougiatioti A, Cerully KM, Capps SL, Hite JR, Carlton AG, Lee S, Bergin MH, Ng NL, Nenes A, Weber RJ. “Particle water and pH in the southeastern United States.” Oral presentation at the American Association for Aerosol Research Annual Conference. Orlando, Florida, October 2014.
  13. King L, Guo H, Fang T, Verma V, Edgerton E, Russell A, Weber R. “The Southeastern Center for Air Pollution and Epidemiology: preliminary results from the measurement campaign.” Poster presentation at the American Association for Aerosol Research Annual Conference. Orlando, Florida, October 2014.
  14. Ng NL, Kollman M, Papapostolou V, Lawrence J, Suresh S, Verma V, Jayne J, Croteau P, Weber R, Russell A, Koutrakis P. “Investigating the health effects of fresh and aged traffic aerosols: Linking particle oxidative potential to chemical composition.” Oral presentation at the American Association for Aerosol Research Annual Conference. Orlando, Florida, October 2014.
  15. Verma V, Fang T, Guo H, King L, Bates JT, Peltier RE, Edgerton E, Russell AG, Weber RJ. “Reactive oxygen species associated with water-soluble PM<sub>2.5</sub> in the southeastern United States: spatiotemporal trends and source apportionment.” Oral presentation at the American Association for Aerosol Research Annual Conference. Orlando, Florida, October 2014.

16. Verma V, Fang T, Xu L, Peltier RE, Russell AG, Ng NL, Weber RJ. "Organic aerosols associated with ROS generation." Oral presentation at the American Association for Aerosol Research Annual Conference. Orlando, Florida, October 2014.
17. Verma V, Wang Y, Rawan El-Afifi, Fang T, Rowland JR, Russell AG, Weber RJ. "On the contribution of atmospheric quinones to reactive oxygen species associated with water-soluble PM<sub>2.5</sub>." Poster presentation at the American Association for Aerosol Research Annual Conference. Orlando, Florida, October 2014.
18. Walker M, Williams B, Martinez R, Zhang Y, Mitroo D, Hagan D, Shawan S, Du L, Turner J, Guo H, King L, Weber R, Hu L, Baasandorj M, Millet D. "Instrument intercomparison of black carbon measurements and correlations with gas and aerosol composition during an urban field study." American Association for Aerosol Research Annual Conference. Orlando, Florida, October 2014.
19. Williams B, Mitroo D, Martinez R, Zhang Y, Walker M, Oxford C, Zuo X, Hagan D, Dhawan S, Du L, Turner J, McMeeking G, King L, Guo H, Weber R, Baasandorj M, Hu L, Millet D. "Highlights from the St. Louis Air Quality Regional Study (SLAQRS) 2013." American Association for Aerosol Research Annual Conference. Orlando, Florida, October 2014.
20. Xu L, Guo H, Boyd C, Klein M, Bougiatioti A, Cerully K, Hite J, Isaacman-VanWertz G, Kreisberg NM, Knotte C, Olson K, Koss A, Goldstein AH, Hering SV, de Gouw J, Baumann K, Lee S-H, Nenes A, Weber R, Ng NL. "Effects of anthropogenic emissions on aerosol formation from isoprene and monoterpenes in the southeastern United States." Oral presentation at the American Association for Aerosol Research Annual Conference. Orlando, Florida, October 2014.
21. Bates J, Abrams J, Tolbert P, Gass K, Klein M, Verma, V, Weber R, Mulholland J, Russell A. "Sources and health effects of reactive oxygen species in Atlanta air pollution." Poster at the 9th Annual Georgia Environmental Conference. Jekyll Island, Georgia, August 2014.
22. Ng NL, Tuet WY, Verma V, Weber RJ, Champion JA, Knight MB, Grosberg A. "Laboratory chamber and field study characterization of the composition and oxidative properties of particulate matter mixtures: effects of particle phase state, acidity, and transition metals." Poster presentation at the HEI Annual Conference. Alexandria, Virginia, May 2014.
23. Weber R, Liu J, Bergin M, Jai Devi J, Scheuer E, Dibb J, Anderson BE, Thornhill KL, Schwartz J, Gao R. "Recent studies on the sources, prevalence and optical importance of brown carbon." American Meteorological Society 94<sup>th</sup> Annual Meeting. Atlanta, Georgia, February 2014.
24. Weber RJ, Liu J, Bergin M, Edgerton ES, Guo H, King LE. "Size-resolved measurements of brown carbon for estimating contributions to fine particle light absorption." Poster presentation at the American Geophysical Union 46<sup>th</sup> Annual Fall Meeting. San Francisco, California, December 2013.
25. Weber R, Ng NL, Nenes A, Bergin M, Xu L, Guo H, Cerully K, Bougiatioti A, King L, Agostini G, Lin J, Fang T, Verma V, McKenzie M, Jeryraman J, Carlton A, Nguyen TK, Petters M, Suda A, Edgerton E. "Fine particle water-soluble organic carbon over the southeastern United States." Oral presentation at the American Geophysical Union 46<sup>th</sup> Annual Fall Meeting. San Francisco, California, December 2013.
26. Xu L, Guo H, Cerully K, Bougiatioti, King L, Weber R, Nenes A, Ng NL, Carlton AM, Nguyen K. "Chemical characterization of water soluble organic aerosol during SOAS using high resolution aerosol mass spectrometer." Oral presentation at the American Geophysical Union 46<sup>th</sup> Annual Fall Meeting. San Francisco, California, December 2013.
27. Fang T, Verma V, Weber RJ. "Semi-automated system for measuring oxidative potential of ambient particles collected on filters using dithiothreitol (DTT) assay." Poster presentation at the American Association for Aerosol Research Annual Meeting. Portland, Oregon, September 2013.

28. Lu X, Guo H, King L, Verma V, Weber R, Ng NL. "A study of secondary organic aerosol formation influenced by mixed anthropogenic and biogenic emissions in Atlanta area by high resolution mass spectrometer." Oral presentation at the American Association for Aerosol Research Annual Meeting. Portland, Oregon, September 2013.
29. Verma V, Fang T, Weber RJ. "Contrasting Profiles of the Oxidative Properties of Ambient Aerosols collected from Urban and Rural Environments in Atlanta." Oral presentation at the American Association for Aerosol Research Annual Meeting. Portland, Oregon, September 2013.
30. King L, Verma V, Weber RJ. "Semi-continuous online measurements of reactive oxygen species in the particle and gas phase." Oral presentation at the American Association of Aerosol Research Annual Meeting. Minneapolis, Minnesota, October 2012.
31. Kotra N, Verma V, Liu J, Surratt JD, Edgerton E, Ng NL, Weber RJ. "Performance Evaluation of a Recently Developed Aerosol Chemical Speciation Monitor (ACSM)." Poster presentation at the American Association of Aerosol Research Annual Meeting. Minneapolis, Minnesota, October 2012.
32. Verma V, Kotra N, King L, Liu J, Rico-Martinez R, Snell TW, Weber RJ. "Comparative analysis of the contribution of water-soluble and insoluble PM components in the toxicological properties of ambient atmospheric aerosols." Oral presentation at the American Association of Aerosol Research Annual Meeting. Minneapolis, Minnesota, October 2012.
33. Verma V, Rico-Martinez R, Kotra N, King L, Liu J, Snell TW, Weber RJ. "Contribution of water-soluble and insoluble species and their hydrophobic/hydrophilic sub-fractions in the toxicological properties of ambient atmospheric aerosols." Poster presentation at the International Global Atmospheric Chemistry Open Science Conference. Beijing, China, September 2012.
34. King L, Verma V, Weber R. "Refinement and testing of a fluorometric assay for continuous online ROS measurement and results from preliminary field deployments." American Association for Aerosol Research Annual Meeting. Orlando, Florida, October 2011.
35. Kotra N, King L, Weber RJ. "Development and testing of a continuous Amplex Red method for measuring particle-bound ROS." American Association of Aerosol Research Annual Meeting. Orlando, Florida, October 2011.

**Future Activities:**

A goal is to complete the following manuscripts:

1. King et al., Chemiluminescence measurements of NO<sub>x</sub> and NO versus cavity ring down NO<sub>2</sub> at various sites in the southeastern US.
2. King et al., On the spatial and seasonal distribution of a suite of air quality parameters based on paired measurements to investigate roadway emissions.
3. Devlin, Verma, et al., PM generated ROS species associated with biological changes in humans exposed to fine concentrated air pollutants
4. Verma et al., Overall summary of Project finding on ROS measured by the DTT assay; sources, atmospheric processing, and health impacts.
5. Fang et al., Online measurements of ROS via the DTT assay.
6. Gao et al., Stability of ROS on archived filters.

Depending on availability of funds the following research areas will be explored:

1. Online ROS system: We will continue to work on the online DTT instrument development. In the next year we plan to assess and verify the instrument performance by comparing with filter measurements of total DTT.



2. To date, our work has focused on the water- and methanol-soluble components that contribute to fine particle ROS. Other studies have shown that solid particles, especially soot, can also be effective at generating ROS and are highly DTT active. The approach would be to modify the automated DTT/AA analysis system so that the redox chemistry can be done on an immersed filter, instead of in the filter extract. The system will be assessed by comparison to published diesel exhaust DTT intrinsic activities and contrasts between roadside to other sites (comparison between sites with high EC versus low EC concentrations). This area of research was proposed in last year's report but was not pursued due to lack of funding. The plan is to revisit the problem in the following year.

**Supplemental Keywords:** reactive oxygen species, ROS, oxidative stress, oxidative potential

**Relevant Web Sites:** [www.scape.gatech.edu](http://www.scape.gatech.edu)

**Date of Report:** July 31, 2015

**EPA Agreement Number:** R834799

**Center Name & Internal Number:** Southeastern Center for Air Pollution and Epidemiology  
(R834799C002)

**Project Title:** Examining In-Vehicle Pollution and Oxidative Stress in a Cohort of Daily Commuters  
(Project 2)

**Investigator(s):** Jeremy Sarnat, ScD<sup>1</sup> ([jsarnat@emory.edu](mailto:jsarnat@emory.edu)); Michael Bergin, PhD<sup>5</sup>  
[mike.bergin@ce.gatech.edu](mailto:mike.bergin@ce.gatech.edu)); W. Dana Flanders, MD, ScD<sup>1</sup> ([wflande@emory.edu](mailto:wflande@emory.edu)); Andrea Winquist,  
PhD<sup>1</sup> ([awinqui@emory.edu](mailto:awinqui@emory.edu)); Anne Fitzpatrick, PhD<sup>1</sup> ([amentro@emory.edu](mailto:amentro@emory.edu)); Roby Greenwald, PhD<sup>3</sup>  
([robby.greenwald@emory.edu](mailto:robby.greenwald@emory.edu)); David Diaz-Sanchez, PhD<sup>4</sup> ([diaz-sanchez.david@epa.gov](mailto:diaz-sanchez.david@epa.gov))

**Institution(s) of PI(s):** <sup>1</sup>Emory University, <sup>2</sup>Georgia Institute of Technology, and <sup>3</sup>Georgia State University,  
Atlanta, Georgia; <sup>4</sup>Environmental Protection Agency; <sup>5</sup>Duke University, Durham, North Carolina

**Research Category:** Air Quality and Air Toxics

**Project Period:** 08/01/2014 – 7/31/2015

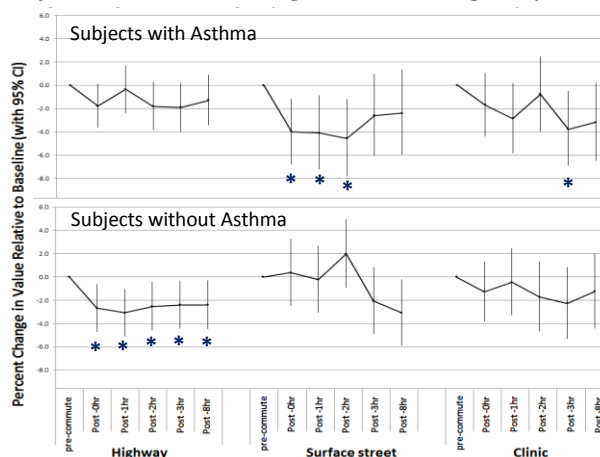
**Objective of Research:** The primary aim of Atlanta Commuters Exposure Study Project 2 (ACE-2) is to examine the effects of exposure to particulate mixtures occurring during automobile commuting and within indoor, non-commuting microenvironments ( $\mu\text{E}'\text{s}$ ) and corresponding measures of oxidative stress-mediated response.

**Progress Summary/Accomplishments:**

The following is a summary of specific Project 2 tasks completed during the previous reporting period:

1. Completed data processing for all continuously and integrated measured pollutant parameters for main Project 2 commuter study (ACE-2), including PM<sub>2.5</sub> mass concentration; particle number concentration; particle bound PAHs; black carbon concentration; and noise, PM<sub>2.5</sub> mass concentration; particulate trace elements; elemental and organic carbon; water soluble organic carbon, and DTT (integrated).
2. During the previous reporting period we also completed data analysis and processing for the following ACE-2 health endpoints: Inflammation biomarkers in DBS and plasma.
3. Completed metabolomic analyses of all ACE-2 plasma samples using HR-MS under the supervision of Project 2 co-investigator, D Jones. Feature extraction and initial analyses will begin in Fall 2015.
4. Published manuscript on effect measure modification of ACE-1 results by asthma control status (Mirabelli et al., *Epidemiology*. 2015). Results indicate that poorly-controlled asthmatics may be more susceptible to acute changes in lung function and pulmonary inflammation from exposures to specific in-vehicle pollutant.
5. Completed initial draft of manuscript comparing cytokine quantitation in Dried Blood Spots (DBS using ELISA) compared to plasma (using electrochemiluminescence).

6. Completed initial draft of epidemiologic analyses for Project 2 (ACE-2). Findings show that highway commuting in the ACE-2 study was associated with significantly reduced lung function following a scripted 2h highway commute compared to clinic exposure scenarios. Figure 1 shows measured mean Forced Vital Capacity (FVC) in ACE-2 subjects at periods prior to participating in the study protocol and at several post-exposure time-points. In-vehicle PAHs and BC levels were most predictive of corresponding lung function decrement (Results not shown).



#### Publications:

1. Bergin MH, Tripathi SN, Devi JJ, Gupta T, Mckenzie M, Rana KS, Shafer MM, Villalobos AM, Schauer JJ. The discoloration of the Taj Mahal due to particulate carbon and dust deposition. *Environmental Science & Technology* 49(2):808-812, 2015. (Project 2)
2. Mirabelli MC, Golan R, Greenwald R, Raysoni AU, Holguin F, Kewada P, Winquist A, Flanders WD, Sarnat JA. Modification of traffic-related respiratory response by asthma control in a population of car commuters. *Epidemiology* 26(4):546-555, 2015. (Project 2)
3. Greenwald R, Bergin MH, Yip F, Kewada P, Shafer MM, Schauer JJ, Sarnat JA. On-roadway in-cabin exposure to particulate matter: measurement results using both continuous and time-integrated sampling approaches. *Aerosol Science & Technology* 48:664-675, 2014. (Project 2)
4. Sarnat JA, Golan R, Greenwald R, Raysoni AU, Kewada P, Winquist A, Sarnat SE, Flanders WD, Mirabelli MC, Zora JE, Bergin MH, Yip F. Exposure to Traffic Pollution, Acute Inflammation and Autonomic Response in a Panel of Car Commuters. *Environmental Research* 133:66-76, 2014. (Project 2, Core C)
5. Sarnat JA, Sarnat SE, Chang H, Mulholland J, Özkaynak H, Isakov V. Spatiotemporally resolved air exchange rate as a modifier of acute air pollution-related morbidity. *Journal of Exposure Science and Environmental Epidemiology*, doi: 10.1038/jes.2013.32. (Project 2, Project 4)
6. Brown MS, Sarnat SE, DeMuth KA, Brown LAS, Whitlock DR, Brown SW, Tolbert PE, Fitzpatrick AM. Residential proximity to a major roadway is associated with features of asthma control in children. *PLoS ONE* 7(5):e37044, 2012. (Project 2, Project 4)

#### Presentations:

1. Ladva CN, Yu T, Golan R, Greenwald R, Tran V, Jones DP, Sarnat JA. "Innovative Method for Traffic Pollution Exposure Assessment Using Metabolomic Profiling in Commuter Panel Studies." Platform presentation at the International Society for Exposure Science Annual Meeting. Henderson, Nevada. October 2015.
2. Sarnat JA, Liang D, Golan R, Moutinho J, Ladva CN, Greenwald R, Weber RJ, Ebel Sarnat S, Russell AG, Verma V, Jones D. Mu'ltipollutant Indicators of Primary Traffic Pollution in the Dorm Room Inhalation to Vehicle Emissions (DRIVE) Study." Platform presentation at the International Society for Exposure Science Annual Meeting. Henderson, Nevada. October 2015.

3. Golan R, Ladva CN, Greenwald R, Raysoni AU, Liang D, Winqvist A, Flanders WD, Bergin M, Sarnat JA. "Associations between In-Vehicle Pollutant Mixtures and Acute Respiratory Response in Panels of Car Commuters." Poster presentation at the International Society for Environmental Epidemiology Annual Meeting. Sao Paolo, Brazil. August 2015.
4. Ladva CN, Liang D, Yu T, Golan R, Greenwald R, Tran V, Jones DP, Sarnat JA. "An Innovative Method for Examining Traffic Pollution Exposures and Acute Biological Effects in Commuter Panel Studies." Platform presentation at the International Society for Environmental Epidemiology Annual Meeting. Sao Paolo, Brazil. August 2015.
5. Liang D, Golan R, Moutinho J, Ladva CN, Greenwald R, Weber RJ, Ebelt Sarnat S, Russell AG, Verma V, Jones D, Sarnat JA. "Associations between Primary Traffic Pollution and Metabolomic Response Patterns in the Dorm Room Inhalation to Vehicle Emissions (Drive) Study." Platform presentation at the International Society for Environmental Epidemiology Annual Meeting. Sao Paolo, Brazil. August 2015.
6. Ladva CN, Greenwald R, Flanders WD, Sarnat JA. "Association between On-Road Particulate Matter Mixtures and Acute Cardiorespiratory Response in a Commuters Panel Study." Platform presentation at the International Society for Exposure Science Annual Meeting. Cincinnati, Ohio, October 2014.
7. Golan R, Greenwald R, Early-Jones B, Winqvist A, Kewada P, Raysoni AU, Flanders WD, Sarnat S, Yip F, Sarnat JA. "Malondialdehyde in plasma and exhaled breath condensate following highway commutes." Platform presentation at the International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.
8. Golan R, Greenwald R, Raysoni AU, Kewada P, Ladva CN, Early-Jones B, Winqvist A, Flanders WD, Sarnat JA. "Respiratory effects of exposure to car commuting in young adults– a randomized crossover study." Poster presentation at the International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.
9. Golan R, Sarnat J. "Pollution Intersects Life: Acute Health Effects of Exposure to Traffic Pollution", Morning Session, 26th International Society for Environmental Epidemiology (ISEE), Seattle, Washington, August 2014.
10. Golan R, Greenwald R, Raysoni AU, Kewada P, Ladva CN, Early-Jones B, Winqvist A, Flanders WD, Sarnat JA. "Respiratory Effects of Exposure to Car Commuting in Young Adults– A Randomized Crossover Study", Platform presentation at the 7th Postdoctoral Fellow Research Symposium, Emory University, Atlanta, March 2014.
11. Greenwald R, Kewada P, Yip F, Sarnat J. "Exposure during short-lived air pollution events is more predictive of airway oxidative stress than mean concentration." Poster presentation at the Joint Annual Conference of the International Society for Environmental Epidemiology and Exposure Science and Indoor Air Quality. Basel, Switzerland, August 2013.
12. Greenwald R, Kewada P, Yip F, Sarnat J. "A method to identify and characterize short-lived air pollution events from time-series analysis of continuously-measured parameters." Oral presentation at the Joint Annual Conference of the International Society for Environmental Epidemiology and Exposure Science and Indoor Air Quality. Basel, Switzerland, August 2013.
13. Ladva C, Chen J, Johnson B, Sarnat J. "Characterizing noise and particulate matter in the vehicle microenvironment." Poster presentation at the Joint Annual Conference of the International Society for Environmental Epidemiology and Exposure Science and Indoor Air Quality. Basel, Switzerland, August 2013.
14. Sarnat J, Greenwald G, Kewada K, Flanders WD, Sarnat S, Yip F, Boehmer T, Raysoni A, Bergin M. "Exposure to traffic pollution, acute inflammation and autonomic response in a panel of car commuters." Oral presentation at the Joint Annual Conference of the International Society for

Environmental Epidemiology and Exposure Science and Indoor Air Quality. Basel, Switzerland, August 2013.

15. Chen J, Greenwald R, Johnson, BA, Sarnat JA. "Associations between In-Vehicle Noise and Speciated Pollutant Exposures in a Commuting Microenvironment." Platform presentation at the International Society for Exposure Science Annual Conference. Seattle, Washington, October 2012.
16. Greenwald, R, Li W, Yip F, Boehmer T; Sarnat JA. "Increased airway lipid peroxidation following a 2-hour commute in Atlanta." Platform presentation at the International Society for Exposure Science Annual Conference. Seattle, Washington, October 2012.
17. Greenwald R, Li W, Flanders WD, Kewada P, Bergin M, Sarnat JA. "Acute lipid peroxidation in breath and traffic pollution among a panel of commuters in Atlanta." Poster presentation at the International Society for Environmental Epidemiology Annual Conference. Columbia, South Carolina, August 2012.
18. Sarnat JA, Greenwald R, Sarnat SE, Kewada P, Yip F, Boehmer TK, Bergin MH. "In-vehicle pollutant exposures and acute cardiorespiratory response in a cohort of healthy and asthmatic car commuters in the Atlanta Commuters' Exposure Study." International Society for Environmental Epidemiology Annual Meeting. Barcelona, Spain, September 2011.

**Future Activities:** During the next 6 months, we expect to complete analyses of all pollutant and health endpoints, including feature extractions and analyses of plasma samples using HR-MS analyses involving the characterization of metabolomic profiles before and after ACE-2 exposures. Primary attention will continue to focus on completing and submitting the draft manuscripts that are currently in preparation.

**Supplemental Keywords:** health effects, oxidative stress, inflammation, human health, susceptibility, vulnerability, PAHs, PM2.5, organics, elemental carbon, metals, ozone, oxidants, PAH, sulfates, source characterization, mobile sources, Georgia, GA

**Relevant Web Sites:** [www.scape.gatech.edu](http://www.scape.gatech.edu)

**Date of Report:** July 31, 2015

**EPA Agreement Number:** R834799

**Center Name & Internal Number:** Southeastern Center for Air Pollution and Epidemiology  
(R834799C003)

**Project Title:** Novel Estimates of Pollutant Mixtures and Pediatric Health in Two Birth Cohorts (Project 3)

**Investigator(s):** PI -- Matthew Strickland, PhD<sup>1</sup> ([mjstric@emory.edu](mailto:mjstric@emory.edu)); Lyndsey Darrow, PhD<sup>1</sup> ([ldarrow@emory.edu](mailto:ldarrow@emory.edu)); Mitchel Klein, PhD<sup>1</sup> ([mklein@emory.edu](mailto:mklein@emory.edu)); Yang Liu, PhD<sup>1</sup> ([yang.liu@emory.edu](mailto:yang.liu@emory.edu)); Lance Waller, PhD<sup>1</sup> ([lwaller@sph.emory.edu](mailto:lwaller@sph.emory.edu)); Howard Chang, PhD<sup>1</sup> ([howard.chang@emory.edu](mailto:howard.chang@emory.edu)); Randy Guensler, PhD<sup>2</sup> ([randy.guensler@ce.gatech.edu](mailto:randy.guensler@ce.gatech.edu)); James Mulholland, PhD<sup>2</sup> ([james.mulholland@ce.gatech.edu](mailto:james.mulholland@ce.gatech.edu)); Armistead Russell, PhD<sup>2</sup> ([ted.russell@ce.gatech.edu](mailto:ted.russell@ce.gatech.edu))

**Institution(s) of PI(s):** <sup>1</sup>Emory University and <sup>2</sup>Georgia Institute of Technology, Atlanta, Georgia

**Research Category:** Air Quality and Air Toxics

**Project Period:** 08/01/2014 – 7/31/2015

**Objective of Research:** *In utero* and early life experiences affect physiological development and can influence sensitivity to environmental factors throughout life. In this Project, we explore the interplay between certain early life events, characterizations of air pollutant mixtures developed as part of the Center's Mixtures Characterization Toolkit, and a range of pediatric health outcomes using two large, population-based birth cohorts. One cohort consists of roughly 1.7 million Georgia birth records that have been geocoded to the Census block level and linked with pediatric emergency department visits by staff at the Georgia Department of Human Resources. Using this statewide birth cohort, we are investigating acute effects of air pollution mixtures on respiratory health outcomes and ear infections in children, and we are assessing whether children who were born premature or low birth weight are more sensitive to ambient air pollutant concentrations than their counterparts. Further, we are using the statewide birth cohort to investigate whether ambient air pollutant mixtures during pregnancy are associated with the risk of preterm delivery or reduced birth weight. The second birth cohort is comprised of children who were members of the Kaiser Permanente Georgia Health Maintenance Organization in metropolitan Atlanta. In this birth cohort, where comprehensive medical and residential histories are available for each study subject, we will examine whether air pollutant mixtures during the first year of life are associated with the incidence of childhood asthma.

**Progress Summary/Accomplishments:** We have made progress in many areas of this project. Some notable accomplishments include:

1. Published associations of ambient air pollution with several different types of respiratory emergency visits among children age 0-4 years in Atlanta (Darrow et al. 2014 *Am J Epidemiol*), which received the 2014 Society of Toxicology Occupational Public Health Specialty Section Paper of the Year award. Also published a related manuscript describing the relationship between emergency visits for bronchiolitis during infancy and subsequent risk of emergency visits for asthma after age five in Georgia (Strickland et al. 2014 *Paediatr Perinat Epidemiol*).
2. Published joint effects estimates for NO<sub>2</sub>, ozone, and PM<sub>2.5</sub> using classification and regression trees for pediatric asthma emergency visits in a three-city study (Atlanta, Dallas, St. Louis) (Gass et al. 2015 *Environ Health*). The estimates plateaued on moderately-high pollution days and did not increase further on days when all three pollutants were high.
3. Published pediatric asthma emergency visits analyses using the Bayesian ensemble source apportionment estimates in Atlanta (Gass et al. 2015 *Am J Epidemiol*). Analyses are innovative in part because they enable the uncertainty from the source apportionment models to be propagated through the epidemiologic analyses.

4. Georgia analyses of fused CMAQ estimated in relation to preterm birth accepted for publication at *Environ Health Perspect* on June 19, 2015. Associations were observed for traffic-related pollutants across several pregnancy windows, and associations tended to be higher for mothers with low educational attainment and for African American mothers.
5. Georgia analyses of satellite-derived PM<sub>2.5</sub> and emergency visits for pediatric respiratory disease accepted for publication at *Environ Health Perspect* on May 21, 2015. We observed associations between short-term changes in PM<sub>2.5</sub> with asthma/wheeze and with upper respiratory infections. Estimated associations were similar in urban, suburban, and rural areas.
6. Published Atlanta time-series analyses using mixtures estimated from self-organizing maps (Pearce et al. 2015 *Environ Health*). Using a low pollution day type as the reference level, we found significant associations of increased asthma morbidity in three of nine categories suggesting adverse effects when combinations of primary (CO, NO<sub>2</sub>, NO<sub>x</sub>, EC, and OC) and/or secondary (O<sub>3</sub>, NH<sub>4</sub>, SO<sub>4</sub>) pollutants exhibited elevated concentrations (typically, occurring on dry days with low wind speed).
7. A manuscript describing the fusion of observational data with chemical transport model simulations and a manuscript describing the link between reactive oxygen species and cardiorespiratory effects are under peer review.
8. Preliminary results generated for a Georgia-wide analysis of pediatric ED visits and fused CMAQ estimates and a first draft manuscript has been prepared.
9. Finalized the CMAQ + RLINE fusion air quality model for estimating PM<sub>2.5</sub> from traffic emissions in Atlanta for use in the Kaiser Permanente analyses.
10. Presented preliminary results for associations between RLINE estimates and incidence of asthma in the Kaiser Permanente cohort at the 2015 Society for Epidemiologic Research annual meeting. We have drafted a related manuscript on asthma diagnosis issues within the cohort, and have also investigated the link between C-section delivery and asthma diagnosis later in childhood. These findings were presented at the Society for Pediatric and Perinatal Epidemiology conference (2015) and at the Society for Epidemiologic Research conference (2015).

#### **Publications:**

1. Hao H, Chang HH, Holmes HA, Mulholland JA, Klein M, Darrow LA, Strickland MJ. Ambient air pollution and preterm birth in Georgia. *Environ Health Perspectives*, accepted. (Core B, Core C, Project 3)
2. Strickland MJ, Hao H, Hu X, Chang HH, Darrow LA, Liu Y. Pediatric emergency visits and short-term changes in PM<sub>2.5</sub> concentrations in the U.S. State of Georgia. *Environmental Health Perspectives*, accepted. (Core B, Core C, Project 3)
3. Chang HH, Warren JL, Darrow LA, Reich BJ, Waller LA. Assessment of critical exposure and outcome windows in time-to-event analysis with application to air pollution and preterm birth study. *Biostatistics* 16(3):509-521, 2015. (Core C, Project 3)
4. Gass KM, Balachandran S, Chang HH, Russell AG, Strickland MJ. Ensemble-based source apportionment of fine particulate matter and emergency department visits for pediatric asthma. *American Journal of Epidemiology* 181:504-512, 2015. (Core B, Core C, Project 3)
5. Gass K, Klein M, Sarnat SE, Winquist A, Darrow LA, Flanders WD, Chang HH, Mulholland JA, Tolbert PE, Strickland MJ. Associations between ambient air pollutant mixtures and pediatric asthma emergency department visits in three cities: a classification and regression tree approach. *Environmental Health*, 14: 58, 2015. (Core B, Core C, Project 3, Project 4)
6. Pearce JL, Waller LA, Mulholland JA, Sarnat SE, Strickland MJ, Chang HH, Tolbert PE. 2015. Exploring associations between multipollutant day types and asthma morbidity: epidemiologic applications of self-organizing map ambient air quality classifications. *Environmental Health*, 14: 55, 2015. (Core C, Project 3, Project 4)

7. Strickland MJ, Gass KM, Goldman GT, Mulholland JA. Effects of ambient air pollution measurement error on health effect estimates in time series studies: a simulation-based analysis. *Journal of Exposure Science and Environmental Epidemiology*, 25:160-166, 2015.
8. **Chang HH, Hu X, Liu Y. Calibrating MODIS aerosol optical depth for predicting daily PM<sub>2.5</sub> concentrations via statistical downscaling. *Journal of Exposure Science and Environmental Epidemiology*, 24:398-404, 2014. (Project 3, Core B, Core C).**
9. Darrow LA, Klein M, Flanders WD, Mulholland JA, Tolbert PE, Strickland MJ. Air pollution and acute respiratory infections among children 0-4 years: an 18-year time-series study. *American Journal of Epidemiology* 180:968-77, 2014. (Project 3, Core B, Core C)
10. Gass K, Klein M, Chang HH, Flanders WD, Strickland MJ. Classification and regression trees for epidemiologic research. *Environmental Health* 13:17, 2014. (Core C, Project 3, Project 4)
11. Hu X, Waller LA, Lyapustin A, Wang Y, Al-Hamdan MZ, Crosson WL, Estes MG, Estes SM, Quattrochi DA, Puttaswamy SJ, Liu Y. Estimating ground-level PM<sub>2.5</sub> concentrations in the Southeastern United States using MAIAC AOD retrievals and a two-stage model. *Remote Sensing of Environment* 140:220-232, 2014. (Core B, Core C, Project 3)
12. Hu X, Waller LA, Lyapustin A, Wang Y, Liu Y. 2014. 10-year spatial and temporal trends of PM<sub>2.5</sub> concentrations in the southeastern U.S. estimated using high-resolution satellite data. *Atmospheric Chemistry and Physics* 14:6301-6314. (Core B, Core C, Project 3).
13. Ma Z, Hu X, Huang L, Bi J, Liu Y. Estimating ground-level PM<sub>2.5</sub> in China using satellite remote sensing. *Environmental Science and Technology*, 48:7436-7444, 2014. (Core B, Project 3)
14. Pearce JL, Waller LA, Chang HH, Klein M, Mulholland JA, Sarnat JS, Sarnat SE, Strickland MJ, Tolbert PE. Using self-organizing maps to develop ambient air quality classifications for use in multipollutant health studies: a time-series example. *Environmental Health* 13:56, 2014. (Core C, Core B, Project 3, Project 4)
15. Reich BJ, Chang HH, Strickland MJ. Spatial health effects analysis with uncertain residential locations. *Statistical Methods in Medical Research* 23:156-68, 2014. (Core C, Project 3)
16. Russell A, Holmes H, Friberg M, Ivey S, Hu Y, Balachandran S, Mulholland J, Tolbert P, Sarnat J, Sarnat S, Strickland M, Chang H, Liu Y. Use of Air Quality Modeling Results in Health Effects Research. In *Air Pollution Modeling and Its Application XXIII* (D. Steyn and R. Mathur eds.) 2014. (Core B, Core C, Project 3, Project 4)
17. Sororian S, Holmes H, Friberg M, Ivey C, Hu Y, Mulholland J, Russell A, Strickland M, Chang H. Temporally and spatially resolved air pollution in Georgia using fused ambient monitoring data and chemical transport model results. In *Air Pollution Modeling and Its Application XXIII* (D. Steyn and R. Mathur eds.) 2014. (Core B, Core C, Project 3)
18. Strickland MJ, Klein M, Flanders WD, Chang HH, Mulholland JA, Tolbert PE, Darrow LA. Modification of the effect of ambient air pollution on pediatric asthma emergency visits: susceptible subpopulations. *Epidemiology* 25(6):843-50, 2014. (Project 3, Core B, Core C)
19. Strickland MJ, Marsh CA, Darrow LA. Gestational age-specific associations between infantile acute bronchiolitis and asthma after age five. *Pediatric and Perinatal Epidemiology* 28:521-26, 2014. (Project 3)
20. Winquist A, Kirrane E, Klein M, Strickland M, Darrow LA, Sarnat SE, Gass K, Mulholland JA, Russell AG, Tolbert PE. Joint effects of ambient air pollutants on pediatric asthma emergency department visits in Atlanta, 1998-2004. *Epidemiology* 25:666-73, 2014. (Core B, Core C, Project 3, Project 4)
21. **Yu C, Di Girolamo L, Chen L, Zhang X, Liu Y. Statistical evaluation of the feasibility of satellite-retrieved cloud parameters as indicators of PM<sub>2.5</sub> levels. *Journal of Exposure Science and Environmental Epidemiology*, 2014, doi: 10.1038/jes.2014.49. (Core B, Project 3)**



22. Hu X, Waller LA, Al-Hamdan MZ, Crosson WL, Estes MG, Estes SM, Quattrochi DA, Sarnat JA, Liu Y. Estimating ground-level PM2.5 concentrations in the southeastern U.S. using geographically weighted regression. *Environmental Research* 121:1-10, 2013. (Core B, Core C, Project 3)  
Inadvertently omitted SCAPE acknowledgement.
23. Waller LA. Commentary: Regarding assessments of chance in investigations of 'cluster series'. *International Journal of Epidemiology* 42:449-452, 2013. (Core C, Project 3)
24. Balachandran S, Pachon JE, Hu Y, Lee D, Mulholland JA, Russell AG. Ensemble-trained source apportionment of fine particulate matter and method uncertainty analysis. *Atmospheric Environment* 61:387-394, 2012. (Core B, Project 3, Project 4)
25. Goldman GT, Mulholland JA, Russell AG, Gass K, Strickland MJ, Klein M, Tolbert PE. Characterization of ambient air pollution measurement error in a time-series health study using a geostatistical simulation approach. *Atmospheric Environment* 57:101-108, 2012. (Core B, Project 3, Project 4)
26. Pachon JE, Balachandran S, Hu Y, Mulholland JA, Darrow LA, Sarnat JA, Tolbert PE, Russell AG. Development of outcome-based, multipollutant mobile source indicators. *Journal of Air and Waste Management Association* 62(4):431-442, 2012. (Core B, Project 3, Project 4)  
Inadvertently omitted SCAPE acknowledgement.
27. Reich BJ, Chang HH, Strickland MJ. Spatial health effects analysis with uncertain residential locations. *Statistical Methods in Medical Research*, 23:156-68, 2014. (Core C, Project 3)
28. Flanders WD, Klein M, Darrow LA, Strickland MJ, Sarnat SE, Sarnat JA, Waller LA, Winquist A, Tolbert PE. A method to detect residual confounding in spatial and other observational studies. *Epidemiology* 22:823-826, 2011. (Core C, Project 3, Project 4)
29. Flanders WD, Klein M, Darrow LA, Strickland MJ, Sarnat SE, Sarnat JA, Waller LA, Winquist A, Tolbert PE. A method for detection of residual confounding in time-series and other observational studies. *Epidemiology* 22:59-67, 2011. (Core C, Project 3, Project 4)
30. Goldman GT, Mulholland JA, Russell AG, Strickland MJ, Klein M, Waller LA, Tolbert PE. Impact of exposure measurement error in air pollution epidemiology: effect of error type in time-series studies. *Environmental Health* 10:61, 2011. (Core B, Project 3, Project 4)
31. Strickland MJ, Darrow LA, Mulholland JA, Klein M, Flanders WD, Winquist A, Tolbert PE. Implications of different approaches for characterizing ambient air pollutant concentrations within the urban airshed for time-series studies and health benefits analyses. *Environmental Health* 10:36, 2011. (Project 3, Project 4)

#### **Presentations:**

1. Flak AL, Chang HH, Lavoue D, Klein M, Bates JT, Holmes HA, Russell AG, Hansen C, Strickland MJ, Darrow LA. "Ambient PM2.5 exposure during the first year of life and asthma incidence in a birth cohort." Oral presentation at the International Society for Environmental Epidemiology Annual Meeting. Sao Paulo, Brazil, August 2015.
2. Pearce JL, Waller LA, Mulholland JA, Sarnat SE, Strickland MJ, Chang HH, Tolbert PE. Acute associations between multipollutant mixtures and pediatric asthma morbidity: epidemiologic applications of self-organizing map ambient air quality classifications at the day level. Oral presentation at the International Society for Environmental Epidemiology Annual Meeting, Sao Paulo, Brazil, August 30-September 3, 2015.
3. Krall JR, Chang HH, Gass KM, Caudle WM, Strickland MJ. "Do your exposures need supervision?" Poster and Oral presentation at the National Institutes of Environmental Health Sciences Statistical Approaches for Assessing Health Effects of Environmental Chemical Mixtures in Epidemiology Studies Workshop. Research Triangle Park, North Carolina. July 2015.

4. Flak AL, Strickland MJ, Klein M, Hansen C, Drews-Botsch CD, Darrow LA. Cesarean delivery and childhood asthma incidence in a birth cohort. Oral presentation at the Society for Pediatric and Perinatal Epidemiologic Research Annual Meeting. Denver, Colorado, June 2015.
5. Darrow LA, Strickland MJ, Chang HH. "Acute associations between heat waves and preterm birth in Atlanta, 1994-2006." Poster presentation at the Society for Epidemiologic Research Annual Meeting. Denver, Colorado, June 2015.
6. Flak AL, Chang HH, Lavoue D, Klein M, Hansen C, Holmes HA, Russell AG, Strickland MJ, Darrow LA. "Ambient PM2.5 exposure during the first year of life and asthma incidence in a birth cohort." Poster presentation at the Society for Epidemiologic Research Annual Meeting. Denver, Colorado, June 2015.
7. Chang HH, Warren JL, Darrow LA, Reich BJ, Waller LA. "Assessment of critical exposure and outcome windows for estimating associations between air pollution and preterm birth." Poster presentation at the International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.
8. Flak AL, Darrow LA, Pearce JL, Hansen C, Strickland MJ. "Distribution of ambient air pollution and asthma incidence by race and socioeconomic status in a birth cohort." International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.
9. Gass K, Strickland M, Klein M, Flanders D, Chang H. "Classification and regression trees for epidemiologic research." Oral presentation at the International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.
10. Gass K, Klein M, Sarnat S, Flanders D, Chang H, Strickland M. "A three-city analysis of multipollutant joint effects: a comparison of classification and regression trees with multipollutant regression models." Oral presentation at the International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.
11. Hao H, Liu Y, Hu X, Chang HH, Darrow LA, Strickland MJ. "Satellite-Derived Estimates of Ambient Fine Particulate Matter and Pediatric Emergency Department visits in Georgia, 2002-2010: A case-crossover study." Poster presentation at International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.
12. Hao H, Chang H, Darrow L, Holmes H, Mulholland J, Strickland M. "Ambient air pollution and preterm birth: a time-to-event analysis in Georgia, 2002-2006." Poster presentation at International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.
13. Pearce JL, Waller LA, Sarnat SA, Strickland M, Klein M, Chang HH, Mulholland J, Tolbert PE. "A framework for exploring the temporal associations between air quality day types and pediatric asthma: a case study of Atlanta, Georgia." Poster presentation at the International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.
14. Strickland MJ, Klein M, Flanders WD, Chang HH, Mulholland JA, Tolbert PE, Darrow LA. "Modification of the effect of ambient air pollution on pediatric asthma emergency visits: susceptible subpopulations." Oral presentation at the International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.
15. Strickland MJ, Gass KM, Goldman GT, Mulholland JA. "Effects of ambient air pollution measurement error on health effects estimates in single-pollutant time-series models: a simulation-based analysis." Oral presentation at the International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.
16. Gass K, Klein M, Flanders WD, Chang H, Strickland M. "Classification and regression trees for epidemiologic research." Society for Epidemiologic Research Annual Meeting. Seattle, Washington, June 2014.

17. Flak AL, Strickland MJ, DeMuth K, Hansen C, Darrow LA. "Early-life asthma classification in an electronic medical record setting." Poster presentation at the Society for Epidemiologic Research Annual Meeting. Seattle, Washington, June 2014.
18. Flak AL, Strickland MJ, DeMuth K, Hansen C, Darrow LA. "Early-life asthma classification in an electronic medical record setting." Poster presentation at the Society for Pediatric and Perinatal Epidemiologic Research Annual Meeting. Seattle, Washington, June 2014.
19. Liu Y, Satellite-Predicted High-Resolution PM<sub>2.5</sub> Maps in the Southeastern United States. USEPA Work-In-Progress Webinar for the Clean Air Research Centers. May 14, 2014.
20. Gass K, Klein M, Chang H, Sarnat S, Flanders W, Strickland M. "Utilizing regression trees to identify complex patterns of multipollutant joint effects." Poster presentation at the Joint Annual Conference of the International Society for Environmental Epidemiology and Exposure Science and Indoor Air Quality. Basel, Switzerland, August 2013.
21. Klein M, Hu X, Strickland M, Sarnat S, Tolbert P, Liu Y. "The application of satellite remote sensing data in a time series study of asthma exacerbation in metro Atlanta." Oral presentation at the Joint Annual Conference of the International Society for Environmental Epidemiology and Exposure Science and Indoor Air Quality. Basel, Switzerland, August 2013.
22. Winquist A, Kirrane E, Klein M, Strickland M, Darrow L, Sarnat S, Gass K, Mulholland J, Russell A, Tolbert P. "Joint effects of air pollutants on pediatric asthma emergency department visits." Poster presentation at the Joint Annual Conference of the International Society for Environmental Epidemiology and Exposure Science and Indoor Air Quality. Basel, Switzerland, August 2013.
23. Zhai X, Ivey C, Sororian S, Friberg M, Holmes H, Hu Y, Russell A, Mulholland J, Chang H, Strickland M, Zhang W. "Spatially-resolved source impact estimates for air quality health risk assessment." Oral presentation at the Joint Annual Conference of the International Society for Environmental Epidemiology and Exposure Science and Indoor Air Quality. Basel, Switzerland, August 2013.
24. Russell A, Holmes H, Friberg M, Ivey C, Hu Y, Balachandran S, Mulholland J, Tolbert P, Sarnat J, Sarnat S, Strickland M, Chang H, Liu Y. "Use of air quality modeling results in health effects research." Oral presentation at the NATO/SPS International Technical Meeting on Air Pollution Modeling and its Application, Miami, Florida, August 2013.
25. Sororian S, Holmes H, Friberg M, Ivey C, Hu Y, Mulholland JA, Russell AG, Strickland M, Chang H. "Temporally and spatially resolved air pollution in Georgia using fused ambient monitoring data and chemical transport model results." Poster presentation at the NATO/SPS International Technical Meeting on Air Pollution Modeling and its Application. Miami, Florida, August 2013.
26. Russell A, Holmes H, Friberg M, Ivey C, Hu Y, Balachandran S, Mulholland J, Tolbert P, Sarnat J, Sarnat S, Strickland M, Chang H, Liu Y. "Use of air quality modeling in health effects research." Poster presentation at the AEESP 50th Anniversary Conference. Golden, Colorado, July 2013.
27. Pearce J. "Use of spatial profiles to characterize multi-pollutant exposure areas in an urban environment." Oral presentation at the URISA GIS in Public Health Conference. Miami, Florida, June 2013.
28. Darrow L. "Ambient air pollution and respiratory emergency department visits among children 0-4 years." Oral presentation at the 13<sup>th</sup> International Congress on Combustion By-Products and Their Health Effects. Baton Rouge, Louisiana, May 2013.
29. Liu Y. "Estimating Ground-Level PM<sub>2.5</sub> Concentrations in the Southeastern United States Using MAIAC AOD Retrievals and a Two-Stage Model." Oral presentation at the American Thoracic Society International Conference. Philadelphia, Pennsylvania, May 2013.
30. Holmes H, Sororian S, Maier ML, Friberg M, Balachandran S, Ivey C, Hu Y, Russell AG, Mulholland JA, Sarnat SE, Sarnat JA, Strickland MJ, Winquist A, Klein M, Tolbert PE. "Development of a Mixtures Characterization Toolkit: Estimating air pollution source impacts to investigate air

quality and human health associations using time-series epidemiologic analysis." Community Modeling and Analysis System Conference. Raleigh, North Carolina, October 2012.

31. Hu X, Lyapustin A, Wang Y, Liu Y. "Estimating ground-level PM<sub>2.5</sub> concentrations in the Southeastern U.S. using MAIAC AOD retrievals." Oral presentation at the International Society for Exposure Science Annual Conference. Seattle, Washington, October 2012.
32. Darrow LA, Strickland MJ, Klein M, Tolbert PE. "Ambient air pollution and respiratory emergency department visits among children age 0-4 years." Oral presentation at the International Society for Environmental Epidemiology Annual Conference. Columbia, South Carolina, August 2012.
33. Gass K, Strickland MJ, Darrow LA, Klein M, Mulholland JA, Tolbert PE. "Short-term associations between ambient air pollutants and pediatric asthma emergency visits and the role of seasonal interaction." Poster presentation at the International Society for Environmental Epidemiology Annual Conference. Columbia, South Carolina, August 2012.
34. Flanders WD, Klein M, Darrow LA, Strickland MJ, Sarnat SE, Sarnat JA, Waller LA, Winquist A, Tolbert PE. "A method for detection of residual confounding in spatial and other observational studies." International Society of Environmental Epidemiology. Barcelona, Spain, September 2011.

**Future Activities:**

1. Ensure all manuscripts currently in peer review process are published.
2. Finalize analyses and submit manuscript for statewide pediatric ED visit and fused CMAQ analysis.
3. Finalize analyses and submit manuscript for statewide birth weight analyses.
4. Prepare and submit a manuscript describing the CMAQ and RLINE fusion model estimates in Atlanta.
5. Prepare and submit a manuscript on the Kaiser Permanente asthma incidence analyses.
6. Prepare and submit a manuscript on the Kaiser Permanente asthma classification approach.
7. Examine associations between pregnancy exposures to PM<sub>2.5</sub> from traffic and asthma in the Kaiser Permanente cohort.
8. Further sub-analyses of both cohorts.

**Supplemental Keywords:** ambient air, atmosphere, health effects, human health, susceptibility, vulnerability, sensitive populations, infants, children, risk, dose-response, cumulative effects, epidemiology, exposure, public policy, air quality modeling, monitoring, measurement methods, aerosol, particulates, PM<sub>2.5</sub>, organics, elemental carbon, metals, ozone, oxidants, PAH, sulfates, source characterization, mobile sources, Georgia, GA, Southeast

**Relevant Web Sites:** [www.scape.gatech.edu](http://www.scape.gatech.edu)

**Date of Report:** July 31, 2015

**EPA Agreement Number:** R834799

**Center Name & Internal Number:** Southeastern Center for Air Pollution and Epidemiology

**Project Title:** A Multi-City Time-Series Study of Pollutant Mixtures and Acute Morbidity (Project 4)

**Investigator(s):** PI -- Stefanie Sarnat, ScD<sup>1</sup> ([sebelt@sph.emory.edu](mailto:sebelt@sph.emory.edu)); Howard Chang ([howard.chang@emory.edu](mailto:howard.chang@emory.edu)); Lyndsey Darrow, PhD<sup>1</sup> ([ldarrow@emory.edu](mailto:ldarrow@emory.edu)); Mitchel Klein, PhD<sup>1</sup> ([mklein@emory.edu](mailto:mklein@emory.edu)); Paige Tolbert, PhD<sup>1</sup> ([tolbert@sph.emory.edu](mailto:tolbert@sph.emory.edu)); Andrea Winquist, MD<sup>1</sup> ([awinqui@emory.edu](mailto:awinqui@emory.edu)); James Mulholland, PhD<sup>2</sup> ([james.mulholland@ce.gatech.edu](mailto:james.mulholland@ce.gatech.edu)); Armistead Russell, PhD<sup>2</sup> ([ted.russell@ce.gatech.edu](mailto:ted.russell@ce.gatech.edu)); Richard A. Bilonick, PhD<sup>3</sup> ([bilonickra@upmc.edu](mailto:bilonickra@upmc.edu)); Evelyn O. Talbott, DrPH, MPH<sup>3</sup> ([eot1@pitt.edu](mailto:eot1@pitt.edu))

**Institution(s) of PI(s):** <sup>1</sup>Emory University and <sup>2</sup>Georgia Institute of Technology, Atlanta, Georgia;

<sup>3</sup>University of Pittsburgh

**Research Category:** Air Quality and Air Toxics

**Project Period:** 08/01/2014 – 7/31/2015

**Objective of Research:** Although associations between ambient air pollution and acute cardiorespiratory outcomes have been observed in numerous studies, questions remain about the degree to which these findings are generalizable between locations and whether the observed health effects are due to the individual pollutants measured or to pollutants acting in combination with other pollutants. In Project 4, we are conducting a multi-city time-series study to clarify the impacts of air quality on acute cardiorespiratory morbidity in five US cities (Atlanta, GA; Birmingham, AL; Dallas, TX; Pittsburgh, PA; St. Louis, IL-MO) using novel mixture characterization metrics. Our overarching hypothesis is that factors related to air pollution mixtures, seasonality and climate, concentration-response functions, exposure measurement error, and population susceptibility and vulnerability can help explain apparent between-city heterogeneity in short-term associations between air quality measures and cardiorespiratory emergency department (ED) visits.

**Progress Summary/Accomplishments:** During the current reporting period, work on Project 4 has focused on remaining data acquisition activities as well as single- and multi-city epidemiologic analyses.

**Database development.** Database activities included acquisition of the remaining health outcome data for the study. Health outcome data for Atlanta, Birmingham, Dallas, and St. Louis are complete. In the past year, a subcontract with University of Pittsburgh collaborators was continued as planned. University of Pittsburgh collaborators have acquired and processed ED visit data from Pittsburgh-area hospitals; for sharing these data with Emory, data use agreements between Emory and relevant Pittsburgh-area hospitals were finalized. Data were transferred to Emory at the end of the current reporting period and will be incorporated into epidemiologic analyses moving forward.

**Data analyses.** A number of data analysis activities were conducted over the reporting period:

1. We continued efforts on application of spatially-refined modeled estimates of ambient concentrations in multi-city epidemiologic analyses, including satellite-derived air quality estimates and the SCAPE data fusion approach, which combines monitoring and CMAQ modeled air quality data (Friberg et al., submitted to ES&T), in health effect analyses and compared results with use of traditional monitoring-based exposure assignment approaches (Chang et al., APHA 2014; Sarnat et al., ENV-VISION 2015; Sarnat et al., ISEE 2015). Application of the different exposure metrics had a large impact on observed associations for NO<sub>2</sub> and SO<sub>2</sub>, with stronger associations with use of data fusion exposure assignment approach, while associations for O<sub>3</sub> and PM<sub>2.5</sub> were largely similar across exposure assignment approaches. Results of these analyses also point to some consistency in

estimated effects across 4 cities, such as strong positive associations of NO<sub>2</sub> and PM<sub>2.5</sub> with respiratory disease ED visits in all cities with no significant heterogeneity detected. Some heterogeneity in estimated effects across cities is also observed, such as strong positive associations for SO<sub>2</sub> and respiratory ED visits in Birmingham and Dallas, but not in Atlanta or St. Louis; these findings are being further evaluated in multi-city effect modification analyses.

2. With the Air Quality and Biostatistics Cores, we continued work on methods for detecting and analyzing air pollution mixtures using multi-pollutant monitoring data: **a)** an approach for using classification and regression trees (C&RT) in multi-city air pollution epidemiologic research was published (Gass et al., 2015); **b)** our self-organizing maps approach to characterizing air pollution mixtures was published (Pearce et al., 2014) and an extension of this approach for use in epidemiologic analyses was also published (Pearce et al., 2015) and will be presented at ISEE (Pearce et al., ISEE 2015); **c)** our approach to estimating the joint effects of multiple pollutants previously published (Winquist et al., 2014) is being incorporated along with other approaches to estimating the effects of pollutant groups (Ye et al., ISEE 2015); **d)** working with Project 1, we have continued our examination of the effect of reactive oxygen species (ROS) on cardiorespiratory ED visits by retrospectively predicting DTT activity using a prediction model developed based on Project 1 data; results suggest a strong association between DTT and ED visits that is independent of the effect of PM<sub>2.5</sub> (Bates et al., submitted to ES&T; Bates et al., CMAS 2015 abstract pending, Bates et al., AAAR 2015); and finally **e)** we used source apportionment to estimate daily mass concentrations of PM<sub>2.5</sub> by source type for four US cities, and for sources similar in chemical composition between cities, we estimated associations with respiratory disease ED visits (Krall et al., submitted to EHP; Krall et al. JSM 2015). We found PM<sub>2.5</sub> from mobile sources, biomass burning, and dust was similar in chemical composition between cities, but PM<sub>2.5</sub> from coal combustion and metal sources varied across cities. We found evidence of positive associations of ED visits for respiratory disease with PM<sub>2.5</sub> from biomass burning and little evidence of associations with PM<sub>2.5</sub> from dust. Associations with PM<sub>2.5</sub> from mobile sources were not consistent across cities.
3. We continued work on examining detailed PM<sub>2.5</sub> components data in epidemiologic analyses: **a)** analyses examining the health effects of a range of PM components from the St. Louis Supersite was published (Sarnat et al., 2015); **b)** we applied and compared several approaches to estimating the effect of volatile organic compound chemical structure groups on cardiorespiratory ED visits in Atlanta (Ye et al., ISEE 2015); and **c)** we collaborated with the Biostatistics Core on a review article concerning statistical methods and challenges for estimating between PM components and health (Krall et al., submitted to CEHR).
4. We conducted preliminary multi-city analyses examining the shape of concentration-response functions using categorical pollution indicators.
5. Finally, we assessed potential modifiers of the effects of ambient air pollution on health: **a)** multi-city analyses examining modification of air pollution-health associations by age were conducted and published for asthma (Alhanti et al., accepted at JESEE) as well as for cardiovascular outcomes; **b)** analyses examining modification of air pollution-health associations by neighborhood socioeconomic factors were conducted for pediatric asthma/wheeze (O'Lenick et al., submitted to JECH; O'Lenick et al., SER 2015) as well as for cardiovascular outcomes; **c)** we continued work on estimating air exchange rates in each of the five cities and application of these data in epidemiologic models.

#### **Publications:**

1. **Krall JR, Mulholland JA, Russell AG, Balachandran S, Winquist A, Tolbert PE, Waller LA, Sarnat SE. Associations between source-apportioned particulate matter and emergency department visits for respiratory disease in four US cities, *submitted*. (Core B, Core C, Project 4)**

2. Bates JT, Weber RJ, Abrams J, Verma V, Fang T, Klein M, Strickland MJ, Sarnat SE, Chang HH, Mulholland JA, Tolbert PE, Russell AG. Reactive oxygen species in ambient particulate matter linked to cardiorespiratory effects, *submitted*. (Core B, Core C, Project 3, Project 4)
3. Krall JR, Chang HH, Sarnat SE, Peng RD, Waller LA. Statistical methods for estimating associations between PM chemical constituents and health in epidemiologic studies, *submitted*. (Core C, Project 4)
4. Friberg MD, Zhai X, Holmes HA, Russell AG, Mulholland JA, Chang HH, Strickland MJ, Sarnat SE, Tolbert PE. Fusion of observational data and chemical transport model simulations for estimating spatiotemporally-resolved ambient air quality concentrations for use in health studies, *in revision*. (Core B, Core C, Project 3, Project 4)
5. Alhanti BA, Chang HH, Winquist A, Mulholland J, Darrow L, Sarnat SE. Ambient air pollution and emergency department visits for asthma: a multi-city assessment of effect modification by age. *Journal of Exposure Science and Environmental Epidemiology*, accepted. (Core C, Project 4)
6. Gass K, Klein M, Sarnat SE, Winquist A, Darrow LA, Flanders WD, Chang HH, Mulholland JA, Tolbert PE, Strickland MJ. Associations between ambient air pollutant mixtures and pediatric asthma emergency department visits in three cities: a classification and regression tree approach. *Environmental Health*, 14:58, 2015. (Core B, Core C, Project 3, Project 4)
7. Pearce JL, Waller LA, Mulholland JA, Sarnat SE, Strickland MJ, Chang HH, Tolbert PE. Exploring associations between multipollutant day types and asthma morbidity: epidemiologic applications of self-organizing map ambient air quality classifications. *Environmental Health*, 14:55, 2015. (Core B, Core C, Project 3, Project 4)
8. Sarnat SE, Winquist A, Schauer JJ, Turner JA, Sarnat JA. Fine particulate matter components and emergency department visits for cardiovascular and respiratory diseases in St. Louis, Missouri-Illinois, metropolitan area. *Environmental Health Perspectives*, 123:437-444, 2015. (Project 4)
9. Winquist A, Schauer JJ, Turner J, Klein M, Sarnat SE. Impact of ambient fine particulate matter carbon measurement methods on observed associations with acute cardiorespiratory morbidity. *Journal of Exposure Science and Environmental Epidemiology*, 25:215-221, 2015. (Core C, Project 4)
10. Chang HH, Hao H, Sarnat SE. A statistical modeling framework for projecting future ambient ozone and its health impact due to climate change. *Atmospheric Environment* 89:290-297, 2014. (Core C, Project 4)
11. Dionisio KL, Baxter LK, Chang HH. An empirical assessment of exposure measurement error and effect attenuation in bipollutant epidemiologic models. *Environmental Health Perspectives* 122(11):1216-24, 2014. (Core C, Project 4)
12. Gass K, Klein M, Chang HH, Flanders WD, Strickland MJ. Classification and regression trees for epidemiologic research. *Environmental Health* 13:17, 2014. (Core C, Project 3, Project 4)
13. Pearce JL, Waller LA, Chang HH, Klein M, Mulholland JA, Sarnat JS, Sarnat SE, Strickland MJ, Tolbert PE. Using self-organizing maps to develop ambient air quality classifications for use in multipollutant health studies: a time-series example. *Environmental Health* 13:56, 2014. (Core C, Core B, Project 3, Project 4)
14. Russell A, Holmes H, Frieberg M, Ivey S, Hu Y, Balachandran S, Mulholland J, Tolbert P, Sarnat J, Sarnat S, Strickland M, Chang H, Liu Y. Use of Air Quality Modeling Results in Health Effects Research. In *Air Pollution Modeling and Its Application XXIII* (D. Steyn and R. Mathur eds.) 2014. (Core B, Core C, Project 3, Project 4)
15. Winquist A, Kirrane E, Klein M, Strickland M, Darrow LA, Sarnat SE, Gass K, Mulholland JA, Russell AG, Tolbert PE. Joint effects of ambient air pollutants on pediatric asthma emergency

- department visits in Atlanta, 1998-2004. *Epidemiology* 25:666-73, 2014. (Core B, Core C, Project 3, Project 4)
16. Baxter LK, Dionisio KL, Burke J, Sarnat SE, Sarnat JA, Hodas N, Rich DQ, Turpin BJ, Jones RR, Mannshardt E, Kumar N, Beevers SD, Özkaynak H. Exposure prediction approaches used in air pollution epidemiology studies: Key findings and future recommendations. *Journal of Exposure Science and Environmental Epidemiology* 23:654-659, 2013. (Project 4)
  17. Dionisio KL, Isakov V, Baxter L, Sarnat JA, Sarnat SE, Burke J, Rosenbaum A, Graham SE, Cook R, Mulholland J, Özkaynak H. Development and evaluation of alternative approaches for exposure assessment of multiple air pollutants in Atlanta, Georgia. *Journal of Exposure Science and Environmental Epidemiology* 23:581-592, 2013. (Project 4)
  18. Maier ML, Balachandran S, Sarnat SE, Turner JR, Mulholland JA, Russell AG. Application of an ensemble-trained source apportionment approach at a site impacted by multiple point sources. *Environmental Science and Technology* 47:3743-3751, 2013. (Core B, Project 4)
  19. Pachon JE, Weber RJ, Zhang X, Mulholland JA, Russell AG. Revising the use of potassium (K) in the source apportionment of PM<sub>2.5</sub>. *Atmospheric Pollution Research* 4(1):14-21, 2013. (Core B, Project 4)
  20. Sarnat JA, Sarnat SE, Chang H, Mulholland J, Özkaynak H, Isakov V. Spatiotemporally resolved air exchange rate as a modifier of acute air pollution-related morbidity. *Journal of Exposure Science and Environmental Epidemiology*, 23:606-615, 2013. (Project 2, Project 4)
  21. Sarnat SE, Sarnat JA, Mulholland J, Isakov V, Özkaynak H, Chang H, Klein M, Tolbert PE. Application of alternative spatiotemporal metrics of ambient air pollution exposure in a time-series epidemiological study in Atlanta. *Journal of Exposure Science and Environmental Epidemiology*, 23:593-605, 2013. (Core C, Project 4)
  22. Balachandran S, Pachon JE, Hu Y, Lee D, Mulholland JA, Russell AG. Ensemble-trained source apportionment of fine particulate matter and method uncertainty analysis. *Atmospheric Environment* 61:387-394, 2012. (Core B, Project 3, Project 4)
  23. Brown MS, Sarnat SE, DeMuth KA, Brown LAS, Whitlock DR, Brown SW, Tolbert PE, Fitzpatrick AM. Residential proximity to a major roadway is associated with features of asthma control in children. *PLoS ONE* 7(5):e37044, 2012. (Project 2, Project 4)
  24. Darrow LA, Hess J, Rogers CA, Tolbert PE, Klein M, Sarnat SE. Ambient pollen concentrations and emergency department visits for asthma and wheeze. *Journal of Allergy and Clinical Immunology* 130(3):630-638, 2012. (Project 4)
  25. Goldman GT, Mulholland JA, Russell AG, Gass K, Strickland MJ, Klein M, Tolbert PE. Characterization of ambient air pollution measurement error in a time-series health study using a geostatistical simulation approach. *Atmospheric Environment* 57:101-108, 2012. (Core B, Project 3, Project 4)
  26. Pachon JE, Balachandran S, Hu Y, Mulholland JA, Darrow LA, Sarnat JA, Tolbert PE, Russell AG. Development of outcome-based, multipollutant mobile source indicators. *Journal of Air and Waste Management Association* 62(4):431-442, 2012. (Core B, Project 3, Project 4)  
Inadvertently omitted SCAPE acknowledgement.
  27. Winquist A, Klein M, Tolbert P, Flanders WD, Hess J, Sarnat SE. Comparison of emergency department and hospital admissions data for air pollution time-series studies. *Environmental Health* 11:70, 2012. (Project 4)
  28. Winquist A, Klein M, Tolbert P, Sarnat SE. Power estimation using simulations for air pollution time-series studies. *Environmental Health* 11:68, 2012. (Project 4)
  29. Flanders WD, Klein M, Darrow LA, Strickland MJ, Sarnat SE, Sarnat JA, Waller LA, Winquist A, Tolbert PE. A method to detect residual confounding in spatial and other observational studies. *Epidemiology* 22:823-826, 2011. (Core C, Project 3, Project 4)



30. Flanders WD, Klein M, Darrow LA, Strickland MJ, Sarnat SE, Sarnat JA, Waller LA, Winquist A, Tolbert PE. A method for detection of residual confounding in time-series and other observational studies. *Epidemiology* 22:59-67, 2011. (Core C, Project 3, Project 4)
31. Goldman GT, Mulholland JA, Russell AG, Strickland MJ, Klein M, Waller LA, Tolbert PE. Impact of exposure measurement error in air pollution epidemiology: effect of error type in time-series studies. *Environmental Health* 10:61, 2011. (Core B, Project 3, Project 4)
32. Strickland MJ, Darrow LA, Mulholland JA, Klein M, Flanders WD, Winquist A, Tolbert PE. Implications of different approaches for characterizing ambient air pollutant concentrations within the urban airshed for time-series studies and health benefits analyses. *Environmental Health* 10:36, 2011. (Project 3, Project 4)

**Presentations:**

1. **Bates JT, Weber RJ, Abrams J, Verma V, Fang T, Klein M, Strickland MJ, Sarnat SE, Chang HH, Mulholland JA, Tolbert PE, Russell AG. Source impacts on reactive oxygen species generated by water-soluble PM<sub>2.5</sub> in Atlanta and associations with cardiorespiratory effects. Oral presentation at the American Association for Aerosol Research Annual Conference, Minneapolis, MN, October 12-16, 2015.**
2. **Sarnat SE, Winquist A, Mulholland JA, Chang HH, Klein M, Sarnat JA, Russell AG, Tolbert PE. Comparison of exposure assignment approaches in a multi-city time-series study of ambient air pollution and cardiorespiratory emergency department visits. Platform presentation at the International Society for Environmental Epidemiology Annual Meeting, Sao Paulo, Brazil, August 30-September 3, 2015.**
3. **Ye D, Klein M, Chang HH, Sarnat JA, Mulholland JA, Winquist A, Tolbert PE, Sarnat SE. Estimating the health effects of ambient volatile organic compounds. Platform presentation at the International Society for Environmental Epidemiology Annual Meeting, Sao Paulo, Brazil, August 30-September 3, 2015.**
4. **Winquist A, Hess J, Grundstein A, Chang HH, Sarnat SE. Relationship between warm-season ambient maximum temperature and emergency department visits across age groups. Poster presentation at the International Society for Environmental Epidemiology Annual Meeting, Sao Paulo, Brazil, August 30-September 3, 2015.**
5. **Pearce JL, Waller LA, Mulholland JA, Sarnat SE, Strickland MJ, Chang HH, Tolbert PE. Acute associations between multipollutant mixtures and pediatric asthma morbidity: epidemiologic applications of self-organizing map ambient air quality classifications at the day level. Oral presentation at the International Society for Environmental Epidemiology Annual Meeting, Sao Paulo, Brazil, August 30-September 3, 2015.**
6. **Krall J, Mulholland JA, Russell AG, Balachandran S, Winquist A, Tolbert PE, Waller L, Sarnat SE. Estimating associations between source-apportioned particulate matter and emergency department visits in multicity studies. Platform presentation at the Joint Statistical Meeting, Seattle, Washington, August 8-13, 2015.**
7. **O'Lenick C, Winquist A, Mulholland J, Friberg M, Chang HH, Kramer M, Sarnat SE. Neighborhood-level socioeconomic status modifies air pollution-asthma associations in Atlanta. Platform presentation at the Society for Epidemiologic Research Annual Meeting, Denver, CO, June 16-19, 2015.**
8. **Sarnat SE, Winquist A, Mulholland JA, Russell AG, Sarnat JA, Tolbert PE. Comparison of exposure assignment approaches in a multi-city time-series study of ambient air pollution and cardiorespiratory emergency department visits. Platform presentation at ENV•VISION (Environmental Vision - An International Electricity Sector Conference), Crystal City, VA, May 12-14, 2015.**

9. Chang HH, Sarnat S, Waller L, Liu Y. **Satellite-Derived Air Quality Estimates in Health Studies: A Critical Evaluation.** 142<sup>nd</sup> APHA Annual Meeting and Exposition, New Orleans, LA, November 15-19, 2014.
10. Alhanti B, Winquist A, Chang HH, Mulholland JA, Sarnat SE. **“Ambient air pollution and emergency department visits for asthma: a multi-city assessment of effect modification by age.”** Oral presentation at International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.
11. O'Lenick C, Winquist A, Mullholand J, Friberg M, Chang HH, Kramer M, Sarnat SE. **“An evaluation of neighborhood-level socioeconomic influences on air pollution-asthma associations in Atlanta.”** Poster presentation at International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.
12. Chang HH, Hao H, Sarnat SE. **“A statistical modeling framework for projecting future ambient ozone and its health impact due to climate change.”** International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.
13. Gass K, Klein M, Sarnat S, Flanders WD, Chang H, Strickland M. **“A three-city analysis of multipollutant joint effects: a comparison of classification and regression trees with conventional multipollutant models.”** International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.
14. Pearce JL, Waller LA, Sarnat SA, Strickland M, Klein M, Chang HH, Mulholland J, Tolbert PE. **“A framework for exploring the temporal associations between air quality day types and pediatric asthma: a case study of Atlanta, Georgia.”** International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.
15. Gass K, Klein M, Flanders WD, Chang H, Strickland M. **“Classification and regression trees for epidemiologic research.”** Poster presentation at the Society for Epidemiologic Research Annual Meeting. Seattle, Washington, June 2014.
16. Russell AG, Tolbert P, Mulholland J, Hu Y, Odman T, Henneman L, Klein M, Sarnat S, Strickland M. **“Impact of emissions changes on air quality and acute health effects in the Southeast 1993-2012.”** Poster presentation at the HEI Annual Conference. Alexandria, Virginia, May 2014.
17. Holmes HA, Ivey C, Friberg M, Zhai X, Balachandran S, Hu Y, Russell A, Mulholland J, Tolbert P, Sarnat S. **“Use of air quality modeling results as exposure estimates in health studies.”** Oral presentation at the American Geophysical Union 46<sup>th</sup> Annual Fall Meeting. San Francisco, California, December 2013.
18. Dionisio KL, Baxter LK, Isakov V, Sarnat SE, Sarnat JA, Burke J, Ozkaynak H. **“Modeling as an exposure estimation approach for use in epidemiologic studies.”** 12th Annual Community Modeling & Analysis System Conference. Chapel Hill, NC, October 28-30, 2013.
19. Chang HH, Liu Y, Sarnat SE. **“Time series analysis of air pollution and health accounting for spatial exposure uncertainty.”** Oral presentation at the Joint Statistical Meeting. Montreal, Canada, August 2013.
20. Gass K, Klein M, Chang H, Sarnat S, Flanders W, Strickland M. **“Utilizing regression trees to identify complex patterns of multipollutant joint effects.”** Poster presentation at the Joint Annual Conference of the International Society for Environmental Epidemiology and Exposure Science and Indoor Air Quality. Basel, Switzerland, August 2013.
21. Klein M, Hu X, Strickland M, Sarnat S, Tolbert P, Liu Y. **“The application of satellite remote sensing data in a time series study of asthma exacerbation in metro Atlanta.”** Oral presentation at the Joint Annual Conference of the International Society for Environmental Epidemiology and Exposure Science and Indoor Air Quality. Basel, Switzerland, August 2013.
22. Özkaynak H, Dionisio K, Baxter L, Burke J, Rich D, Sarnat S, Sarnat J, Jones R. **Overview and evaluation of alternative air quality exposure metrics used in recent air pollution epidemiological**

- studies. Poster presentation at the Joint Annual Conference of the International Society for Environmental Epidemiology and Exposure Science and Indoor Air Quality. Basel, Switzerland, August 2013.
23. Sarnat J, Sarnat S, Flanders WD, Chang H, Mulholland J, Baxter L, Isakov V, Ozkaynak H. "Spatiotemporally-resolved air exchange rate as a modifier of acute air pollution-related morbidity." Oral presentation at the Joint Annual Conference of the International Society for Environmental Epidemiology and Exposure Science and Indoor Air Quality. Basel, Switzerland, August 2013.
  24. Sarnat S, Winqvist A, Maier M, Hopke P, Mulholland J, Sarnat J, Tolbert P, Russell A. "Comparison of source apportionment methods in a time-series investigation of source-resolved particle mixtures and cardiorespiratory emergency department visits." Poster presentation at the Joint Annual Conference of the International Society for Environmental Epidemiology and Exposure Science and Indoor Air Quality. Basel, Switzerland, August 2013.
  25. Winqvist A, Kirrane E, Klein M, Strickland M, Darrow L, Sarnat S, Gass K, Mulholland J, Russell A, Tolbert P. "Joint effects of air pollutants on pediatric asthma emergency department visits." Joint Annual Conference of the International Society for Environmental Epidemiology and Exposure Science and Indoor Air Quality. Basel, Switzerland, August 2013.
  26. Winqvist A, Schauer J, Turner J, Klein M, Sarnat S. "Impact of ambient PM<sub>2.5</sub> carbon measurement methods on observed associations with acute cardiorespiratory morbidity." Poster presentation at the Joint Annual Conference of the International Society for Environmental Epidemiology and Exposure Science and Indoor Air Quality. Basel, Switzerland, August 2013.
  27. Russell A, Holmes H, Friberg M, Ivey C, Hu Y, Balachandran S, Mulholland J, Tolbert P, Sarnat J, Sarnat S, Strickland M, Chang H, Liu Y. "Use of air quality modeling results in health effects research." Oral presentation at the NATO/SPS International Technical Meeting on Air Pollution Modeling and its Application, Miami, Florida, August 2013.
  28. Chang HH, Liu Y, Sarnat S, Reich B. "Time series analysis of air pollution and health accounting for spatial exposure uncertainty." Oral presentation at International Biometric Society ENAR Meeting. Orlando, Florida, March 2013.
  29. Dionisio KL, Baxter L, Chang H, Burke J, Isakov V, Graham SE, Mulholland J, Sarnat JA, Sarnat SE, Özkaynak H. "Comparison of modeling approaches for exposure assessment of multiple air pollutants in Atlanta, Georgia." International Society for Exposure Science Annual Conference. Seattle, Washington, October 2012.
  30. Holmes H, Sororian S, Maier ML, Friberg M, Balachandran S, Ivey C, Hu Y, Russell AG, Mulholland JA, Sarnat SE, Sarnat JA, Strickland MJ, Winqvist A, Klein M, Tolbert PE. "Development of a Mixtures Characterization Toolkit: Estimating air pollution source impacts to investigate air quality and human health associations using time-series epidemiologic analysis." Community Modeling and Analysis System Conference. Raleigh, North Carolina, October 2012.
  31. Holmes HA, Maier ML, Friberg M, Balachandran S, Hu Y, Russell AG, Mulholland JA, Sarnat SE, Sarnat JA, Winqvist A, Klein M, Tolbert PE. "Development of a Mixtures Characterization Toolkit to estimate air pollution source impacts for time series epidemiologic analysis to investigate air quality and human health associations: Application to a High Biogenic and a High Industrial Emissions Areas." Poster presentation at the 12<sup>th</sup> International Global Atmospheric Chemistry Open Science Conference. Beijing, China, September 2012.
  32. Waller L, Chang H, Pearce J, Sarnat S, Tolbert P. "Spatial uncertainty estimation and public health data: air pollution epidemiology in Atlanta, Georgia." Oral presentation at the Joint Statistical Meetings. San Diego, California, July 2012.
  33. Sarnat J, Sarnat S, Isakov V, Baxter L, Crooks J, Özkaynak H, Mulholland J, Russell A, Kewada P, Tolbert P. "Challenges in evaluating alternative exposure metrics in an epidemiologic setting: results

from the Atlanta EPA COOP Study." International Society of Exposure Science Annual Meeting. Baltimore, Maryland, October 2011.

34. Flanders WD, Klein M, Darrow LA, Strickland MJ, Sarnat SE, Sarnat JA, Waller LA, Winquist A, Tolbert PE. "A method for detection of residual confounding in spatial and other observational studies." International Society of Environmental Epidemiology. Barcelona, Spain, September 2011.
35. Sarnat SE, Sarnat JA, Winquist A, Schauer JJ, Turner JR, Klein M, Tolbert PE. "Associations of source-resolved particulate air pollution mixtures and cardiorespiratory emergency department visits in St. Louis, MO-IL." International Society for Environmental Epidemiology Annual Meeting. Barcelona, Spain, September 2011. *Environmental Health Perspectives* <http://dx.doi.org/10.1289/ehp.isee2011>.

**Future Activities:** Over the coming year, we anticipate completing our ED visit database by incorporating data from University of Pittsburgh collaborators. Manuscript preparation will begin and/or continue for analyses conducted over the past year. Current manuscripts in preparation include: 1) Exposure assignment considerations in a multi-city time-series study of ambient air pollution and cardiorespiratory emergency department visits; 2) Estimating the health effects of ambient volatile organic compounds; and 3) Relationship between warm-season ambient maximum temperature and emergency department visits across age groups. Additional planned manuscripts will focus on our multi-city assessment of air pollution and cardiovascular ED visits, further examination of retrospectively-predicted ROS on health, assessment of concentration-response function shape, assessment of air exchange rates as a modifier of ambient air pollution health effects, and extension of analyses considering modification of air pollution-health associations by neighborhood socioeconomic status to multiple cities.

**Supplemental Keywords:** ambient air, health effects, sensitive populations, dose-response, cumulative effects, epidemiology, exposure, air quality modeling, PM<sub>2.5</sub>, organics, elemental carbon, metals, oxidants, sulfates, source characterization

**Relevant Web Sites:** [www.scape.gatech.edu](http://www.scape.gatech.edu)

**Date of Report:** July 31, 2015

**EPA Agreement Number:** R834799

**Center Name:** Southeastern Center for Air Pollution and Epidemiology

**Project Title:** Air Quality Core (Core B)

**Investigator(s):** PI -- Armistead Russell, PhD<sup>1</sup> ([ted.russell@ce.gatech.edu](mailto:ted.russell@ce.gatech.edu)); M. Talat Odman, PhD<sup>1</sup> ([odman@gatech.edu](mailto:odman@gatech.edu)); Yongtao Hu, PhD<sup>1</sup> ([yh29@mail.gatech.edu](mailto:yh29@mail.gatech.edu)); James Mulholland, PhD<sup>1</sup> ([james.mulholland@ce.gatech.edu](mailto:james.mulholland@ce.gatech.edu)); Yang Liu, PhD<sup>2</sup> ([yang.liu@emory.edu](mailto:yang.liu@emory.edu))

**Institution(s) of PI(s):** <sup>1</sup>Georgia Institute of Technology and <sup>2</sup>Emory University, Atlanta, Georgia

**Research Category:** Air Quality and Air Toxics

**Project Period:** 08/01/2014 – 7/31/2015

**Objective of Research:** The primary mission of the Air Quality Core (AQC) is to provide SCAPE researchers with the methods and data to comprehensively characterize air pollutants relevant to the four projects and other cores. Project activities are supported by collecting and managing atmospheric data, developing a “Mixture Characterization Toolkit” (MC Toolkit) for further analyses specific to the projects, and providing the expertise and resources to facilitate the application of the various components of the toolkit. An additional mission of the AQC is to facilitate transmission of atmospheric data and methods to potential users outside of the Center.

First, comprehensive characterization of air pollutants is developed by analyses of the detailed chemical and physical measurements conducted by the Center, along with those available from ambient air quality monitoring networks and special field campaigns. Next, spatial and temporal characterization of the air pollutant mixtures and emission sources are determined by using extended receptor-oriented models, chemical transport models (CTMs), regression approaches, hybrid methods, and remote sensing applied over multiple scales.

In addition to these functions, the AQC team assists in the preparation of reports and journal publications resulting from Center activities.

**Progress Summary/Accomplishments:** During the past year, we continued to support Development and Deployment of an Instrumentation Suite for Comprehensive Air Quality Characterization including Aerosol ROS (Project 1), Examining In-Vehicle Pollution and Oxidative Stress in a Cohort of Daily Commuters (Project 2), the Georgia Birth Cohorts Study (Project 3), and the Multi-City Morbidity (Project 4) by conducting data analyses and providing specific air quality metrics, including pollutant concentration fields and source impacts. We have also been contributing to various collaborative projects, including, Characterization of primary and secondary traffic related particles (Collaborators: Harvard and SCAPE), Mobile and Fixed Site Characterization of Vehicle Emission Impacts in Atlanta (Collaborators: SCAPE, CCAR, and EPA), and the Inter-comparison of ambient PM<sub>2.5</sub> estimation models in NC (Collaborators: SCAPE, Harvard, CCAR, and EPA). Further, we continue to develop advanced spatiotemporal modeling methods for broader use by the community. We also led the Spatiotemporal Characterization Method Workshop held after the 2014 CLARC meeting in Atlanta, and are working on the manuscript to summarize the various methods being used by the CLARCs.

All four SCAPE projects are using different source apportionment (SA) methods and chemical transport model outputs in order to generate multi-year spatial and receptor-specific fields of source impacts for use in health studies. SA methods include the traditional receptor models such as CMB (Chemical Mass Balance) and PMF (Positive Matrix Factorization), the source oriented approach using CMAQ-DDM (Decoupled Direct Method) and the development of novel methods including a Bayesian Ensemble SA technique and a Hybrid Kriging (HK) model.

The ensemble approach uses three receptor models and one chemical transport model. We use two CMB methods: CMB-LGO which incorporates gas-based constraints, and CMB-MM which uses molecular marker observations. We use one factor analytic method, PMF and one CTM, the Community Multiscale Air Quality (CMAQ) model. Bayesian techniques were applied to estimate SA uncertainties. The Bayesian Ensemble SA method has been used by Project 4 in multiple cities and by Project 1 for analysis of their ROS measurements.

Our OBS-CMAQ data fusion method has undergone refinement and is being used in the Georgia Birth Cohorts Study (Project 3). Temporally and spatially resolved concentrations for 12 pollutants were calculated using fused ambient monitoring data and CMAQ outputs for Georgia. Pollutant fields include five gases (1-hour max CO, 1-hr max NO<sub>2</sub>, 1-hr max NO<sub>x</sub>, 1-hr max SO<sub>2</sub> and 8-hr max O<sub>3</sub>) and seven PM types measures (24-hr average PM<sub>10</sub>, PM<sub>2.5</sub>, SO<sub>4</sub><sup>2-</sup>, NO<sub>3</sub><sup>-</sup>, NH<sub>4</sub><sup>+</sup>, EC and OC). Ambient concentrations were collected from the regulatory monitoring networks for the State and modelled concentrations were extracted from CMAQ simulations originally run for different domains. We extended that work to apply the Integrated Mobile Source Indicator (IMSI) method to assess spatial mobile source impacts. It was applied to the 24-hour average concentrations obtained from the 12-km OBS-CMAQ fused data for 2002-2008 and from the 4-km fused data for 2008-2010.

We applied and extended our new CMAQ-CMB hybrid source apportionment technique to the US over a longer time period, and those activities continue. A major extension of the method, called hybrid kriging (HK), takes the receptor specific results and krigs the impact adjustment factors spatially and temporally to develop comprehensive source impact fields. This can reduce uncertainties in interpolated fields. Hybrid Kriging (HK) used observations from 189 monitors across CONUS. The CMAQ-DDM model was used to determine the source impact for 40 PM<sub>2.5</sub> species (5 ions, 35 metals) in the 36-km CONUS domain for 2006. The DDM package was used to quantify CMAQ sensitivities to emission changes for 20 source categories including biomass burning, on-road mobile sources and other combustion sources. Simulation results from the coupling of CMAQ-DDM and HK models suggest that in 2006 the three dominant sources were coal combustion, biogenics and on-road gasoline combustion. Moreover, each source impact was ranked by importance of its contribution to seasonal concentrations in nine distinct climate regions.

In support of Project 3, we have been developing air quality metrics in a 250 m resolution grid covering the Atlanta area. ARC (Atlanta Regional Commission) provided us with the 2011 link-based emissions, and associated PM fields calculated using RLINE, from the transportation sector in 15 counties. Our analysis of the RLINE results provided found that they were biased, and we developed rescaling approaches based upon observations of PM<sub>2.5</sub> at multiple monitors in Atlanta, as well as our CMB results. We also calculated hourly NO<sub>x</sub> and PM<sub>2.5</sub> emissions in the 250 m grid for use in a statistical downscaling model, along with CMAQ results. We also blended the RLINE fields with the OBS-CMAQ fused fields, and those were provided to Project 3 to allow fine spatial scale analysis of pollutant impacts.

As part of Project 3, Emory University has developed a statistical downscaling model for predicting daily spatially resolved PM<sub>2.5</sub> concentrations at 12 km for 2003-2005. MODIS Aerosol Optical Depth (AOD) values and PM<sub>2.5</sub> concentrations are linked in space and time by treating AOD as a predictor of PM<sub>2.5</sub> in a linear regression setting. Spatio-temporal regression coefficients include land use and meteorological components. We have been applying the same downscaling approach by replacing AOD with our 12 km CMAQ outputs for 2002-2005. This work continues.

We have been working with Project 1 to quantify major ROS-associated emission sources by determining DTT activity in the water-soluble fraction of atmospheric fine aerosols. A large number of samples were collected at two Atlanta urban sites, one rural site, and a site adjacent to a major traffic route, from June 2012 through April 2013. Source apportionment on ambient (Atlanta, GA) PM<sub>2.5</sub> was performed using the Chemical Mass Balance Method with ensemble-averaged source impact profiles. Linear regression modeling was used to relate PM<sub>2.5</sub> emissions sources to ROS-generation potential and to estimate historical levels of DTT activity for use in an epidemiologic analysis. This work was followed by a similar analysis of the ascorbic acid assay measurements from Project 1.

As part of Projects 1 and 2 and the collaborative with CCAR, mobile platform measurements coupled with stationary site observations are being used to investigate the spatial distribution of vehicle emission impacts from downtown Atlanta to Yorkville rural area. We provided CMAQ simulations for comparison to the observations, and are now developing RLINE fine scale results as well.

As part of the Collaborative with Harvard, CCAR and EPA “Inter-comparison of ambient PM<sub>2.5</sub> estimation models in NC,” we applied the OBS-CMAQ fusion approach to NC for comparison to the satellite retrieval-based results. Our activities on the “Characterization of primary and secondary traffic related particles” collaborative have included providing air quality data.

#### **Publications:**

1. **Hao H, Chang HH, Holmes HA, Mulholland JA, Klein M, Darrow LA, Strickland MJ. Ambient air pollution and preterm birth in the U.S. state of Georgia. *Environmental Health Perspectives*, accepted. (Core B, Core C, Project 3)**
2. **Ma Z, Hu X, Sayer A, Levy R, Zhang Q, Xue Y, Tong S, Bi J, Huang L, Liu Y. 2014. Satellite-based spatiotemporal trends in PM<sub>2.5</sub> concentrations: China, 2004 - 2013. *Environmental Health Perspectives*, in press.**
3. **Strickland MJ, Hao H, Hu X, Chang HH, Darrow LA, Liu Y. Pediatric emergency visits and short-term changes in PM<sub>2.5</sub> concentrations in the U.S. State of Georgia. *Environmental Health Perspectives*, accepted. (Core B, Core C, Project 3)**
4. **Strickland MJ, Hao H, Hu X, Chang HH, Darrow LA, Liu Y. Pediatric emergency visits and short-term changes in PM<sub>2.5</sub> concentrations in the U.S. State of Georgia. *Environmental Health Perspectives*, accepted. (Project 3, Core B, Core C)**
5. **Yu C, Chen L, Zhang X, Girolamo LD, Liu Y. 2014. Effects of MODIS-retrieved Cloud Properties on PM<sub>2.5</sub> Levels in the Southeastern United States. *Journal of Exposure Science and Environmental Epidemiology*, in press. (Core B, Project 3)**
6. **Gass KM, Balachandran S, Chang HH, Russell AG, Strickland MJ. Ensemble-based source apportionment of fine particulate matter and emergency department visits for pediatric asthma. *American Journal of Epidemiology* 181:504-512, 2015, 2015. (Core B, Core C, Project 3)**
7. **Gass K, Klein M, Sarnat SE, Winqvist A, Darrow LA, Flanders WD, Chang HH, Mulholland JA, Tolbert PE, Strickland MJ. Associations between ambient air pollutant mixtures and pediatric asthma emergency department visits in three cities: a classification and regression tree approach. *Environmental Health* 14:58, 2015. (Core B, Core C, Project 3, Project 4)**
8. **Hu Y, Odman MT, Chang ME, Russell AG. Operational forecasting of source impacts for dynamic air quality management. *Atmospheric Environment* 116:320-322, 2015. (Core B)**

9. Ivey CE, Holmes HA, Hu YT, Mulholland JA, Russell AG. Development of PM<sub>2.5</sub> source impact spatial fields using a hybrid source apportionment air quality model. *Geoscientific Model Development* 8:2153-2165, 2015. (Core B)
10. Pearce JL, Waller LA, Mulholland JA, Sarnat SE, Strickland MJ, Chang HH, Tolbert PE. Exploring associations between multipollutant day types and asthma morbidity: epidemiologic applications of self-organizing map ambient air quality classifications. *Environmental Health* 14:55, 2015. (Core B, Core C, Project 3, Project 4)
11. Strickland MJ, Gass KM, Goldman GT, Mulholland JA. Effects of ambient air pollution measurement error on health effect estimates in time series studies: a simulation-based analysis. *Journal of Exposure Science and Environmental Epidemiology* 25:160-166, 2015. (Core B, Project 3).
12. Xu L, Guo H, Boyd CM, Klein M, Bougiatioti A, Cerully KM, Hite JR, Isaacman-VanWertz G, Kreisberg NM, Knotte C, Olson K, Koss A, Goldstein AH, Hering SV, de Gouw J, Baumann K, Lee SH, Nenes A, Weber RJ, Ng NL. Effects of anthropogenic emissions on aerosol formation from isoprene and monoterpenes in the southeastern United States. *Proceedings of the National Academy of Sciences USA* 112(1):37-42, 2015 (Core B, Core C, Project 1)
13. Chang HH, Hu X, Liu Y. Calibrating MODIS aerosol optical depth for predicting daily PM<sub>2.5</sub> concentrations via statistical downscaling. *Journal of Exposure Science and Environmental Epidemiology* 24:398-404, 2014. (Core B, Core C, Project 3).
14. Darrow LA, Klein M, Flanders WD, Mulholland JA, Tolbert PE, Strickland MJ. Air pollution and acute respiratory infections among children 0-4 years: an 18-year time-series study. *American Journal of Epidemiology* 180:968-77, 2014. (Project 3, Core B, Core C)
15. Holmes H, Zhai X, Redman J, Digby K, Ivey C, Balachandran S, Sororian S, Friberg M, Zhang W, Maier M, Hu Y, Russell A, Mulholland J, Chang H. Improved spatiotemporal air pollutant mixtures characterization for health studies. In *Air Pollution Modeling and Its Application XXIII* (D. Steyn and R. Mathur eds.) 2014. (Core B, Core C)
16. Hu X, Waller LA, Lyapustin A, Wang Y, Al-Hamdan MZ, Crosson WL, Estes MG, Estes SM, Quattrochi DA, Puttaswamy SJ, Liu Y. Estimating ground-level PM<sub>2.5</sub> concentrations in the southeastern United States using MAIAC AOD retrievals and a two-stage model. *Remote Sensing of Environment* 140:220-232, 2014. (Core B, Core C, Project 3)
17. Hu X, Waller LA, Lyapustin A, Wang Y, Liu Y. 2014. 10-year spatial and temporal trends of PM<sub>2.5</sub> concentrations in the southeastern U.S. estimated using high-resolution satellite data. *Atmospheric Chemistry and Physics* 14:6301-6314. (Core B, Core C, Project 3).
18. Hu X, Waller LA, Lyapustin A, Wang Y, Liu Y. Improving satellite-driven PM<sub>2.5</sub> models with Moderate Resolution Imaging Spectroradiometer fire counts in the southeastern US. *Journal of Geophysical Research: Atmosphere*, 2014, 119:11375-11386. (Core B)
19. Hu Y, Balachandran S, Pachon JE, Baek J, Ivey C, Holmes H, Odman MT, Mulholland JA, Russell AG. Fine particulate matter source apportionment using a hybrid chemical transport and receptor model approach. *Atmospheric Chemistry and Physics* 14:5415-5431, 2014. (Core B)
20. Ivey C, Holmes H, Hu Y, Russell A, Mulholland J. Spatial and temporal extension of a novel hybrid source apportionment model. In *Air Pollution Modeling and Its Application XXIII* (D. Steyn and R. Mathur eds.) 2014. (Core B)
21. Ma Z, Hu X, Huang L, Bi J, Liu Y. Estimating ground-level PM<sub>2.5</sub> in China using satellite remote sensing. *Environmental Science and Technology*, 2014, 48:7436-7444, 2014. (Core B, Project 3)
22. Pearce JL, Waller LA, Chang HH, Klein M, Mulholland JA, Sarnat JS, Sarnat SE, Strickland MJ, Tolbert PE. Using self-organizing maps to develop ambient air quality classifications for use in multipollutant health studies: a time-series example. *Environmental Health* 13:56, 2014. (Core C, Core B, Project 3, Project 4)



23. Russell A, Holmes H, Friberg M, Ivey S, Hu Y, Balachandran S, Mulholland J, Tolbert P, Sarnat J, Sarnat S, Strickland M, Chang H, Liu Y. Use of Air Quality Modeling Results in Health Effects Research. In *Air Pollution Modeling and Its Application XXIII* (D. Steyn and R. Mathur eds.) 2014. (Core B, Core C, Project 3, Project 4)
24. Sororian S, Holmes H, Friberg M, Ivey C, Hu Y, Mulholland J, Russell A, Strickland M, Chang H. Temporally and spatially resolved air pollution in Georgia using fused ambient monitoring data and chemical transport model results. In *Air Pollution Modeling and Its Application XXIII* (D. Steyn and R. Mathur eds.) 2014. (Core B, Core C, Project 3)
25. Strickland MJ, Klein M, Flanders WD, Chang HH, Mulholland JA, Tolbert PE, Darrow LA. Modification of the effect of ambient air pollution on pediatric asthma emergency visits: susceptible subpopulations. *Epidemiology* 25(6):843-50, 2014. (Project 3, Core B, Core C)
26. Winquist A, Kirrane E, Klein M, Strickland M, Darrow LA, Sarnat SE, Gass K, Mulholland JA, Russell AG, Tolbert PE. Joint effects of ambient air pollutants on pediatric asthma emergency department visits in Atlanta, 1998-2004. *Epidemiology* 25:666-73, 2014. (Core B, Core C, Project 3, Project 4)
27. **Yu C, Di Girolamo L, Chen L, Zhang X, Liu Y. Statistical evaluation of the feasibility of satellite-retrieved cloud parameters as indicators of PM<sub>2.5</sub> levels. *Journal of Exposure Science and Environmental Epidemiology*, 2014, doi: 10.1038/jes.2014.49. (Core B, Project 3)**
28. Balachandran S, Chang HH, Pachon JE, Holmes HA, Mulholland JA, Russell AG. Bayesian-based ensemble source apportionment of PM<sub>2.5</sub>. *Environmental Science & Technology* 47:13511-13518, 2013. (Core B) Inadvertently omitted SCAPE acknowledgement. Erratum adding SCAPE cite has been accepted.
29. Balachandran S, Pachon JE, Lee S, Oakes MM, Rastogi N, Shi W, Tagaris E, Yan B, Davis A, Zhang X, Weber RJ, Mulholland JA, Bergin MH, Zheng M, Russell AG. Particulate and gas sampling of prescribed fires in South Georgia, USA. *Atmospheric Environment* 81:125-135, 2013.
30. Hu X, Waller LA, Al-Hamdan MZ, Crosson WL, Estes MG, Estes SM, Quattrochi DA, Sarnat JA, Liu Y. Estimating ground-level PM<sub>2.5</sub> concentrations in the southeastern U.S. using geographically weighted regression. *Environmental Research* 121:1-10, 2013. (Core B, Core C, Project 3) Inadvertently omitted SCAPE acknowledgement.
31. Maier ML, Balachandran S, Sarnat SE, Turner JR, Mulholland JA, Russell AG. Application of an ensemble-trained source apportionment approach at a site impacted by multiple point sources. *Environmental Science and Technology* 47:3743-3751, 2013. (Core B, Project 4)
32. Pachon JE, Weber RJ, Zhang X, Mulholland JA, Russell AG. Revising the use of potassium (K) in the source apportionment of PM<sub>2.5</sub>. *Atmospheric Pollution Research* 4(1):14-21, 2013. (Core B, Project 4)
33. Park SK, Russell AG. Regional adjustment of emission strengths via four dimensional data assimilation. *Asia-Pacific Journal of Atmospheric Sciences* 49(3):361-374, 2013. (Core B)
34. Park SK, Marmur A, Russell AG. Environmental risk assessment: comparison of receptor and air quality models for source apportionment. *Human and Ecological Risk Assessment: An International Journal* 19: 1385-1403, 2013. (Core B)
35. Balachandran S, Pachon JE, Hu Y, Lee D, Mulholland JA, Russell AG. Ensemble-trained source apportionment of fine particulate matter and method uncertainty analysis. *Atmospheric Environment* 61:387-394, 2012. (Core B, Project 3, Project 4)
36. Goldman GT, Mulholland JA, Russell AG, Gass K, Strickland MJ, Klein M, Tolbert PE. Characterization of ambient air pollution measurement error in a time-series health study using a geostatistical simulation approach. *Atmospheric Environment* 57:101-108, 2012. (Core B, Project 3, Project 4)

37. Pachon JE, Balachandran S, Hu Y, Mulholland JA, Darrow LA, Sarnat JA, Tolbert PE, Russell AG. Development of outcome-based, multipollutant mobile source indicators. *Journal of Air and Waste Management Association* 62(4):431-442, 2012. (Core B, Project 3, Project 4)  
Inadvertently omitted SCAPE acknowledgement.
38. Goldman GT, Mulholland JA, Russell AG, Strickland MJ, Klein M, Waller LA, Tolbert PE. Impact of exposure measurement error in air pollution epidemiology: effect of error type in time-series studies. *Environmental Health* 10:61, 2011. (Core B, Project 3, Project 4)

**Presentations:**

1. **Holmes H, Chang H, Mulholland J, Russell A. "Comparison of data fusion techniques using observations, chemical transport models, and satellite retrievals for air pollution exposure estimates in health studies."** Oral presentation at the AGU 47th Annual Fall Meeting. San Francisco, California, December 2014.
2. **Hu X, Waller LA, Lyapustin, Wang Y, Liu Y. "Improving satellite-driven PM2.5 models with MODIS fire counts in the southeastern U.S."** International Society of Exposure Science 24<sup>th</sup> Annual Meeting. Cincinnati, Ohio, October 2014.
3. **Ivey C, Holmes H, Hu Y, Mulholland J, Russell A. "Temporal and regional analysis of spatially-resolved PM2.5 source apportionment results over continental US."** Oral presentation at the American Association for Aerosol Research Annual Conference. Orlando, Florida, October 2014.
4. **Henneman L, Lavoue D, Holmes H, Mulholland J, Russell A. "Estimating the impact of air pollution controls on ambient concentrations."** Poster presentation at the American Association for Aerosol Research Annual Conference. Orlando, Florida, October 2014.
5. **Zhai X, Sororian SA, Friberg M, Holmes H, Hu Y, Mulholland J, Russell A. "Novel approach for estimating light duty gasoline and heavy duty diesel mobile source impacts based on mobile source emissions and fused observation-CMAQ data."** Poster presentation at the American Association for Aerosol Research Annual Conference. Orlando, Florida, October 2014.
6. **Ivey C, Lavoue D, Davis A, Hu Y, Russell A. "CMAQ Simulations using Fire Inventory of NCAR (FINN) Emissions."** 13<sup>th</sup> Annual Community Modeling & Analysis System (CMAS) Conference. Chapel Hill, North Carolina, October 2014
7. **Ivey C, Holmes H, Hu Y, Mulholland J, Russell A. "Python Data Assimilation Routine for CMAQ-DDM and Observations for Spatiotemporal PM2.5 Source Impacts."** 13<sup>th</sup> Annual Community Modeling & Analysis System (CMAS) Conference. Chapel Hill, North Carolina, October 2014.
8. **Bates J, Abrams J, Tolbert P, Gass K, Klein M, Verma V, Weber R, Mulholland J, Russell A. "Sources and health effects of reactive oxygen species in Atlanta air pollution."** Poster at the 9<sup>th</sup> Annual Georgia Environmental Conference. Jekyll Island, Georgia, August 2014.
9. **El-Afifi R, Wang Y, Verma V, Weber R, Russell A. "Seasonal and temporal assessment of organic aerosols in Atlanta"**. Poster presentation at the 107<sup>th</sup> Annual Air & Waste Management Association's Conference and Exhibition. Long Beach, CA, June 2014.
10. **Friberg M, Sororian S, Holmes H, Hu Y, Russell A, Mulholland J. "Spatiotemporal air quality metrics developed for Georgia for use in health studies"**. Oral presentation at the 107<sup>th</sup> Annual Air & Waste Management Association's Conference & Exhibition. Long Beach, CA, June 2014.
11. **Ivey C, Holmes H, Hu Y, Mulholland J. "Novel Data Assimilation Technique for Spatiotemporal PM2.5 Source Impact Estimates"**. Oral presentation at the Goldschmidt Conference. Sacramento, CA, June 2014.
12. **Holmes H, Ivey C, Hu Y, Russell A, Sriramasamudram J, Pardyjak E. "Wintertime high PM events in the western United States"**. Poster presentation at the Goldschmidt Conference, Sacramento, CA, June 2014.

13. Ivey C, Holmes H, Hu Y, Mulholland J, Russell A. "Novel Data Assimilation Technique for Spatiotemporal PM2.5 Source Impact Estimates." Oral Presentation at the *Goldschmidt Conference*, Sacramento, CA, June 2014.
14. Ivey C, Holmes H, Hu Y, Mulholland J, Russell A. "What Air Pollution Sources Contribute to Your Personal Exposure to Ambient Particulate Matter?" Poster presentation at the Georgia Tech Innovation and Research Conference. Atlanta, GA. Feb 2014.
15. Ivey C, Holmes H, Hu Y, Mulholland J, Russell A. "A novel hybrid source apportionment method for ambient particulate matter". Poster presentation at the 107th Annual Air & Waste Management Association's Annual Conference & Exhibition. Long Beach, CA, June 2014.
16. Russell A, Tolbert P, Mulholland J, Hu Y, Odman T, Henneman L, Klein M, Sarnat S, Strickland M. "Impacts of emission changes on air quality and acute health effects in the Southeast 1993–2012". Oral presentation at the Health Effects Institute Annual Conference. Alexandria, VA, May 2014.
17. Holmes H, Ivey C, Friberg M, Zhai X, Balachandran S, Hu Y, Russell A, Mulholland J, Tolbert P, Sarnat S (2013). "Use of air quality modeling results as exposure estimates in health studies". Oral presentation at the American Geophysical Union 46th Annual Fall Meeting. San Francisco, CA, December 2013.
18. Ivey C, Holmes H, Hu Y, Mulholland J, Russell A. "Spatiotemporal Comparison of Novel Hybrid Source Apportionment and Receptor Modeling Results". Poster presentation at the 12th Annual Community Modeling & Analysis System (CMAS) Conference. Chapel Hill, NC, October 2013.
19. Zhai X, Sororian S, Friberg M, Holmes H, Hu Y, Mulholland J, Russell A. "Generating spatially-resolved mobile source impacts using an observation-CMAQ data fusion technique and an emission-based indicator source apportionment approach". Poster presentation at the 12th annual Community Modeling & Analysis System (CMAS) Conference. Chapel Hill, NC, October 2013.
20. Ivey C, Holmes H, Hu Y, Russell A, Mulholland J. "Spatial and temporal assessment of a hybrid source apportionment model using nonlinear optimization." Oral presentation at the American Association for Aerosol Research Annual Meeting. Portland, Oregon, September 2013.
21. Sororian S, Holmes H, Friberg M, Ivey C, Hu Y, Mulholland J, Russell A, Strickland M, Chang H. "Temporally and spatially resolved air pollution in Georgia using fused ambient monitoring data and chemical transport model results". Poster presentation at the International Technical Meeting on Air Pollution Modeling and its Application. Miami, FL, August 2013.
22. Hu X, Waller L, Lyapustin A, Liu Y. "A Time Series Analysis of PM2.5 Concentrations in the Southeastern U.S. Using MAIAC AOD in a Two-stage Spatial Statistical Model." Oral presentation at the Joint Annual Conference of the International Society for Environmental Epidemiology and Exposure Science and Indoor Air Quality. Basel, Switzerland, August 2013.
23. Klein M, Hu X, Strickland M, Sarnat S, Tolbert P, Liu Y. "The application of satellite remote sensing data in a time series study of asthma exacerbation in metro Atlanta." Oral presentation at the Joint Annual Conference of the International Society for Environmental Epidemiology and Exposure Science and Indoor Air Quality. Basel, Switzerland, August 2013.
24. Winquist A, Kirrane E, Klein M, Strickland M, Darrow L, Sarnat S, Gass K, Mulholland J, Russell A, Tolbert P. "Joint effects of air pollutants on pediatric asthma emergency department visits." Poster presentation at the Joint Annual Conference of the International Society for Environmental Epidemiology and Exposure Science and Indoor Air Quality. Basel, Switzerland, August 2013.
25. Zhai X, Ivey C, Sororian S, Friberg M, Holmes H, Hu Y, Russell A, Mulholland J, Chang H, Strickland M, Zhang W. "Spatially-resolved source impact estimates for air quality health risk assessment."

- Oral presentation at the Joint Annual Conference of the International Society for Environmental Epidemiology and Exposure Science and Indoor Air Quality. Basel, Switzerland, August 2013.
26. Holmes H, Zhai X, Redman J, Digby K, Ivey C, Balachandran S, Sororian S, Friberg M, Zhang W, Maier M, Hu Y, Russell AG, Mulholland JA, Chang H. "Improved spatiotemporal air pollutant mixtures characterization for health studies." Oral presentation at the NATO/SPS International Technical Meeting on Air Pollution Modeling and its Application. Miami, Florida, August 2013.
  27. Ivey C, Holmes H, Hu Y, Russell AG, Mulholland JA. "Spatial and Temporal Extension of a Novel Hybrid Source Apportionment Model." Poster presentation at the NATO/SPS International Technical Meeting on Air Pollution Modeling and its Application. Miami, Florida, August 2013.
  28. Russell A, Holmes H, Friberg M, Ivey C, Hu Y, Balachandran S, Mulholland J, Tolbert P, Sarnat J, Sarnat S, Strickland M, Chang H, Liu Y. "Use of air quality modeling results in health effects research." Oral presentation at the NATO/SPS International Technical Meeting on Air Pollution Modeling and its Application, Miami, Florida, August 2013.
  29. Sororian S, Holmes H, Friberg M, Ivey C, Hu Y, Mulholland JA, Russell AG, Strickland M, Chang H. "Temporally and spatially resolved air pollution in Georgia using fused ambient monitoring data and chemical transport model results." Poster presentation at the NATO/SPS International Technical Meeting on Air Pollution Modeling and its Application. Miami, Florida, August 2013.
  30. Russell A, Holmes H, Friberg M, Ivey C, Hu Y, Balachandran S, Mulholland J, Tolbert P, Sarnat J, Sarnat S, Strickland M, Chang H, Liu Y. "Use of air quality modeling in health effects research." AEESP 50th Anniversary Conference. Golden, Colorado, July 2013.
  31. Liu Y. "Estimating Ground-Level PM<sub>2.5</sub> Concentrations in the Southeastern United States Using MAIAC AOD Retrievals and a Two-Stage Model." Oral presentation at the American Thoracic Society International Conference. Philadelphia, Pennsylvania, May 2013.
  32. Balachandran S, Baumann K, Pachon J, Mulholland J, Russell A. "Verification of Fire Weather Forecasts Using PM<sub>2.5</sub> Sensitivity Analysis." Poster presentation at the American Association of Aerosol Research Annual Meeting. Minneapolis, Minnesota, October 2012.
  33. Balachandran S, Chang H, Mulholland J, Russell A. "A Bayesian – Based Ensemble Technique for Source Apportionment of PM<sub>2.5</sub>." Platform presentation at the American Association of Aerosol Research Annual Meeting. Minneapolis, Minnesota, October 2012.
  34. Holmes H, Sororian S, Maier ML, Friberg M, Balachandran S, Ivey C, Hu Y, Russell AG, Mulholland JA, Sarnat SE, Sarnat JA, Strickland MJ, Winquist A, Klein M, Tolbert PE. "Development of a Mixtures Characterization Toolkit: Estimating air pollution source impacts to investigate air quality and human health associations using time-series epidemiologic analysis." Community Modeling and Analysis System Conference. Raleigh, North Carolina, October 2012.
  35. Hu X, Lyapustin A, Wang Y, Liu Y. "Estimating ground-level PM<sub>2.5</sub> concentrations in the Southeastern U.S. using MAIAC AOD retrievals." Oral presentation at the International Society for Exposure Science Annual Conference. Seattle, Washington, October 2012.
  36. Ivey C, Holmes H, Hu Y, Russell A, Mulholland J. "Extending the Hybrid Source Apportionment Method by Spatial Interpolation of Source Impact Adjustment Factors." Poster presentation at the 11<sup>th</sup> Annual Community Modeling and Analysis System Conference. Chapel Hill, North Carolina, October 2012.
  37. Ivey C, Holmes H, Hu Y, Russell A, Mulholland J. "Improving Particulate Matter Source Apportionment: A Hybrid Approach Utilizing Chemical Transport and Receptor Models with Geostatistical Methods." Poster presentation at the American Association of Aerosol Research Annual Meeting. Minneapolis, Minnesota, October 2012.
  38. Holmes HA, Maier ML, Friberg M, Balachandran S, Hu Y, Russell AG, Mulholland JA, Sarnat SE, Sarnat JA, Winquist A, Klein M, Tolbert PE. "Development of a Mixtures Characterization Toolkit to estimate air pollution source impacts for time series epidemiologic analysis to investigate air

quality and human health associations: Application to a High Biogenic and a High Industrial Emissions Areas.” Poster presentation at the 12<sup>th</sup> International Global Atmospheric Chemistry Open Science Conference. Beijing, China, September 2012.

39. Ivey C, Holmes H, Hu Y, Russell A, Mulholland J. “Hybrid Chemical Transport-Receptor-Geostatistical Modeling for Spatial and Temporal Source Impact Assessment in Health Studies.” Platform presentation at the 12<sup>th</sup> International Global Atmospheric Chemistry Open Science Conference. Beijing, China, September 2012.
40. Greenwald R, Li W, Flanders WD, Kewada P, Bergin M, Sarnat JA. “Acute lipid peroxidation in breath and traffic pollution among a panel of commuters in Atlanta.” Poster presentation at the International Society for Environmental Epidemiology Annual Conference. Columbia, South Carolina, August 2012.

**Future Activities:** Activities planned for the coming period are aimed at further refining the methods discussed above and to provide the various projects and collaboratives with final data products. In particular, as part of Project 1, we will continue to use our advanced source impact analysis tools to understand the spatiotemporal impacts of sources contributing to ROS, as estimated using both the DTT and AA methods. In particular, we will refine our application of the Bayesian SA technique in Atlanta, working with Project 4 personnel in the application of those results to health measures in Atlanta. Further, we will use the CMAQ-CMB, with HK to more fully use the ROS measurements (e.g., outside Atlanta, which was the only location we could apply the Bayesian SA approach due to data limitations). We continue to apply the CMAQ-CMB with HK method to more years. At present, those results are available for two full years. We plan to have about 10 years available. Also, we plan to develop methods to improve source profiles and the treatment of secondary aerosol formation impacts. Those results can be used directly in Projects 3 and 4.

As part of Project 3, we continue to explore methods to provide very fine scale exposure fields in the Atlanta area using a variety of products including CMAQ (with OBS fusion), AOD, RLINE and observations. As part of the “Inter-comparison of ambient PM<sub>2.5</sub> estimation models in NC” collaboration, we continue to intercompare and assess methods. We also will apply the IMSI technique to our results to get mobile source impacts over NC. We continue to work with CCAR as part of the “Mobile and Fixed Site Characterization of Vehicle Emission Impacts in Atlanta” collaborative. In particular, we are still conducting detailed RLINE modeling and will provide those results and expertise on interpreting their observations in Atlanta.

As we are approaching the end of SCAPE, a major activity will be to communicate our method advances for use by others. This will be done by finishing the various manuscripts and presentation of the results at conferences. We will also make results available for use by others.

**Supplemental Keywords:** Air Quality, Chemical Transport Modeling, Receptor Modeling, Exposure Measurement Error

**Relevant Web Sites:** [www.scape.gatech.edu](http://www.scape.gatech.edu)

**Date of Report:** July 31, 2015

**EPA Agreement Number:** R834799

**Center Name:** Southeastern Center for Air Pollution and Epidemiology

**Project Title:** Biostatistics Core (Core C)

**Investigator(s):** Co-PIs -- W. Dana Flanders, MD, ScD ([wflande@emory.edu](mailto:wflande@emory.edu)) and Lance Waller, PhD ([lwaller@sph.emory.edu](mailto:lwaller@sph.emory.edu)); Howard Chang, PhD ([howard.chang@emory.edu](mailto:howard.chang@emory.edu)); Mitchel Klein, PhD ([mklein@emory.edu](mailto:mklein@emory.edu))

**Institution(s) of PI(s):** Emory University

**Research Category:** Air Quality and Air Toxics

**Project Period:** 08/01/2013 – 7/31/2014

**Objective of Research:** The Biostatistics Core provides quantitative analytic support to all SCAPE Projects and Cores.

### **Progress Summary/Accomplishments:**

In the past year, members of the Biostatistics Core collaborated with SCAPE investigators on all Projects, Cores, and Collaborative Projects, with the majority of effort devoted to the epidemiologic analyses associated with Projects 3 and 4. Core members contributed to the development of novel quantitative methods to address analytic challenges in SCAPE projects including (but not limited to) expanded application of multivariate classification algorithms (e.g., classification and regression trees and self-organizing maps) to explore health effects of pollutant mixtures, statistical assessments of source apportionment, identification and evaluation of potential confounding effects, adjustments for effect modification, and identification of critical gestational exposure windows. Core efforts resulted in peer-reviewed literature in the environmental health, epidemiology, biostatistics, exposure science, and general science literature.

### **Publications:**

1. Alhanti BA, Chang HH, Winqvist A, Mulholland J, Darrow L, Sarnat SE. Ambient air pollution and emergency department visits for asthma: a multi-city assessment of effect modification by age. *Journal of Exposure Science and Environmental Epidemiology*, accepted. (Core C, Project 4)
2. Hao H, Chang HH, Holmes HA, Mulholland JA, Klein M, Darrow LA, Strickland MJ. Ambient air pollution and preterm birth in the U.S. state of Georgia. *Environmental Health Perspectives*, accepted. (Core B, Core C, Project 3)
3. Strickland MJ, Hao H, Hu X, Chang HH, Darrow LA, Liu Y. Pediatric emergency visits and short-term changes in PM<sub>2.5</sub> concentrations in the U.S. State of Georgia. *Environmental Health Perspectives*, accepted. (Core B, Core C, Project 3)
4. Chang HH, Warren JL, Darrow LA, Reich BJ, Waller LA. Assessment of critical exposure and outcome windows in time-to-event analysis with application to air pollution and preterm birth study. *Biostatistics* 16(3):509-521, 2015. (Core C, Project 3)
5. Gass K, Klein M, Sarnat SE, Winqvist A, Darrow LA, Flanders WD, Chang HH, Mulholland JA, Tolbert PE, Strickland MJ. Associations between ambient air pollutant mixtures and pediatric asthma emergency department visits in three cities: a classification and regression tree approach. *Environmental Health* 14:58, 2015. (Core B, Core C, Project 3, Project 4)
6. Gass KM, Balachandran S, Chang HH, Russell AG, Strickland MJ. Ensemble-based source apportionment of fine particulate matter and emergency department visits for pediatric asthma. *American Journal of Epidemiology* 181:504-512, 2015. (Core B, Core C, Project 3)

7. Pearce JL, Waller LA, Mulholland JA, Sarnat SE, Strickland MJ, Chang HH, Tolbert PE. Exploring associations between multipollutant day types and asthma morbidity: epidemiologic applications of self-organizing map ambient air quality classifications. *Environmental Health* 14:55, 2015. (Core B, Core C, Project 3, Project 4)
8. Winquist A, Schauer JJ, Turner J, Klein M, Sarnat SE. Impact of ambient fine particulate matter carbon measurement methods on observed associations with acute cardiorespiratory morbidity. *Journal of Exposure Science and Environmental Epidemiology*, 25:215-221, 2015. (Core C, Project 4)
9. Xu L, Guo H, Boyd CM, Klein M, Bougiatioti A, Cerully KM, Hite JR, Isaacman-VanWertz G, Kreisberg NM, Knote C, Olson K, Koss A, Goldstein AH, Hering SV, de Gouw J, Baumann K, Lee SH, Nenes A, Weber RJ, Ng NL. Effects of anthropogenic emissions on aerosol formation from isoprene and monoterpenes in the southeastern United States. *Proceedings of the National Academy of Sciences USA* 112(1):37-42, 2015 (Core B, Core C, Project 1)
10. Chang HH, Hao H, Sarnat SE. A statistical modeling framework for projecting future ambient ozone and its health impact due to climate change. *Atmospheric Environment* 89:290-297, 2014. (Core C, Project 4)
11. Chang HH, Hu X, Liu Y. Calibrating MODIS aerosol optical depth for predicting daily PM<sub>2.5</sub> concentrations via statistical downscaling. *Journal of Exposure Science and Environmental Epidemiology* 24:398-404, 2014. (Core B, Core C, Project 3).
12. Darrow LA, Klein M, Flanders WD, Mulholland JA, Tolbert PE, Strickland MJ. Air pollution and acute respiratory infections among children 0-4 years: an 18-year time-series study. *American Journal of Epidemiology* 180:968-77, 2014. (Project 3, Core B, Core C)
13. Dionisio KL, Baxter LK, Chang HH. An empirical assessment of exposure measurement error and effect attenuation in bipollutant epidemiologic models. *Environmental Health Perspectives* 122(11):1216-24, 2014. (Core C, Project 4)
14. Gass K, Klein M, Chang HH, Flanders WD, Strickland MJ. Classification and regression trees for epidemiologic research. *Environmental Health* 13:17, 2014. (Core C, Project 3, Project 4)
15. Hu X, Waller LA, Lyapustin A, Wang Y, Al-Hamdan MZ, Crosson WL, Estes MG, Estes SM, Quattrochi DA, Puttaswamy SJ, Liu Y. Estimating ground-level PM<sub>2.5</sub> concentrations in the Southeastern United States using MAIAC AOD retrievals and a two-stage model. *Remote Sensing of Environment* 140:220-232, 2014. (Core B, Core C, Project 3)
16. Hu X, Waller LA, Lyapustin A, Wang Y, Liu Y. 2014. 10-year spatial and temporal trends of PM<sub>2.5</sub> concentrations in the southeastern U.S. estimated using high-resolution satellite data. *Atmospheric Chemistry and Physics* 14:6301-6314. (Core B, Core C, Project 3).
17. Neelon B, Chang HH, Ling Q, Hastings NS. Flexible space-time hurdle models for zero-inflated count data: exploring spatiotemporal trends in emergency department visits. *Statistical Methods and Medical Research*, 2014, DOI: 10.1177/0962280214527079. (Core C)
18. Neelon B, Chang HH, Ling Q, Hastings NS. Spatiotemporal hurdle models for zero-inflated count data: Exploring trends in emergency department visits. *Statistical Methods in Medical Research*, 2014, DOI: 10.1177/0962280214527079. (Core C)
19. Pearce JL, Waller LA, Chang HH, Klein M, Mulholland JA, Sarnat JS, Sarnat SE, Strickland MJ, Tolbert PE. Using self-organizing maps to develop ambient air quality classifications for use in multipollutant health studies: a time-series example. *Environmental Health* 13:56, 2014. (Core C, Core B, Project 3, Project 4)
20. Reich BJ, Chang HH, Foley K. A spectral method for spatial downscaling. *Biometrics* 70:932-42, 2014. (Core C)
21. Reich BJ, Chang HH, Strickland MJ. Spatial health effects analysis with uncertain residential locations. *Statistical Methods in Medical Research* 23:156-68, 2014. (Core C, Project 3)

22. Sarnat JA, Golan R, Greenwald R, Raysoni AU, Kewada P, Winquist A, Sarnat SE, Flanders WD, Mirabelli MC, Zora JE, Bergin MH, Yip F. Exposure to Traffic Pollution, Acute Inflammation and Autonomic Response in a Panel of Car Commuters. *Environmental Research* 133:66-76, 2014. (Project 2, Core C)
23. Strickland MJ, Klein M, Flanders WD, Chang HH, Mulholland JA, Tolbert PE, Darrow LA. Modification of the effect of ambient air pollution on pediatric asthma emergency visits: susceptible subpopulations. *Epidemiology* 25(6):843-50, 2014. (Project 3, Core B, Core C)
24. Winquist A, Kirrane E, Klein M, Strickland M, Darrow LA, Sarnat SE, Gass K, Mulholland JA, Russell AG, Tolbert PE. Joint effects of ambient air pollutants on pediatric asthma emergency department visits in Atlanta, 1998-2004. *Epidemiology* 25:666-73, 2014. (Core B, Core C, Project 3, Project 4)
25. Hu X, Waller LA, Al-Hamdan MZ, Crosson WL, Estes MG, Estes SM, Quattrochi DA, Sarnat JA, Liu Y. Estimating ground-level PM2.5 concentrations in the southeastern U.S. using geographically weighted regression. *Environmental Research* 121:1-10, 2013. (Core B, Core C, Project 3)  
Inadvertently omitted SCAPE acknowledgement.
26. Sarnat JA, Sarnat SE, Chang H, Mulholland J, Özkaynak H, Isakov V. Spatiotemporally resolved air exchange rate as a modifier of acute air pollution-related morbidity. *Journal of Exposure Science and Environmental Epidemiology*, 23:606-615, 2013. (Core C, Project 2, Project 4)
27. Sarnat SE, Sarnat JA, Mulholland J, Isakov V, Özkaynak H, Chang H, Klein M, Tolbert PE. Application of alternative spatiotemporal metrics of ambient air pollution exposure in a time-series epidemiological study in Atlanta. *Journal of Exposure Science and Environmental Epidemiology*, 23:593-605, 2013. (Core C, Project 4)
28. Waller LA. Commentary: Regarding assessments of chance in investigations of 'cluster series'. *International Journal of Epidemiology* 42:449-452, 2013. (Core C, Project 3)
29. Flanders WD, Klein M, Darrow LA, Strickland MJ, Sarnat SE, Sarnat JA, Waller LA, Winquist A, Tolbert PE. A method to detect residual confounding in spatial and other observational studies. *Epidemiology* 22:823-826, 2011. (Core C, Project 3, Project 4)
30. Flanders WD, Klein M, Darrow LA, Strickland MJ, Sarnat SE, Sarnat JA, Waller LA, Winquist A, Tolbert PE. A method for detection of residual confounding in time-series and other observational studies. *Epidemiology* 22:59-67, 2011. (Core C, Project 3, Project 4)

#### **Presentations:**

1. Pearce JL, Waller LA, Mulholland JA, Sarnat SE, Strickland MJ, Chang HH, Tolbert PE. Acute associations between multipollutant mixtures and pediatric asthma morbidity: epidemiologic applications of self-organizing map ambient air quality classifications at the day level. Oral presentation at the International Society for Environmental Epidemiology Annual Meeting, Sao Paulo, Brazil, August 30-September 3, 2015.
2. Krall J, Mulholland JA, Russell AG, Balachandran S, Winquist A, Tolbert PE, Waller L, Sarnat SE. "Estimating associations between source-apportioned particulate matter and emergency department visits in multicity studies." Platform presentation at the Joint Statistical Meeting, Seattle, Washington, August 8-13, 2015.
3. Chang HH, Sarnat SE, Waller LA, Liu Y. "Application of satellite-derived PM2.5 estimates in time-series health analysis." Oral presentation at 142nd Annual Meeting and Exposition of the American Public Health Association. New Orleans, Louisiana, November 2014.
4. Alhanti B, Winquist A, Chang HH, Mulholland JA, Sarnat SE. "Ambient air pollution and emergency department visits for asthma: a multi-city assessment of effect modification by age." Oral presentation at International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.



5. Chang HH, Hao H, Sarnat SE. "A statistical modeling framework for projecting future ambient ozone and its health impact due to climate change." International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.
6. Chang HH, Warren JL, Darrow LA, Reich BJ, Waller LA. "Assessment of critical exposure and outcome windows for estimating associations between air pollution and preterm birth." Poster presentation at the International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.
7. Gass K, Strickland M, Klein M, Flanders D, Chang H. Classification and regression trees for epidemiologic research." International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.
8. Gass K, Klein M, Sarnat S, Flanders D, Chang H, Strickland M. A three-city analysis of multipollutant joint effects: a comparison of classification and regression trees with conventional multipollutant models. International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.
9. Hao H, Liu Y, Hu X, Chang HH, Darrow LA, Strickland MJ. "Satellite-Derived Estimates of Ambient Fine Particulate Matter and Pediatric Emergency Department visits in Georgia, 2002-2010: A case-crossover study." Poster presentation at International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.
10. Hao H, Chang H, Darrow L, Holmes H, Mulholland J, Strickland M. "Ambient air pollution and preterm birth: a time-to-event analysis in Georgia, 2002-2006." Poster presentation at International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.
11. O'Lenick C, Winquist A, Mullholland J, Friberg M, Chang HH, Kramer M, Sarnat SE. "An evaluation of neighborhood-level socioeconomic influences on air pollution-asthma associations in Atlanta." Poster presentation at International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.
12. Pearce JL, Waller LA, Sarnat SA, Strickland M, Klein M, Chang HH, Mulholland J, Tolbert PE. "A framework for exploring the temporal associations between air quality day types and pediatric asthma: a case study of Atlanta, Georgia." International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.
13. Strickland MJ, Klein M, Flanders WD, Chang HH, Mulholland JA, Tolbert PE, Darrow LA. "Modification of the effect of ambient air pollution on pediatric asthma emergency visits: susceptible subpopulations." International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.
14. Gass K, Klein M, Flanders WD, Chang H, Strickland M. "Classification and regression trees for epidemiologic research." Poster presentation at the Society for Epidemiologic Research Annual Meeting. Seattle, Washington, June 2014.
15. Pearce JL, Waller LA, Mulholland J, Tolbert PE. "Use of self-organizing maps to classify multipollutant exposure areas in an urban environment." Oral presentation at the Association of American Geographers Annual Meeting. Tampa, Florida, April 2014.
16. Chang HH, Liu Y, Sarnat SE. "Time series analysis of air pollution and health accounting for spatial exposure uncertainty." Oral presentation at the Joint Statistical Meeting. Montreal, Canada, August 2013.
17. Hu X, Waller L, Lyapustin A, Liu Y. "A Time Series Analysis of PM2.5 Concentrations in the Southeastern U.S. Using MAIAC AOD in a Two-stage Spatial Statistical Model." Oral presentation at the Joint Annual Conference of the International Society for Environmental Epidemiology and Exposure Science and Indoor Air Quality. Basel, Switzerland, August 2013.

18. Winquist A, Kirrane E, Klein M, Strickland M, Darrow L, Sarnat S, Gass K, Mulholland J, Russell A, Tolbert P. "Joint effects of air pollutants on pediatric asthma emergency department visits." Poster presentation at the Joint Annual Conference of the International Society for Environmental Epidemiology and Exposure Science and Indoor Air Quality. Basel, Switzerland, August 2013.
19. Pearce J. "Use of spatial profiles to characterize multi-pollutant exposure areas in an urban environment." Oral presentation at the URISA GIS in Public Health Conference. Miami, Florida, June 2013.
20. Chang HH, Liu Y, Sarnat S, Reich B. "Time series analysis of air pollution and health accounting for spatial exposure uncertainty." Oral presentation at International Biometric Society ENAR Meeting. Orlando, Florida, March 2013.
21. Waller, LA. "Spatial Uncertainty Estimation and Public Health Data." Oral presentation at the American Association for the Advancement of Science Annual Meeting. Boston, Massachusetts, February 2013.
22. Chang HH, Liu Y, Reich BJ, Miranda ML. "Spatial exposure uncertainties in air pollution and health studies." Oral presentation at Spatial Statistics Conference. Miami, Florida, December 2012.
23. Balachandran S, Chang H, Mulholland J, Russell A. "A Bayesian – Based Ensemble Technique for Source Apportionment of PM2.5." Platform presentation at the American Association of Aerosol Research Annual Meeting. Minneapolis, Minnesota, October 2012.
24. Holmes HA, Maier ML, Friberg M, Balachandran S, Hu Y, Russell AG, Mulholland JA, Sarnat SE, Sarnat JA, Winquist A, Klein M, Tolbert PE. "Development of a Mixtures Characterization Toolkit to estimate air pollution source impacts for time series epidemiologic analysis to investigate air quality and human health associations: Application to a High Biogenic and a High Industrial Emissions Areas." Poster presentation at the 12<sup>th</sup> International Global Atmospheric Chemistry Open Science Conference. Beijing, China, September 2012.
25. Darrow LA, Strickland MJ, Klein M, Tolbert PE. "Ambient air pollution and respiratory emergency department visits among children age 0-4 years." Oral presentation at the International Society for Environmental Epidemiology Annual Conference. Columbia, South Carolina, August 2012.
26. Gass K, Strickland MJ, Darrow LA, Klein M, Mulholland JA, Tolbert PE. "Short-Term Associations between Ambient Air Pollutants and Pediatric Asthma Emergency Visits and the Role of Seasonal Interaction." Poster presentation at the International Society for Environmental Epidemiology Annual Conference. Columbia, South Carolina, August 2012.
27. Pearce J. "Application of self-organizing maps to classify the spatiotemporal characteristics of multiple air pollutants." Oral presentation at the International Society for Environmental Epidemiology Annual Conference. Columbia, South Carolina, August 2012.
28. Waller LA. "Spatial uncertainty in regression associations" Oral presentation at the International Society for Environmental Epidemiology Annual Conference. Columbia, South Carolina, August 2012.
29. Waller L, Chang H, Pearce J, Sarnat S, Tolbert P. "Spatial uncertainty estimation and public health data: air pollution epidemiology in Atlanta, Georgia." Oral presentation at the Joint Statistical Meetings. San Diego, California, July 2012.
30. Flanders WD, Klein M, Darrow LA, Strickland MJ, Sarnat SE, Sarnat JA, Waller LA, Winquist A, Tolbert PE. "A method for detection of residual confounding in spatial and other observational studies." International Society of Environmental Epidemiology. Barcelona, Spain, September 2011.
31. Sarnat JA, Greenwald R, Sarnat SE, Kewada P, Yip F, Boehmer TK, Bergin MH. "In-vehicle pollutant exposures and acute cardiorespiratory response in a cohort of healthy and asthmatic

car commuters in the Atlanta Commuters' Exposure Study." International Society for Environmental Epidemiology Annual Meeting. Barcelona, Spain, September 2011.

32. Sarnat SE, Sarnat JA, Winquist A, Schauer JJ, Turner JR, Klein M, Tolbert PE. "Associations of source-resolved particulate air pollution mixtures and cardiorespiratory emergency department visits in St. Louis, MO-IL." International Society for Environmental Epidemiology Annual Meeting. Barcelona, Spain, September 2011.

**Future Activities:** Future plans for the Biostatistics Core build on current activities relating to development and application of accurate and reliable analytic methods for each SCAPE project

1. Project 1
  - a. Continue investigation into linkages between air quality measures and the epidemiologic studies in Projects 3 and 4.
1. Project 2
  - a. Collaboration on clustering algorithms for summarizing physiologic responses to scripted commutes.
  - b. Statistical support for graduate student research on this project.
2. Project 3
  - a. Providing statistical support for the continuing Georgia state-wide analysis of ambient air pollution and preterm birth.
  - b. Providing statistical support for the continuing Georgia state-wide analysis of PM2.5 and pediatric emergency department visit.
  - c. Conducting analysis on the association between PM2.5 and birth weight as part of the measurement error collaboration with CCAR.
  - d. Providing statistical support for exposure assessment in for PM2.5 (with Air Quality Core) and pediatric asthma incidence with the Kaiser cohort.
3. Project 4
  - a. Providing statistical support for examining effect modification of air pollution health risk by socio-economic factors, age, sex, and race.
  - b. Providing statistical support for estimating daily historical ROS activity (with Air Quality Core) and its health effects.

Results of these efforts will be submitted for publication in the peer-reviewed literature and presented at national and international conferences in public health, environmental health, biostatistics, and epidemiology.

**Supplemental Keywords:** Biostatistics, Data analysis, Study design, Confounder control

**Relevant Web Sites:** [www.scape.gatech.edu](http://www.scape.gatech.edu)