Annual Center Progress Report
Southeastern Center for Air Pollution and Epidemiology
Georgia Tech/Emory EPA Clean Air Research Center
August 1, 2012 – July 31, 2013

This Progress Report covers the work of the Southeastern Center for Air Pollution and Epidemiology (SCAPE) from August 1, 2012 – July 31, 2013. Four Research Projects are supported by three Cores: an Administrative Core, an Air Quality Core and a Biostatistics Core. 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. The third annual meeting for SCAPE's ten member Science Advisory Committee is scheduled for November 2013 in Atlanta. 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. Deployed DCFH-ROS online instrument based on a mist chamber collector for measuring ROS (total), ROS (gas) and particle-bound ROS by difference. Ambient data were analyzed and a paper was published describing the new instrument and ambient results (King et al., 2013).
2. Conducted Project 1 ambient sampling program with a suite of instrumentation at paired sites: Jefferson Street (JST) and a mobile site (trailer) rotated between rural, near road and roadside sites. Each paired measurement was for nominally one month sampling periods. Data are archived for use by other SCAPE investigators.
3. Developed two automated ROS analytical systems for high throughput analysis of extracts from high volume and EPA CAPs filters via DTT assay. Analysis protocol included water and methanol extracts for investigating secondary and primary species, followed by each solvent extract being further divided into hydrophilic and hydrophobic (HULIS) fractions for DTT analysis.
4. Extracted and analyzed DTT activity of over 170 Project 1 high volume filters following the protocol of (3).
5. Analyzed DTT activity of EPA CAPS filters from two CAPS experiments as part of a collaborative study with Bob Devlin to investigate possible links between DTT activity and health endpoints.
6. Analyzed DTT activity of Project 2 in-vehicle filters.
7. Developed GC-MS method and began analysis of high volume filters for PAHs and quinones.
8. Contributed to preliminary work on developing a cyto-toxicity assay in collaboration with Emory researchers (Jeremy Sarnat and Michael Caudle) for comparison of DTT activity to a cellular assay.

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. As of July 5, 2013, 100 (of 120 total) sampling sessions were completed. Review of the health and pollutant measurements indicate satisfactory data capture and completeness.
2. Several manuscripts from the pilot Atlanta Commuters Exposure Study (ACE-1) are currently in preparation.

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. Kaiser Permanente historical birth cohort construction is ongoing and will be finalized later in 2013. Based on preliminary descriptive statistics, there appears to be high sensitivity to correctly identify children with asthma.
2. Characterized air quality throughout Georgia, including through:
    a. development of a method for fusing CMAQ model output with measurements from stationary monitors,
    b. estimates of biomass burning events using high resolution remote sensing data from multiple NASA satellites, and
    c. development of methods to calculate downscaled CMAQ estimates at 250 meter grids over longer time-periods using land use information in support of the Kaiser Permanente birth cohort study.
3. Continued work on measurement error with a publication on the effects of error on health effect estimates in time-series studies (Strickland et al., 2013).
4. Worked on manuscripts and analyses of the substantive associations between air pollutants and pediatric morbidity (including potential effect measure modification by gestational age), which are at various points of development; selected results of this work were shared during the May 2013 CLARC webinar and the July 2013 CLARC 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. Conducted database development, including: calculation of daily population-weighted averages of multiple pollutants by fusion of monitoring and CMAQ modeled data, health outcome data processing for Birmingham and Pittsburg, and a geodatabase for the project.
2. Evaluated metrics for characterizing socioeconomic status at the ZIP code level among the five study areas.
3. Examined study design issues for comparing epidemiologic results among the five cities (e.g., temporal and spatial extent of available data) and progression of analyses.

4. Conducted single-city epidemiological analyses for Atlanta, Dallas, and St. Louis. Methodological work resulted in two publications (Winquist et al., 2012a; Winquist et al., 2012b).
5. Continued efforts on application of spatially-refined modeled estimates of ambient concentrations and population exposures in Atlanta epidemiologic analyses, with several articles in press (Sarnat S et al., 2013; Sarnat J et al., 2013) and in review (Dionisio et al., submitted; Baxter et al., submitted); several conference presentations were made (Dionisio et al., ISES 2012; Chang et al., ENAR 2013) and are planned (Ozkaynak et al., ISEE 2013; Sarnat J et al., ISEE 2013; Klein et al., ISEE 2013; Chang et al., JSM 2013).
6. Continued work on applying $PM_{2.5}$ components data (Winquist et al., ISEE 2013) and $PM_{2.5}$ source apportionment outputs (Sarnat et al., ISEE 2013) to epidemiologic analyses in St. Louis, comparing results among multiple source apportionment approaches (Maier et al., 2013).
7. Continued work on methods for detecting and analyzing air pollution mixtures using multi-pollutant monitoring data, including mobile source indicators (Pachon et al., 2012), self-organizing maps, classification and regression trees (C&RT) (Gass et al., ISEE 2013), and multi-pollutant joint effects (Winquist et al., ISEE 2013). C&RT analyses are currently being extended to the multi-city context (Atlanta, Dallas, St. Louis).
8. Developed a statistical modeling approach to quantifying projection uncertainties in future ambient ozone levels and its health impact due to climate change (manuscript in preparation).

Air Quality Core

Objective: Provide Center researchers the information and methods to comprehensively characterize air pollutant mixtures relevant to their Projects and to support Project activities by collecting and managing 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 MC Toolkit components.

Research Conducted and Results Generated:

1. Applied various receptor modeling approaches (CMB-based, PMF, ensemble) to Atlanta, Dallas and St. Louis (Maier et al., 2013)
2. The ensemble approach was used to characterize uncertainty in the various methods used in source apportionment analyses using Atlanta SEARCH site data (Balachandran et al., 2013).
3. A new Bayesian receptor modeling approach was developed that extends the ensemble modeling approach, and was applied to the Atlanta data sets (Balachandran et al., submitted).
4. Results from the various source apportionment methods were analyzed to better understand their temporal variability and how the application of the receptor methods can alter temporal variability as compared to the base air quality data.
5. In support of Project 3, a significant amount of work has focused on developing spatiotemproal fields of air quality and source impact metrics.
6. In support of Project 3, a new aerosol product with 1 km spatial resolution derived by the Multi-Angle Implementation of Atmospheric Correction (MAIAC) algorithm was examined using a two-stage spatial statistical model with meteorological fields and land use parameters as ancillary variables to estimate daily mean $PM_{2.5}$ concentrations. Both model fitting and cross validation indicate a good fit between the dependent variable and predictor variables.

Biostatistics Core

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

Research Conducted and Results Generated:

1. Began analysis of state-wide association between gestational exposure to PM2.5 and preterm birth. An approach to identify susceptible windows of exposure for preterm birth has been developed and a manuscript is currently under review (Chang et al., submitted 2013b).
2. Evaluated the use of satellite-derived PM2.5 estimates in a time-series analysis of emergency department visits in Atlanta (Chang et al., ENAR 2013).
3. Explored self-organizing map (SOM) and classification and regression tree (C&RT) methods for assessing the health effect of air pollution mixtures observed in Atlanta, St. Louis, and Dallas (Gass et al., submitted; Pearce et al., submitted).
4. Continued work on methods for the identification of model mis-specification, particularly due to confounding.

2. Difficulties in Carrying out Mission of Center

During this third reporting period, the work of the Center has progressed as planned without any major difficulties in carrying out the proposed mission.

3. Absences or Changes in Key Personnel

Key personnel on all Projects and Cores have remained the same since the initial grant funding. There have been minor changes in study staff as described by project below.

Project 1 added two personnel. Ting Fang (PhD student) replaced Neel Kotra (graduated with MS degree) and Dr. Ying Wang (Georgia Tech Research Scientist) is contributing to Project 1 at no cost to the Center (funded with non-sponsored funds through the Georgia Tech School of Earth and Atmospheric Sciences).

At Emory, Project 2 added Rachel Golan, a postdoctoral researcher, and Chandresh Ladva, a PhD student, to the study staff. Amit Raysoni completed his postdoctoral position at Emory and is no longer part of the Project 2 study staff.

Project 3 added Audrey Flak, a PhD student in Epidemiology at Emory who will work on the Kaiser Permanente birth cohort study as part of her dissertation. At Georgia Tech, Sheila Sororian graduated with an MS degree and is no longer working on Project 3 spatial modeling.

4. Quality Assurance

SCAPE's Quality Management Plan (QMP) was submitted to and approved by EPA in March 2011. No changes were to the QMP during the 2013 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 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. Audits for Project 3 and Project 4 were conducted in February 2012, and the audit for Project 1 was completed in August 2012. The Project 2 audit is scheduled for summer 2013. 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. Finally, the Quality Assurance Manager works with the Quality Control Reviewers to maintain updated IRB approvals and inform the Project Officer of any amendments.

5. Planned Future Activities

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

1. Complete field measurement phase.
2. Finish DTT analysis on high volume filters
3. Develop method for analysis of water soluble metals from high volume filter extracts.
4. Develop acellular method based on ascorbate depletion for analysis of a select fraction of high volume filters.
5. Continue collaborations with EPA (Bob Devlin) for analysis of CAPS and possibly to provide filter extracts for EPA ROS analysis with various probes.
6. Continue collaborations with Emory University in development of a cellular assay and analysis of Project 1 filters.
7. Quantify quinones, PAHs and organic tracers in a subset of Project 1 filters.
8. Analyze data and publish results.

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

1. Expect seven ACE-1 manuscripts to be submitted during the upcoming reporting period.
2. Field data collection will continue through fall 2013 for ACE-2, with a target end date for sampling of September 30, 2013.
3. Many of the data parameters have been processed and will be ready for data analysis shortly after sampling ends. Chemical analyses of PM organic and elemental species, blood biomarker analyses and heart rate variability data processing will likely continue through December 2013.
4. Finalize epidemiologic model specification, with initial exposure and health effects modeling commencing in 2014.

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

1. Continue to construct the Kaiser Permanente birth cohort and start epidemiological analyses in early 2014.
2. Develop manuscripts on analyses of associations between air pollution and pediatric respiratory morbidity in Atlanta, and air pollution and preterm delivery in the state-wide cohort.
3. Begin epidemiologic analyses using the source apportionment estimates.

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

1. Complete database management activities.
2. Submit five manuscripts currently in preparation.
3. Continue multi-city C&RT analysis.
4. Initiate analyses focused on effect modification in single- and multi-city context.

Air Quality Core

1. Continue collection of relevant air quality-related data (e.g., emissions data).
2. Continue application of the various source apportionment approaches.
3. Further application of the spatiotemporal extension of the hybrid CTM-CMB approach.
4. Develop spatial PM fields using high resolution AOD data fused with CTM model fields.

Biostatistics Core

1. Continue to support the Air Quality Core on developing and evaluating air quality products for use in health analyses.
2. Continue collaborations on the design and analysis of exposure measurements (Projects 1 and 2) and health effect studies (Projects 3 and 4).
3. Extend classification and regression tree (C&RT) and self-organizing map (SOM) techniques for characterizing air pollution mixtures.

6. 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 (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 Harvard researchers are in the process of integrating their data with Georgia Tech's measurements made during this study, and analysis is in the early stages. In general, it was found that the ACSM and SMPS (and integrated measurements) had reasonable agreement for the SOA and P+SOA atmospheres, though better for the SOA. Both continuous instruments showed the same trends over time, appearing to track together, and we expect that they will be found to be reasonably well correlated.

For the primary particles (P) system, the loading measured by ACSM and filters are both lower than SMPS mass loadings. This could potentially arise from uncertainties in the density (1.5 ug/m^3) used in converting SMPS volume to mass as the P system contains elemental carbon and the fractal dimension needs to be taken into account in this conversion. We are continuing to discuss and interpret these findings.

<u>Collaborative Project 2:</u> Mobile and Fixed Site Characterization of Vehicle Emission Impacts in Atlanta (Collaborators: SCAPE, CCAR, and EPA)

The goal of this collaborative project is 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. Both the Atlanta-based SCAPE and Washington/Washington State CCAR EPA Centers are investigating emissions and spatial distributions of mobile sources of urban traffic, with each center using a distinct approach. The field work for the project is planned for September 4-20, 2013. Results will be presented at the CLARC meeting the following summer and subsequently at various professional society venues.

Three specific objectives are addressed. First, simultaneous in-vehicle (SCAPE) and out-of-vehicle (CCAR) mobile platform measurements will address effects of vehicle infiltration on exposure. The SCAPE and CCAR vehicles will travel in tandem on routes specified to support objectives two and/or three. Second, intensive mobile platform measurements (CCAR) coupled with stationary site measurements using passive badges (CCAR) and ambient monitor station data (SCAPE, SEARCH, EPA) will be used to characterize local-scale gradients at selected locations. Possible areas include the I-75/I-85 connector at the Georgia Tech roadside (RS) monitor to the SEARCH central Atlanta monitor at Jefferson St (JST) and including a railyard near JST, spaghetti junction (I-85/I-285N intersection), and I-285E at the South Dekalb CSN monitor. At each location, approximately 7 passive badges will be deployed. Multiple loops will be conducted on 3 or 4 days for each characterization. Results will be used to refine methods for downscaling CMAQ data to a 250 meter scale, coupled with detailed roadway emissions and land use terms. Third, urban-to-rural regional gradients will be characterized for comparison with spatial fields from fused ambient monitor and CMAQ data. Two routes have been designed for this purpose – one from the Atlanta central site JST monitor to the rural site monitor at Yorkville (approximately 45 miles to west), and the second from JST to Conyers monitor (approximately 30 miles east).

Discussions are on-going as to the feasibility of having one or more EPA Chemvol samplers deployed during this period at the JST, GT or roadside sites (sampling site to be determined based on electrical service) for collection of ultrafine, fine and coarse particles for detailed chemical analysis and possible distribution to other studies for toxicity testing.

<u>Collaborative Project 3:</u> 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) Schwartz group's multi-level model, (3) Chang's spatial downscaler,(4) Liu group's mixed effects model, (5) UW/CCAR group's spatiotemporal model, and (6) Russell group's CMAQ PM2.5 simulation. We propose to design a modeling domain centered in North Carolina for the 2006 – 2008 time period.

To facilitate model cross-comparison, a common input dataset will be compiled by Liu group and distributed to all participating research teams. A common master modeling grid at 3-km resolution will also be 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 July 2013, The Emory team has downloaded the MODIS collection 6 data at 3 km and 10 km resolution over North Carolina for the proposed study period through a collaboration with NASA's Goddard Space Flight Center. Computer codes are being developed to extract and format various AOD parameters and their QA flags. Preliminary data analysis is being done to evaluate the consistency and quality of various AOD parameters in this new product.

<u>Collaborative Project 4:</u> 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)

Objectives: 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.

2013 Progress Summary: We have compiled datasets on air quality, land use, meteorology, and Georgia birth records for the period 2001 to 2005. Preliminary analysis was conducted to assess data quality and linkage. An analytic plan on exposure assessment and health effect modeling was then developed with inputs from all collaborating centers. We have started PM2.5 exposure estimation using a spatio-temporal statistical model developed by the UW collaborators for the MESA Air study. We are also evaluating the utility of meteorological variables and remotely-sensed aerosol optical depth as additional predictors in the model. We expect to complete exposure modeling this fall and begin applying measurement error approaches to the birth weight analysis in 2014. The collaboration fund has begun supporting this project on June 1st, 2013. Harvard may participate in this collaboration in the future.

Date of Report: July 31, 2013
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
Investigator(s): PI -- Rodney Weber, PhD[1] (rweber@eas.gatech.edu); Michael Bergin, PhD[1] (mike.bergin@ce.gatech.edu); James Mulholland, PhD[1] (james.mulholland@ce.gatech.edu); Athanasios Nenes, PhD[2] (nenes@eas.gatech.edu); Jeremy Sarnat, ScD[2] (jsarnat@emory.edu); Stefanie Sarnat, ScD[2] (sebelt@sph.emory.edu); Matthew Strickland, PhD[2] (mjstric@emory.edu)
Institution(s) of PI(s): [1]Georgia Institute of Technology and [2]Emory University, Atlanta, Georgia
Research Category: Air Quality and Air Toxics
Project Period: 08/01/2012 – 7/31/2013

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 the ability of aerosols to catalyze the production of ROS through interactions with antioxidants. These techniques will be deployed during SCAPE to provide a data set for investigating ROS sources and atmospheric processing.

Progress Summary/Accomplishments:

1. ***Deployment of a particle-bound ROS system and publication of method and results:*** In the past year, the MC-DCFH instrument was deployed as part of a suite of instruments for Project 1 field sampling (discussed next). The data were analyzed and a paper describing the method and results was published (King et al., 2013).
2. ***Project 1 Ambient Sampling Program:*** A main goal of Project 1 was to provide detailed aerosol chemical characterization over different seasons at paired sampling sites: a fixed site (JST) and a mobile site. Both sites included a suite of identical instrumentation. Table 1 summarizes the field deployments completed. Each paired study involved roughly one month of intensive sampling with both online and offline (filter) instrumentation. Periodically, the mobile site was stationed at the fixed site (JST/JST) for instrument intercomparisons. The data generated have gone through initial QC and are available to other SCAPE investigators through an FTP site.

Table 1: Project 1 Sampling Schedule and DTT Analysis.

Locations	Sampling Date	DTT Analysis
JST/JST	May 2012	No
YRK/JST	Jun/July 2012	Yes
GT/JST	Aug. 2012	Partial
RS/JST	Sept 2012	Yes
JST/JST	Nov 2012	No
YRK/JST	Dec/Jan 2013	Yes
RS/JST	Feb 2013	Yes
GT/JST	Mar 2013	No
JST/JST	April 2013	No
Birm. AL	Jun/July 2013	No

JST: Jefferson Street, a SEARCH central urban site
YRK: Yorkville, a SEARCH rural site
GT: Georgia Tech, urban near-road site
RS: Roadside, an urban site adjacent to Interstate 75/85.
Birm. AL: SEARCH urban site in Birmingham AL, (trailer only).

3. ***Development of an Automated ROS-DTT Assay Analytical System for High Volume & EPA CAPS Filter Extract Analysis:*** Two automated analytical systems capable of unattended operation were developed for quantifying ROS via the acellular dithiothreitol (DTT) assay. One system was designed for analysis of the more concentrated Project 1 high volume filter extracts and is capable of running 14 samples autonomously. The second system was developed and constructed for analysis of the lower concentration extracts from EPA (CAPS filters), as part of a collaboration with Bob Devlin, and can run eight filters autonomously. Each system requires roughly one hour per sample. These new instruments allow for the analysis of many more filters than what was previously possible manually.
4. ***ROS-DTT Analysis of Project 1 Filters:*** In the past year, significant effort has focused on analysis of the high volume filters collected at the site. Table 1 identifies sites where DTT analysis has been completed. The automated system discussed in (3) allows for extensive analysis and we have used it to investigate the DTT activity of various chemical fractions of ambient aerosols. Our filter extraction and analysis procedure involves:
    i. Extraction in water with DTT analysis for water soluble DTT.
    ii. A portion of the water extract is passed through a C18 SPE column and the DTT activity of the pass-through fraction is determined (i.e., hydrophilic DTT). The difference between the water soluble DTT and hydrophilic DTT is the hydrophobic DTT activity (or HULIS DTT activity).
    iii. After the water extraction, the remaining portion of the filter is extracted in methanol to obtain the DTT activity of insoluble (primary) aerosol species.
    iv. Hydrophilic and hydrophobic DTT activity is determined for the methanol extract.

    Thus, for each high volume filter, four (4) DTT analyses are done. To date DTT activity on roughly 170 filters has been quantified. The data are now being combined with the other chemical data collected at these sites to analyze sources and processes contributing to the ROS activity of ambient PM2.5 particles.
5. ***ROS-DTT analysis of EPA CAPS Filters:*** As part of a collaborative study with Bob Devlin, the automated DTT system was used to analyze CAPS filters from two studies. A similar analysis to what was described above (without hydrophilic/hydrophobic analysis on methanol extract) has been completed on roughly 50 EPA filters. The data have been delivered to Bob Devlin and data analysis is in progress.

Minor Areas of Work:

1. ***ROS-DTT Analysis of Project 2 In-Vehicle Filters:*** ROS analysis with the DTT probe has also been completed on a number of Project 2 filters. Because these filters contain significantly less mass than the high volume or EPA CAPS filters, the DTT analysis has been done by hand. These data have been provided to Project 2.
2. ***GC-MS Method Development and Filter Analysis: Organic Tracers, PAHs and Quinones:*** Methods have been developed for quantification of a group of PAHs and quinones, in addition to a suite of organic tracer species. Analysis of PAHs and quinones on filters is proceeding. Also, methods were explored for various solvent extractions of the hydrophobic components (e.g., HULIS) from the C18 column for both water and methanol samples. The extracts will be chemically characterized via GC-MS and DTT assay.
3. ***Provided Samples for Cellular Assays:*** With the goal to compare acellular assays of ROS to cellular assays, filter samples were collected and extracted at appropriate concentrations for preliminary testing of a cyto-toxicity assay in collaboration with Project 2 PI, Jeremy Sarnat, and Investigator Michael Caudle, who is supported by non-sponsored Emory departmental funds.

Publications:

1. **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'-dichlorofluorescin (DCFH) assay. *Atmospheric Measurement Techniques* 6:1647-1658, 2013. (Project 1)**
2. **Liu J, Bergin M, Guo H, King L, Kotra N, Edgerton E, Weber RJ. Size-resolved measurements of brown carbon and estimates of their contribution to ambient fine particle light absorption based on water and methanol extracts. In review at *Atmospheric Chemistry and Physics Discussions*, July 2013. (Project 1)**
3. 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)
4. 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). Submitted. (Project 1)

Presentations:

1. **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.**
2. **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.**
3. **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.**
4. 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.
5. 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.
6. 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.
7. 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.
8. 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.

9. 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:

1. Finish field measurements in the next few months, including deployments in St. Louis and at the RS site for the CCAR collaborative study.
2. Finish DTT analysis on all Project 1 high volume filters and EPA CAPS filters.
3. Develop a method for analysis of water soluble metals and use this system to analyze Project 1 high volume filters for soluble metals in water extracts and the hydrophilic/hydrophobic portions of water extracts. This method will use an online metals instrument (Xact) based on XRF detection borrowed from the U of Massachusetts, Amherst.
4. Develop an acellular method sensitive to metals. Previous studies show ROS is primarily associated with organic species and redox-active metals. The DTT assay is mainly sensitive to organics, and the ascorbate depletion assay has been found to be most sensitive to metals. Thus, by employing these two methods we hope to establish a comprehensive method for quantifying the ROS activity of all components in ambient particles. The ascorbate assay data will also be compared to the soluble metals results.
5. Continue collaborations with EPA (Bob Devlin) for analysis of additional CAPS and possibly to provide filter extracts for EPA ROS analysis with other probes. Preliminary results suggest that different DTT assay fractions appear to be associated with different groups of biological endpoints, and that the DTT assay was at least as predictive of biological changes as PM mass or particle number.
6. Continue collaborations with Project 2 and Emory researchers in the development, and possibly analysis, of a selective group of Project 1 high volume filters using a cellular assay to provide contrast to the extensive acellular assays ROS data generated as part of this project.
7. Further analyze filters for quinones for a correlation analysis with the DTT data. Also, develop methods for chemical speciation of various organic fractions isolated by the C18 SPE method.
8. Data analysis and publication: More detailed papers are planned for the next year focusing on the DTT results.

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

Relevant Web Sites: www.scape.gatech.edu

Date of Report: July 31, 2013
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
Investigator(s): Jeremy Sarnat, ScD[1] (jsarnat@emory.edu); Michael Bergin, PhD[2] mike.bergin@ce.gatech.edu); W. Dana Flanders, MD, ScD[1] (wflande@emory.edu); Lou Ann Brown, PhD[1] (lbrow03@emory.edu); Andrea Winquist, PhD[1] (awinqui@emory.edu); Anne Fitzpatrick, PhD[1] (amentro@emory.edu); Roby Greenwald, PhD[1] (roby.greenwald@emory.edu); Randy Guensler, PhD[2] (randy.guensler@ce.gatech.edu); Cherry Wongtrakool, MD[1] (cwongtr@emory.edu); David Diaz-Sanchez, PhD[3] (diaz-sanchez.david@epa.gov)
Institution(s) of PI(s): [1]Emory University and [2]Georgia Institute of Technology, Atlanta, Georgia; [3]Environmental Protection Agency
Research Category: Air Quality and Air Toxics
Project Period: 08/01/2012 – 7/31/2013

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 (μE'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. ***Data collection*.** As of July 5, 2013, 100 (of 120 total) sampling sessions have been completed for Project 2. We anticipate completion of the data collection portion of this study by fall 2013. To date, every subject has successfully completed the entire two-day study protocol. Of the 100 sampling sessions, 50 have been highway commutes, 23 surface street commutes, and 27 clinics; with each subject completing a highway commute and randomly assigned either a clinic or surface street μE. Review of the health and pollutant measurements indicate satisfactory data capture and completeness. For all the measured parameters, data have been collected above the designated 90% data capture objective.
2. ***Manuscript preparation of results from Pilot Study.*** Several manuscripts from the pilot Atlanta Commuters Exposure Study (ACE-1) are currently in preparation. By September 2013, we expect the first three manuscripts to be submitted for peer review. The first of these papers (Ladva et al.) examines correlations between in-vehicle pollutant concentrations and corresponding noise levels with the goal of examining the potential of noise to serve as a confounder of traffic pollution health effects. A second paper (Greenwald et al.) summarizes our method for characterizing commuter exposures and presents results on speciated particulate matter concentrations. This paper also presents a novel method for identifying pollutant exposure events during commuting. Finally, a third paper (Sarnat et al.) presents initial epidemiologic results from ACE-1. Among the key findings from this analysis, we observed significant ($p < 0.0001$) increases in exhaled nitric oxide (eNO) (Figure 1a) and decreases in SDNN, a measure of heart rate variability, at three post-commute time periods (Figure 1b). Presentations on the results from each of these papers will be given at the Joint Annual Conference of the International Society for Environmental Epidemiology and Exposure Science and Indoor Air Quality in August.

Publications:

1. **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)**
2. 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:

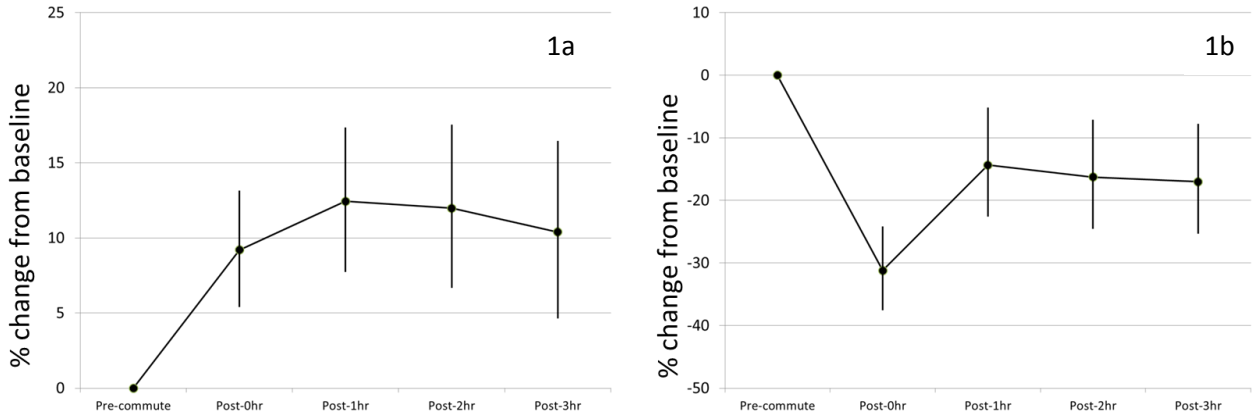
1. **Greenwald R, Kewada P, Yip F, Sarnat J. "Exposure during short-lived air pollution events is more predictive of airway oxidative stress than mean concentration." Poster presentation at the Joint Annual Conference of the International Society for Environmental Epidemiology and Exposure Science and Indoor Air Quality. Basel, Switzerland, August 2013.**
2. **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.**
3. **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.**
4. **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.**
5. 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.
6. 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.
7. 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.
8. 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 upcoming year, Project 2 staff will work on completing manuscripts from ACE-1. We expect seven ACE-1 manuscripts to be submitted during the upcoming reporting period. Field data collection will continue through fall 2013 for ACE-2, with a target end date for sampling of September 30, 2013. Many of the data parameters have been processed and will be ready for data analysis shortly after sampling ends. Chemical analyses of PM organic and elemental species, blood biomarker analyses and heart rate variability data processing will likely continue through December

2013. Finalizing epidemiologic model specification and initial exposure and health effects modeling will commence in 2014.

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



Figures 1a-b. Percent change from baseline in exhaled nitric oxide (1a) and SDNN (1b) immediately following (Post-0hr) a scripted 2 hr commute and at 1hr, 2hr and 3hr post-commute time points. N = 70 commutes for both.

Date of Report: July 31, 2013
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
Investigator(s): PI -- Matthew Strickland, PhD[1] (mjstric@emory.edu); Lyndsey Darrow, PhD[1] (ldarrow@emory.edu); Mitchel Klein, PhD[1] (mklein@emory.edu); Yang Liu, PhD[1] (yang.liu@emory.edu); Lance Waller, PhD[1] (lwaller@sph.emory.edu); Howard Chang, PhD[1] (howard.chang@emory.edu); Randy Guensler, PhD[2] (randy.guensler@ce.gatech.edu); James Mulholland, PhD[2] (james.mulholland@ce.gatech.edu); Armistead Russell, PhD[2] (ted.russell@ce.gatech.edu); Robert Davis, MD[3] (robert.l.davis@kp.org)
Institution(s) of PI(s): [1]Emory University and [2]Georgia Institute of Technology, Atlanta, Georgia (Collaborating Institution: [3]Kaiser Permanente-Georgia, Atlanta, Georgia)
Research Category: Air Quality and Air Toxics
Project Period: 08/01/2011 – 7/31/2012

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 1,705,130 individual-level birth records from 1994-2006 for Georgia. We have 8,252,996 individual-level emergency department visits among children age 0-18 years during 2002-2010 for Georgia and we have 2,458,950 individual-level hospital records for children age 0-18 years during 1999-2010 for Georgia.

Construction of the Kaiser Permanente historical birth cohort is ongoing and will be finalized later in 2013. There are 24,607 children in the cohort. Among these children, 6,287 have 1+ clinical encounter with an ICD-9 code for asthma and 4,382 that have 2+ encounters with an ICD-9 code for asthma. In addition to ICD-9 codes we have information regarding medication dispensings. Among children with an ICD-9 code for asthma, 6,029 (95.5%) have at least one asthma-related medication. Based on these preliminary descriptive statistics it appears we will have high sensitivity to correctly identify children with asthma. We have also requested information regarding allergy test results to explore the possibility of stratifying cases into atopic vs. non-atopic asthma, although those data are pending.

Good progress is being made on characterizing air quality throughout Georgia. A method for fusing CMAQ model output with measurements from stationary monitors has been developed and is

undergoing model evaluation. One manuscript describing the estimation of PM2.5 from satellite remote sensing data has been published (Hu et al., 2012) and two more are under review (Chang et al., submitted 2013a; Hu et al., submitted). Work to estimate biomass burning events using high resolution remote sensing data from multiple NASA satellites is ongoing. Two manuscripts describing the source apportionment of PM2.5 have been published (Balachandran et al., 2012; Maier et al., 2012) and a third is under review (Balachandran et al., submitted). Methods to calculate downscaled CMAQ estimates at 250 meter grids over longer time-periods using land use information in support of the Kaiser Permanente birth cohort study are ongoing.

An epidemiological methods paper on the use of classification and regression trees to estimate joint effects of pollutant mixtures is under review (Gass et al., submitted), as is a methodological paper on time-to-event regression for the identification of susceptible periods of fetal development for the impact of air pollution on gestational age (Chang et al., submitted 2013b)**.** Continuing with our measurement error work from the previous year is a publication on the effects of error on health effect estimates in time-series studies (Strickland et al., 2013), and we are continuing to investigate the potential uses of the future variable indicator (Flanders et al., 2011) in our work. Manuscripts and analyses of the substantive associations between air pollutants and pediatric morbidity (including potential effect measure modification by gestational age) are ongoing and at various points of development; selected results of this work were shared during the May 2013 CLARC webinar and the July 2013 CLARC annual meeting.

Publications:

1. **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.**
2. **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,* doi:10.1038/jes.2013.16. (Project 3).**
3. **Waller LA. Commentary: Regarding assessments of chance in investigations of `cluster series'. *International Journal of Epidemiology* 42:449-452, 2013. (Core C, Project 3)**
4. **Balachandran S, Chang HH, Pachon JE, Holmes HA, Mulholland JA, Russell AG. A Bayesian-based ensemble technique for source apportionment of PM2.5. Submitted. (Core B, Project 3)**
5. Chang HH, Hu X, Liu Y. Calibrating MODIS aerosol optical depth for predicting daily PM2.5 concentrations via statistical downscaling. Submitted 2013a. (Core B, Core C, Project 3)
6. **Chang HH, Warren JL, Darrow LA, Reich BJ, Waller LA. A distributed exposure time-to-event model for estimating associations between air pollution and preterm birth. Submitted, 2013b. (Core C, Project 3)**
7. **Gass K, Klein M, Chang HH, Flanders WD, Strickland MJ. Classification and regression trees for epidemiologic research. Submitted. (Core C, Project 3, Project 4).**
8. 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 PM2.5 Concentrations in the Southeastern United States Using MAIAC AOD Retrievals and a Two-Stage Model. Submitted. (Core B, Core C, Project 3)
9. **Pearce JL, Waller LA, Klein M, Mulholland J, Sarnat J, Sarnat SE, Tolbert P. Profiling environmental mixtures with self-organizing maps: potential for epidemiological research. Submitted. (Core C, Project 3, Project 4)**

10. 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)
11. 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)
12. 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.
13. Reich BJ, Chang HH, Strickland MJ. Spatial health effects analysis with uncertain residential locations. *Statistical Methods in Medical Research*, 2012, DOI: 10.1177/0962280212447151. (Core C, Project 3)
14. 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)
15. 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)
16. 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)
17. 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. **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.**
2. **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.**
3. **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.**
4. **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.**

5. **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.**
6. **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.**
7. **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.**
8. **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.**
9. **Darrow L. "Ambient air pollution and respiratory emergency department visits among children 0-4 years." Oral presentation at the 13th International Congress on Combustion By-Products and Their Health Effects. Baton Rouge, Louisiana, May 2013.**
10. **Liu Y. "Estimating Ground-Level PM2.5 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.**
11. 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.
12. **Hu X, Lyapustin A, Wang Y, Liu Y. "Estimating ground-level PM2.5 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.**
13. 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.
14. 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.
15. 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*:* The subcontract with Kaiser Permanente is now in place and creation of the historical birth cohort is underway. We will continue to construct the cohort during the next project year and we will hopefully be able to start epidemiological analyses in early 2014. Analyses of associations between air pollution and pediatric respiratory morbidity in Atlanta are wrapping up, as are analyses of air pollution and preterm delivery in the state-wide cohort, and manuscripts based on this work will be developed. Epidemiologic analyses utilizing the source apportionment estimates are slated to begin

later in 2013. Model evaluation of the CMAQ-fused estimates should be completed in the next year, and development of the downscaled CMAQ estimates will begin later in 2013.

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, PM2.5, organics, elemental carbon, metals, ozone, oxidants, PAH, sulfates, source characterization, mobile sources, Georgia, GA, Southeast

Relevant Web Sites: www.scape.gatech.edu

Date of Report: July 31, 2013
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
Investigator(s): PI -- Stefanie Sarnat, ScD[1] (sebelt@sph.emory.edu); Howard Chang (howard.chang@emory.edu); Lyndsey Darrow, PhD[1] (ldarrow@emory.edu); Mitchel Klein, PhD[1] (mklein@emory.edu); Paige Tolbert,PhD[1] (tolbert@sph.emory.edu); Andrea Winquist, MD[1] (awinqui@emory.edu); James Mulholland, PhD[2] (james.mulholland@ce.gatech.edu); Armistead Russell, PhD[2] (ted.russell@ce.gatech.edu);
Institution(s) of PI(s): [1]Emory University and [2]Georgia Institute of Technology, Atlanta, Georgia
Research Category: Air Quality and Air Toxics
Project Period: 08/01/2012 – 7/31/2013

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 and hospital admissions (HAs).

Progress Summary/Accomplishments: During the current reporting period, work on Project 4 has focused on data management activities, and furthering work on single- and multi-city epidemiologic analyses, with a focus on applying spatially-resolved air quality metrics and on approaches to studying air pollution mixtures. ***Database development***. Database activities included air quality, health outcome, and mapping focuses. We finalized our initial approach to calculating daily population-weighted averages for multiple pollutants and these data were shared among center investigators for all cities in fall 2012. Since this time, to enable more appropriate comparison of pollutant concentrations across the five cities, a revised approach to calculating population-weighted averages was developed involving fusion of monitoring and CMAQ modeled data. Data for this metric are anticipated for completion in August 2013. Health outcome data for Atlanta, Dallas, and St. Louis are complete. In the past year, data collection and processing of Birmingham and Pittsburgh data have been brought near completion. Finally, a geodatabase for the project was set up for mapping of air quality monitoring sites, hospital locations, and other study characteristics in a consistent fashion across all study areas. ***Data analyses and planning.*** A number of activities were conducted over the project period: 1) evaluated metrics for characterizing socioeconomic status at the ZIP code level among the five study areas; 2) examined study design issues for comparing epidemiologic results among the five cities (e.g., temporal and spatial extent of available data) and progression of analyses; 3) continued single-city epidemiological analyses for Atlanta and St. Louis, and began epidemiologic analyses for Dallas; 4) continued efforts on application of spatially-refined modeled estimates of ambient concentrations and population exposures in Atlanta epidemiologic analyses; 5) with the Air Quality Core, continued work on applying $PM_{2.5}$ components data and $PM_{2.5}$ source apportionment outputs to epidemiologic analyses in St. Louis, comparing results among multiple source apportionment approaches; 6) with the Air Quality and Biostatistics Cores, continued work on methods for detecting and analyzing air pollution mixtures

using multi-pollutant monitoring data, including development of a mobile source indicators approach, self-organizing maps, classification and regression trees (C&RT), and assessing multi-pollutant joint effects; 7) began extension of C&RT analyses to the multi-city context (Atlanta, Dallas, and St. Louis); and 8) developed a statistical modeling approach to quantify projection uncertainties in future ambient ozone levels and their health impact due to climate change.

Publications:

1. **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)**
2. **Pachon JE, Weber RJ, Zhang X, Mulholland JA, Russell AG. Revising the use of potassium (K) in the source apportionment of PM2.5. *Atmospheric Pollution Research* 4(1):14-21, 2013. (Core B, Project 4)**
3. **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)**
4. **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*, accepted. (Project 4)**
5. **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. Submitted. (Project 4)**
6. **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. Submitted. (Project 4)**
7. **Gass K, Klein M, Chang HH, Flanders WD, Strickland MJ. Classification and regression trees for epidemiologic research. Submitted. (Core C, Project 3, Project 4).**
8. **Pearce JL, Waller LA, Klein M, Mulholland J, Sarnat J, Sarnat SE, Tolbert P. Profiling environmental mixtures with self-organizing maps: potential for epidemiological research. Submitted. (Core C, Project 3, Project 4)**
9. 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)
10. 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)
11. 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)
12. 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)
13. 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.

14. 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)
15. 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)
16. 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)
17. 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)
18. 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)
19. 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. **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.**
2. **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.**
3. **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.**
4. **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.**
5. **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.**
6. **Sarnat S, Winquist 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.**
7. **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." Joint**

Annual Conference of the International Society for Environmental Epidemiology and Exposure Science and Indoor Air Quality. Basel, Switzerland, August 2013.

8. **Winquist A, Schauer J, Turner J, Klein M, Sarnat S. "Impact of ambient $PM_{2.5}$ 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.**
9. **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.**
10. **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.**
11. **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.**
12. 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.
13. 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 12th International Global Atmospheric Chemistry Open Science Conference. Beijing, China, September 2012.
14. 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.
15. 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.
16. 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.
17. 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 data processing activities (particularly finalizing the new population-weighted averaging metric and finalizing Birmingham and Pittsburgh health outcome data). Manuscript preparation will begin and/or continue for analyses conducted over the past year. Current manuscripts in preparation include: 1) Joint effects of combinations of ambient air pollutants on pediatric emergency department visits in Atlanta, 1998-2004;

2) Fine particulate matter components and emergency department visits for respiratory and cardiovascular diseases; 3) Impact of organic and elemental carbon measurement methods on associations with acute cardiorespiratory morbidity; 4) A statistical modeling approach for quantifying projection uncertainties in future ambient ozone level and its health impact due to climate change; 5) Profiling environmental mixtures with self-organizing maps: potential for epidemiological research. New and ongoing analyses are also planned, in particular the extension of single-city epidemiologic analyses of Atlanta, Dallas, and St. Louis to the multi-city context, with anticipated focuses on specific cardiorespiratory outcomes; continued extensions of source apportionment, SOMs, and C&RT approaches; and preliminary assessments of effect modification by SES and seasonality/temperature.

Supplemental Keywords: ambient air, health effects, sensitive populations, dose-response, cumulative effects, epidemiology, exposure, air quality modeling, $PM_{2.5}$, organics, elemental carbon, metals, oxidants, sulfates, source characterization

Relevant Web Sites: www.scape.gatech.edu

Date of Report: July 31, 2013
EPA Agreement Number: R834799
Center Name: Southeastern Center for Air Pollution and Epidemiology
Project Title: Air Quality Core
Investigator(s): PI -- Armistead Russell, PhD[1] (ted.russell@ce.gatech.edu); M. Talat Odman, PhD[1] (odman@gatech.edu); Yongtao Hu, PhD[1] (yh29@mail.gatech.edu); James Mulholland, PhD[1] (james.mulholland@ce.gatech.edu); Yang Liu, PhD[2] (yang.liu@emory.edu), Heather Holmes, PhD[1] (heather.holmes@ce.gatech.edu)
Institution(s) of PI(s): [1]Georgia Institute of Technology and [2]Emory University, Atlanta, Georgia
Research Category: Air Quality and Air Toxics
Project Period: 08/01/2012 – 7/31/2013

Objective of Research: The primary mission of the Air Quality Core (AQC) is to provide Center researchers the information and methods to comprehensively characterize air pollutant mixtures relevant to their projects and to support project activities by collecting and managing 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 toolkit components. An additional mission of the AQC is to facilitate transmission of atmospheric data and methods to potential users outside of the Center. The more comprehensive characterization is developed, first, by analyses of the detailed chemical and physical measurements produced by the Center along with those available from other routine monitoring networks and special studies. Further spatial and temporal characterization of the air pollutant mixtures, and the sources involved, will come from the use of extended receptor-oriented and chemical transport models (CTM) applied over multiple scales. A range of both source- and receptor-oriented air quality models, regression approaches, and hybrid methods are being developed. In support of the four research projects and other cores within the Center, the AQC has six functions: 1) atmospheric data collection and management; 2) development of the MC Toolkit to support Center projects; 3) support of project teams using MC Toolkit; 4) application of the extended Models 3/CMAQ; 5) integration of satellite remote sensing into health studies and air pollutant mixture characterization; 6) assessment of exposure misclassification. In addition to these functions, the AQC team assists in the preparation of reports and journal publications resulting from Center activities.

Progress Summary/Accomplishments: The AQC is continuing the development of an MC Toolkit, including data collection and development and application of methods for data analysis, including source apportionment (SA).

In support of Project 4, we have applied various receptor modeling approaches (CMB-based, PMF, ensemble) to Atlanta, Dallas and St. Louis. The ensemble approach application to St. Louis involved using both traditional data (e.g., typically available from CSN network monitors), as well as organic molecular marker data available for a limited period (Maier et al., 2013). These results were supplied to the health effects researchers for use in their epidemiologic analyses. For the St. Louis and Dallas studies, most of the particulate matter speciation data is available only every third day. Two interpolation techniques were developed, tested and written up in a draft manuscript. The ensemble SA method was extended in St. Louis with the temporal interpolation model to generate daily source impact estimates for 6.5 years of data. The ensemble SA method was also applied to Dallas and Birmingham where CMB and PMF were used to generate ensemble source profiles. The application to Dallas, along with the application of the ensemble approach, is now written up in a draft manuscript. The Atlanta SA analysis is completed for the initial period of study, but we are now extending the period

by two years in support of Project 3. Using the extensive data available from the Atlanta SEARCH site, the ensemble approach was also utilized to characterize uncertainty in the various methods used in SA analyses, and was written up in a manuscript which has now been published (Balachandran et al., 2013). The ensemble approach has been applied to multiple monitors in the Atlanta area (e.g., SEARCH Jefferson Street and SEARCH Yorkville) as well as the South Dekalb CSN. A new Bayesian receptor modeling approach was developed that extends the ensemble modeling approach and was applied to the Atlanta data sets. This work is now described in a manuscript (Balachandran et al., submitted). Results from the various source apportionment methods were analyzed to better understand their temporal variability and how the application of the receptor methods can alter temporal variability as compared to the base air quality data (manuscript in preparation).

In support of Project 3, a significant amount of work has focused on developing spatiotemproal fields of air quality and source impact metrics. We developed and applied a spatial data fusion approach to combine chemical transport model (CTM) results and observations to generate spatially resolved species concentrations for use in geocoded health studies. CMAQ results are fused with observations to provide spatial fields of pollutant concentrations and source impacts. We continue to work on a hybrid chemical transport model-receptor modeling approach to provide spatially and temporally complete air quality and source impact fields that also fuse CTM air quality and source impact results with observations. Species-specific sensitivities and source impact profiles from a CTM are used in a CMB model to nudge the CTM results to better match observations. Those results are then interpolated using kriging to provide adjusted spatial fields of pollutant concentrations and source impacts. Spatial PM fields are also being developed using satellite AOD observations and land use regression techniques.

In support of Project 3, a new aerosol product with 1 km spatial resolution derived by the Multi-Angle Implementation of Atmospheric Correction (MAIAC) algorithm was examined using a two-stage spatial statistical model with meteorological fields (e.g., wind speed) and land use parameters (e.g., forest cover, road length, elevation and point emissions) as ancillary variables to estimate daily mean $PM_{2.5}$ concentrations. The study area is the southeastern United States, and data for 2003 were collected from various sources. A cross validation approach was implemented for model validation. We obtained R^2 of 0.83, mean prediction error (MPE) of 1.89 $\mu g/m^3$, and square root of the mean squared prediction errors (RMSPE) of 2.73 $\mu g/m^3$ in model fitting, and R^2 of 0.67, MPE of 2.54 $\mu g/m^3$, and RMSPE of 3.88 $\mu g/m^3$ in cross validation. Both model fitting and cross validation indicate a good fit between the dependent variable and predictor variables.

Publications:

1. **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.**
2. **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)**
3. **Pachon JE, Weber RJ, Zhang X, Mulholland JA, Russell AG. Revising the use of potassium (K) in the source apportionment of PM2.5. *Atmospheric Pollution Research* 4(1):14-21, 2013. (Core B, Project 4)**
4. **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)**

5. **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)**
6. **Balachandran S, Chang HH, Pachon JE, Holmes HA, Mulholland JA, Russell AG. A Bayesian-based ensemble technique for source apportionment of PM2.5. Submitted. (Core B, Project 3)**
7. Chang HH, Hu X, Liu Y. Calibrating MODIS aerosol optical depth for predicting daily PM2.5 concentrations via statistical downscaling. Submitted, 2013a. (Core B, Core C, Project 3)
8. 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 PM2.5 Concentrations in the Southeastern United States Using MAIAC AOD Retrievals and a Two-Stage Model. Submitted. (Core B, Core C, Project 3)
9. 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)
10. 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)
11. 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.
12. 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. **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.**
2. **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.**
3. **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.**
4. **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.**
5. **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.

6. **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.**
7. **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.**
8. **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.**
9. **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.**
10. **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.**
11. **Liu Y. "Estimating Ground-Level PM2.5 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.**
12. Balachandran S, Baumann K, Pachon J, Mulholland J, Russell A. "Verification of Fire Weather Forecasts Using PM2.5 Sensitivity Analysis." Poster presentation at the American Association of Aerosol Research Annual Meeting. Minneapolis, Minnesota, October 2012.
13. 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.
14. 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.
15. **Hu X, Lyapustin A, Wang Y, Liu Y. "Estimating ground-level PM2.5 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.**
16. 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 11th Annual Community Modeling and Analysis System Conference. Chapel Hill, North Carolina, October 2012.
17. 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.

18. 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 12th International Global Atmospheric Chemistry Open Science Conference. Beijing, China, September 2012.
19. 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 12th International Global Atmospheric Chemistry Open Science Conference. Beijing, China, September 2012.
20. 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*:* Plans for 2013-2014 include continued collection of relevant air quality-related data (e.g., emissions data), application of the various source apportionment approaches, and further application of the spatiotemporal extension of the hybrid CTM-CMB approach. We are currently running a 19 sector CMAQ-DDM simulation for one year (2006) and plan to apply the hybrid CTM-CMB SA method to generate one year of spatially resolved source impact estimates at a 36-km resolution for the United States and 4-km resolution for Atlanta, GA. Results from this one year simulation will be compared to the emissions-based indicator SA method applied to the spatially resolved species concentrations and emissions estimates for the state of Georgia. Further, we plan to develop spatial PM fields using high resolution AOD data fused with CTM model fields.

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

Relevant Web Sites: www.scape.gatech.edu
Date of Report: July 31, 2013
EPA Agreement Number: R834799
Center Name: Southeastern Center for Air Pollution and Epidemiology
Project Title: Biostatistics Core
Investigator(s): Co-PIs -- W. Dana Flanders, MD, ScD (wflande@emory.edu) and Lance Waller, PhD (lwaller@sph.emory.edu); Howard Chang, PhD (howard.chang@emory.edu); Mitchel Klein, PhD (mklein@emory.edu); John Pearce, PhD (john.pearce@emory.edu)
Institution(s) of PI(s): Emory University
Research Category: Air Quality and Air Toxics
Project Period: 08/01/2012 – 7/31/2013

Objective of Research: The primary objective of the Biostatistics Core is to provide statistical support to the Center and to the associated Projects. The five primary functions of the Biostatistics Core are to: 1) provide guidance and support to all Projects for design issues; 2) provide guidance and support to all Projects for epidemiologic modeling, including identification and characterization of mixtures and their health effects; 3) perform methodological development, including identification of model misspecification, analyses of time series based on LASSO and C&RT, and identification of mixtures that associate with health outcomes; 4) develop and provide support and guidance for addressing the impact of measurement error; and 5) archive, document, and assure security of analytic data files.

Progress Summary/Accomplishments:

1. Air Quality Core. Biostatistics Core personnel continued to develop methods for combining monitoring measurements and other air quality products (satellite images, numerical model outputs from CMAQ, and simulations from stochastic personal exposure simulators). Three manuscripts are currently under review, including (1) a Bayesian ensemble-based source apportionment approach, (2) a spatial-temporal statistical downscaler for remotely-sensed aerosol optical depth, and (3) a multi-resolution data fusion method in the spectral domain.
2. Core personnel began analysis of state-wide association between gestational exposure to PM2.5 and preterm birth. An approach to identify susceptible windows of exposure for preterm birth has been developed and a manuscript is currently under review (Chang et al., submitted 2013b).
3. Core personnel evaluated the use of satellite-derived PM2.5 estimates in a time-series analysis of emergency department visits in Atlanta. Results were presented at the ENAR 2013 Spring Meeting.
4. Measurement error collaboration. Core personnel have compiled the health and air quality datasets for the state-wide analysis of PM2.5 and birth weight. Progress has been made to apply the spatial-temporal model developed by UW collaborators to estimate long-term exposure to PM2.5 during pregnancy.
5. Development of statistical methods to estimate health effects of observed pollution mixtures. Core personnel have explored self-organizing map (SOM) and classification and regression tree (C&RT) methods for assessing the health effect of air pollution mixtures observed in Atlanta, St. Louis, and Dallas. Two manuscripts are in preparation and several others in the planning stages.
6. Core personnel continued work on methods for the identification of model mis-specification, particularly due to confounding, building on earlier publications relating to this issue (Flanders et al., 2011)
7. Core personnel continue collaborations regarding the assessment of statistical measurement error in the use of satellite remote-sensing measurements of air quality.

8. Core personnel provide continued support for Center Projects with respect to design issues and development of analytic plans for data analysis.

Publications:

1. **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.**
2. **Waller LA. Commentary: Regarding assessments of chance in investigations of `cluster series'. *International Journal of Epidemiology* 42:449-452, 2013. (Core C, Project 3)**
3. Chang HH, Hu X, Liu Y. Calibrating MODIS aerosol optical depth for predicting daily PM2.5 concentrations via statistical downscaling. Submitted, 2013a. (Core B, Core C, Project 3)
4. **Chang HH, Warren JL, Darrow LA, Reich BJ, Waller LA. A distributed exposure time-to-event model for estimating associations between air pollution and preterm birth. Submitted, 2013b. (Core C, Project 3)**
5. **Gass K, Klein M, Chang HH, Flanders WD, Strickland MJ. Classification and regression trees for epidemiologic research. Submitted. (Core C, Project 3, Project 4).**
6. 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 PM2.5 Concentrations in the Southeastern United States Using MAIAC AOD Retrievals and a Two-Stage Model. Submitted. (Core B, Core C, Project 3)
7. **Pearce JL, Waller LA, Klein M, Mulholland J, Sarnat J, Sarnat SE, Tolbert P. Profiling environmental mixtures with self-organizing maps: potential for epidemiological research. Submitted. (Core C, Project 3, Project 4)**
8. Reich BJ, Chang HH, Strickland MJ. Spatial health effects analysis with uncertain residential locations. *Statistical Methods in Medical Research*, 2012, DOI: 10.1177/0962280212447151. (Core C, Project 3)
9. 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)
10. 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. **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.**
2. **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.**
3. **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.**

4. **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.**
5. **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.**
6. 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.
7. **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.**
8. 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.
9. 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 12th International Global Atmospheric Chemistry Open Science Conference. Beijing, China, September 2012.
10. 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.
11. 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.
12. 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.
13. Waller LA. "Spatial uncertainty in regression associations" Oral presentation at the International Society for Environmental Epidemiology Annual Conference. Columbia, South Carolina, August 2012.
14. 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.
15. 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.
16. 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.
17. 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: Biostatistics Core members are involved in analytic aspects of all Center Projects. Planned core collaborations for 2013-2014 include:

1. Continue to support the Air Quality Core on developing and evaluating air quality products for use in health analyses (all Core members).
2. Continue to support Project 3 and Project 4 on statistical issues (Core members Chang, Klein, Flanders and Waller).
3. Extension of classification and regression tree (C&RT) and self-organizing map (SOM) techniques for characterizing air pollution mixtures (Core members Klein, Waller, Pearce).
4. Collaborations regarding characterization of measurement error in remotely sensed and modeled measures of air quality (Core member Chang).
5. Continuing collaborations regarding the detection and adjustment for confounding in health effect models (Core members Flanders, Klein, Waller, and Chang).
6. Continuing collaborations on the impact of measurement error on estimates of health effects of air pollution (Core members Flanders, Klein, Waller, and Chang).
7. Continuing collaborations on the design and analysis of exposure measurements in Projects 1 and 2 (all Core members).
8. Continuing collaborations on the design and analysis of health effect studies in Projects 3 and 4 (all Core members).

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

Relevant Web Sites: www.scape.gatech.edu