Annual Center Progress Report
Southeastern Center for Air Pollution and Epidemiology
Georgia Tech/Emory EPA Clean Air Research Center
August 1, 2013 – July 31, 2014

This Progress Report covers the work of the Southeastern Center for Air Pollution and Epidemiology (SCAPE) from August 1, 2013 – July 31, 2014. 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 fourth annual meeting for SCAPE's ten member Science Advisory Committee is scheduled for November 20-21, 2014, 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. Completed Project 1 ambient sampling program with a suite of instrumentation at paired sites that included Jefferson Street (JST) and a mobile site (trailer) rotated between rural, near road and roadside sites. In addition, completed sampling at three out-of-state sites, Centreville, AL, Birmingham, AL, and St. Louis, MO. Each paired measurement was for nominally one-month sampling periods. Data archived on ftp site for use by other SCAPE investigators.
2. Completed all analyses of collected integrated samples:
    a. VOC Whole Air Samples have been analyzed for suite of VOCs and data archived.
    b. All DTT assay analysis on high-volume filters was finished. Analyses protocol included DTT assay on water, water-hydrophilic, methanol, and methanol hydrophilic extracts. Roughly 2,400 DTT analyses were performed.
    c. Developed automated method for analyses of a suite of water-soluble elements (e.g., water-soluble metals), analyzed all high-volume filters (total water-soluble and hydrophilic water-soluble).
    d. Aerosol mass spectrometer deployed at 8 Project 1 sites data have been analyzed, including PMF for organic speciation/tracers.
    e. Analyzed, WSOC, BrC, ions, OC and EC on all high-volume filters.
    f. Completed GC-MS analyses on subset of high-volume filters for PAHs and quinones.
3. Modified automated DTT analytical system for Ascorbate-depletion Assay (AA) and assessed performance of method.
4. Participated in CCAR-SCAPE collaborative project, Sept 2013.

5. Completed all analyses of DTT activity on Project 2 in-vehicle filters.
6. Redeployed NO2 instrument at Road-Side site and performed 2-month intercomparison with SEARCH NO2 instrument at JST.
7. Deployed online elements instrument (Xact 625 Monitoring System, Cooper Environmental Systems) at JST for a 3-month comparison of PM2.5 and PM10 metals to SEARCH filter-based collection method and offline ICPMS analyses.
8. Data interpretation and work on manuscripts, including the following:
    a. *A Semi-automated System for Quantifying the Oxidative Potential of Ambient Particles in Aqueous Extracts Using the dithiothreitol (DTT) assay: Results from the Southeastern Center for Air Pollution and Epidemiology (SCAPE), T. Fang et al, Atmos. Meas. Techn. 7, 7245-7279*, 2014.
    b. *Reactive Oxygen Species Associated with Water-Soluble $PM_{2.5}$ in the Southeastern United States - Spatiotemporal Trends and Source Apportionment, Verma et al., submitted Atmos. Chem. Phys.*
    c. *Identification of Organic Aerosol Components Contributing to the Particle Associated Reactive Oxygen Species based on Aerosol Mass Spectrometry and DTT Activity, Verma et al., in progress.*
    d. *Polycyclic Aromatic Hydrocarbons and Quinones in Fine Aerosols in Atlanta, El-Afifi et al., in progress.*

<u>Project 2: Examining In-Vehicle Pollution and Oxidative Stress in a Cohort of Daily Commuters</u>
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. Successfully completed field data collection portion of Project 2, which included 120 individual exposure sessions.
2. Completed data processing for all continuously measured pollutant parameters for main Project 2 commuter study (ACE-2).
3. Completed data analysis and processing for all filter-based measurements excluding particulate organic species and ions.
4. Completed manuscript on effect measure modification of ACE-1 results by asthma control status. Results indicate that poorly-controlled asthmatics may be more susceptible to acute changes in lung function and pulmonary inflammation from exposures to specific in-vehicle pollutants. Manuscript is currently in CDC clearance, to be submitted to *Epidemiology*.
5. Published initial results from commuter pilot study (ACE-1) on in-vehicle pollutant exposures and acute cardiorespiratory response during highway commuting periods.
6. Completed preliminary epidemiologic analyses for Project 2 (ACE-2) examining associations between continuously measured pollutants (PM2.5, BC, PAHs, PNC) and corresponding respiratory endpoints.
7. Completed data processing and analysis of ACE-1 and ACE-2 salivary cortisol samples. Completed first draft of a manuscript examining relationships between self-perceived stress from commuting and biological measures of response.
8. Revised draft manuscript of analysis examining correlations between in-vehicle noise and several particulate pollutants. Results show strong correlations between noise and indicators of particle number concentration.

9. Prepared all available ACE-2 plasma samples for metabolomic analyses to be conducted in summer 2014, by Project 2 co-investigator, D Jones.

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

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

Research Conducted and Results Generated:

1. Published time-series epidemiological analysis assessing modification of the acute effect of ambient air pollution on pediatric asthma emergency visits across susceptible subpopulations.
2. Completed the time-series epidemiological analysis of acute effects of ambient air pollution on several different types of respiratory emergency visits among children age 0-4 years (paper in revision). A related manuscript that describes the relationship between emergency visits for bronchiolitis during infancy and subsequent risk of emergency visits for asthma after age five is under peer review.
3. Published our method for using classification and regression trees to estimate the joint effects of pollutant mixtures. A second paper that extends this approach to look at acute associations between air pollutants and pediatric asthma emergency visits in three cities is under peer review.
4. A manuscript for the Atlanta time-series analyses using the Bayesian ensemble source apportionment estimates is under peer review.
5. A manuscript on our method for the self-organizing maps to identify pollutant mixtures has been accepted. Preliminary epidemiologic analyses using estimates from the self-organizing maps have been performed.
6. Preliminary results for a Georgia-wide analysis of associations between air pollutants and preterm birth using the fused CMAQ estimates.
7. Progress is being made on the Kaiser Permanente analysis of incident asthma. Health data are in house and have been prepared for analysis. Initial work on the Bayesian downscaling of CMAQ estimates is ongoing.
8. Published satellite-estimated 10-year PM2.5 concentration time series in Georgia.
9. A manuscript to evaluate the potential of adding satellite-detected fire spots to PM2.5 exposure models in Georgia is under peer review.

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 and ZIP code level estimates of multiple pollutants by fusion of monitoring and CMAQ modeled data, health outcome data processing for Birmingham and Pittsburgh, and merging of air quality, health, and Census data.
2. Conducted single- and multi-city epidemiologic analyses of asthma/wheeze and selected cardiovascular ED visits, with a focus on model development, comparison of modeling approaches, assessment of model misspecification, and assessment of pollutant lag effects.
3. Continued efforts applying spatially-refined modeled estimates of ambient concentrations and population exposures in Atlanta epidemiologic analyses in collaboration with EPA scientists, with several manuscripts published (Baxter et al., 2013; Dionisio et al., 2013, 2014) and preliminary

analyses conducted comparing the use of central monitor site, monitoring-based population weighted averages, and CMAQ-fused population weighted averages in epidemiologic models.
4. Continued work on methods for detecting and analyzing air pollution mixtures using multi-pollutant monitoring data, including classification and regression trees (C&RT) (Gass et al., 2014; Gass et al., submitted), self-organizing maps (Pearce et al., accepted), joint effects estimation (Winquist et al., 2014), and a preliminary examination of the effect of reactive oxygen species (ROS) on health using retrospectively predicted DTT activity.
5. Continued work on examining detailed $PM_{2.5}$ components data in epidemiologic analyses (Winquist et al., accepted; Sarnat et al., submitted).
6. Continued work on developing a statistical modeling approach to quantify projection uncertainties in future ambient ozone levels and their health impact due to climate change (Chang et al., 2014).
7. Assessed potential modifiers of the effects of ambient air pollution on health, including age, neighborhood socioeconomic factors, air exchange rates, and season.

Air Quality Core (Core B)

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

Research Conducted and Results Generated:

1. EPA's CMB (Chemical Mass Balance) receptor model was applied to ambient aerosol concentrations observed at various regulatory monitoring sites (CSN, SEARCH, IMPROVE) in Georgia, Tennessee and Florida. The nine source categories considered in our CMB modeling effort are light duty gasoline vehicle, heavy duty diesel vehicle, soil dust, vegetative/wood burning, coal-fired power plants (primary source), ammonium sulfate, ammonium bi-sulfate, ammonium nitrate, and others.
2. A novel Bayesian ensemble-averaging method was developed to determine source impacts, to apportion sources for long-term dataset and to estimate SA uncertainties as part of Project 4. The ensemble approach uses three receptor models (CMB-LGO, CMB-MM, PMF) and one chemical transport model (CMAQ).
3. The OBS-CMAQ data fusion work was completed for Project 3. Temporally and spatially resolved concentrations of five gases and seven PM types were calculated for CONUS at 36 km, Eastern US at 12 km and Georgia at 4 km.
4. The same data fusion methodology was also applied to Atlanta, Birmingham, Dallas-Fort Worth, Pittsburgh and St. Louis, as part of Project 4. Ambient air quality monitoring data and CMAQ concentration fields for eastern US at 12 km were fused for the same twelve pollutants.
5. As part of Project 3, spatially-resolved concentrations fields from mobile sources were generated for Georgia using the emission-based IMSI (Integrated Mobile Source Indicator) model. IMSI was applied to the 24-hour average concentrations from the 12-km and 4-km OBS-CMAQ fused data.

6. The CMAQ-DDM (Decoupled Direct Method) model was used to determine the source impact for 40 PM2.5 species from 20 source categories in the 36-km CONUS domain. To reduce impact uncertainties for each source category, the Hybrid Kriging (HK) method was applied to CMAQ-DDM concentration fields using interpolated observations from 189 monitors across CONUS.
7. In support of Project 3, various air quality metrics are being developed in a 250 m grid covering 15 counties of the Atlanta area: (i) link-based NOx and PM2.5 emissions from the transportation sector, (ii) pollutant concentrations calculated with AERMOD at road level, (iii) IMSI applied to mobile emissions and concentrations.
8. As part of Project 3, Emory's statistical downscaling model is currently being applied to the 12-km and 4-km CMAQ outputs, SMOKE emissions, link-based mobile emissions and WRF weather outputs in order to predict daily spatially resolved PM2.5 concentrations across northern Georgia and Atlanta urban area.

Biostatistics Core (Core C)

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

Research Conducted and Results Generated:

1. Initiated development of methods addressing causal effect definitions and estimation (in progress, Klein and Flanders).
2. Developed statistical methods to assess critical exposure and outcome windows in the analyses of ambient air pollution and preterm birth (Chang, Waller, manuscript under revision for *Biostatistics*, joint work with Project 3).
3. Expanded methods to estimate ground-level $PM_{2.5}$ concentrations from remote sensing (MODIS) data via geographically weighted regression (Hu et al. 2014).
4. Developed a statistical modeling framework for projecting future ozone levels due to climate change with an emphasis on uncertainty quantification (Chang et al. 2014, joint work with Project 4, and Cores B and C).
5. Investigated and quantified impact of exposure measurement errors in time series analysis of air pollution and health (Dionisio et al., to appear, joint work with Projects 3 and 4). Started a more comprehensive follow-up simulation study (Chang).
6. Facilitated analyses in CLARC collaborative Project 3 and Project 4.
7. Expanded statistical methods for statistical downscaling of pollutant concentrations (Chang et al, 2014, Reich et al., to appear, joint work with Project 3, and Cores B and C).
8. Initiated development of data fusion methods to combine satellite-derived aerosol optical depth and CMAQ outputs (Balachandran et al., 2013, joint work with Project 3 and Cores B and C).
9. Developed, applied, and published approaches for the analysis of joint effects of multiple pollutant using classification and regression trees (Gass et al. 2014) and self-organizing maps (Pearce et al., in press). Joint work with Projects 3 and 4.
10. Developed and applied spatio-temporal hurdle models for zero-inflated data. (Neelon et al., in press, joint work with Core C and Project 4).

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.

- AQC: Josephine Bates, a graduate student, joined the group in August 2013. Post-doc Heather Holmes left the group in November 2013 to take a faculty position and was replaced by David Lavoué. Heather is now working as an assistant professor for the University of Nevada in Reno, and continues to interact with the center. Siv Balachandran left the group in November 2013 after graduating with his PhD. Rawan El-Afifi left the group in June 2014 after graduating with her MS.
- Project 1: Neel Kotra graduated (MS), replaced with Ting Fang (PhD student)
- Project 2: Project 2 co-I, Lou Ann Brown, and research technician, Priya Kewada, are no longer working on the project.
- Project 3: The former Kaiser Permanente PI, Robert Davis, left Kaiser in 2013. For a brief time Michele Marcus was selected as the replacement PI; she has since left Kaiser as well. Because the Kaiser data acquisition is complete we are not seeking a new Kaiser PI to replace Michele Marcus.
- Project 3: Katherine Gass graduated from Emory with a PhD in Epidemiology in May, 2014. Apart from finalizing dissertation manuscripts she will not be working on Project 3 moving forward.
- Project 4: Priya Kewada left study staff to start nursing school; added PhD student Cassandra O'Lenick; added Pittsburgh collaborators, including Richard Bilonick (PI), Evelyn Talbott, and Judy Rager

4. Quality Assurance

SCAPE's Quality Management Plan (QMP) was submitted to and approved by EPA in March 2011. No changes were made to the QMP during the 2014 annual review. Quality Assurance Project Plans (QAPPs) for all four Projects and the Air Quality Core were initially approved by the quality assurance team (Center Co-Directors, Quality Assurance Manager, and two Quality Advisors) in 2011 and are reviewed annually. All necessary Standard Operating Procedures have been drafted and approved.

The Quality Assurance Manager meets with the designated Quality Control Reviewer for each Project and the Air Quality Core on a semiannual basis to review all QA/QC procedures detailed in the Project QAPPs and data management plans and to conduct annual project audits during the first year of research. This reporting year, meetings were held in August 2013 and February 2014. A complete Project 2 audit was performed in August 2013. On Project 3, a Quality Control Reviewer (Audrey Flak) was added to manage the Kaiser data, in addition to the Quality Control reviewer tasked with managing the Georgia Hospital Association data, and the first QA/QC meeting was held in February 2014. On Project 2 and Project 4, new Quality Control Reviewers were selected (Rachel Golan and Andrea Winquist, respectively) to replace the original Quality Control Reviewer who moved on to nursing school (Priya Kewada). The Quality Assurance Manager maintains detailed meeting records and works with the PIs and Quality Control Reviewers to resolve any issues.

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

Finally, a new data management program is currently under development to ensure that all published analyses can easily be replicated should the authors leave Emory or Georgia Tech. Under this program, the first author is responsible for creating a single statistical program to replicate all tables or figures

reported in SCAPE papers. These programs will be stored on secure network drives accessible to SCAPE researchers. Developments under this new plan will be reported in the next Progress Report.

5. Planned Future Activities

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

1. Finish Ascorbate-depletion (AA) assay method and do AA analysis on all high-volume filters, compare results to metals data and DTT activities already completed, publish results.
2. Finish collaboration with EPA (Bob Devlin), including analysis of ultrafine, fine and coarse particles via DTT assay, combine with CAPS DTT data already generated and publish results.
3. Complete all data analysis and publications.
4. Depending on financial considerations:
    a. Assess the potential of developing an online DTT and AA assay based on PILS technology.
    b. Modify automated DTT/AA analysis system for measurement of both soluble and insoluble aerosols by both assays to quantify the contribution of insoluble BC on ROS. Test system by comparison of road-side to other sites.

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

1. Complete analyses of all ACE-2 pollutant and health endpoints, including plasma samples using novel HR-MS analyses involving the characterization of metabolomic profiles.
2. Complete and submit six draft manuscripts currently in preparation of ACE-1 and initial ACE-2 data. The manuscripts include analyses of:
    a. Effect measure modification among asthmatic subjects in ACE-1 (Mirabelli et al);
    b. Correlations between noise and in-vehicle particulate pollution in ACE-1 (Ladva et al);
    c. Frequency of traffic pollution events and corresponding health response in ACE-2 (Greenwald et al);
    d. Associations between salivary cortisol and perceived stress in ACE-1 and ACE-2 (Raysoni et al);
    e. Associations between breath and blood MDA in ACE-1 (Golan et al);
    f. Associations between exposures and acute respiratory response in ACE-2 (Golan et al);
3. Conduct new exposure and epidemiologic analyses of ACE-2 data, including analyses of changes in metabolomic profiles in ACE-2 and epidemiologic associations of in-vehicle mixtures in ACE-2.

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

1. Ensure all manuscripts currently in the peer review process are published.
2. Finalize epidemiologic analysis and write manuscript for statewide preterm birth analysis using fused CMAQ estimates.
3. Finalize epidemiologic analysis and write manuscript for statewide emergency visit analysis using satellite-based PM2.5 estimates and fused CMAQ ozone estimates.
4. Perform time-series analysis in Atlanta using the mixture estimated from self-organizing maps.
5. Develop and publish approach for estimating ROS from source apportionment estimates and use these estimates in an epidemiologic time-series study of asthma in Atlanta.
6. Finalize and publish the approach for the downscaled CMAQ estimates and use these estimates in the Kaiser Permanente birth cohort analysis.

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

1. Complete database management activities.

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

Air Quality Core

1. Apply our OBS-CMAQ data fusion method to the Atlanta metropolitan area using the 4-km CMAQ runs for 2008-2010.
2. Integrate in all our CMAQ runs new daily fire emissions based on FINN emission inventories developed by NCAR.
3. Apply CMAQ-DDM using 36-km CONUS domain nested with 12-km Eastern US and 4-km Georgia grids for 2004-2007.
4. Replace the default on-road mobile emissions in our 4-km CMAQ-DDM runs with the Atlanta Regional Commission mobile emissions for the Atlanta area.
5. Apply the statistical downscaling model to 4-km CMAQ outputs and ARC mobile emissions to get PM2.5 daily concentrations at 250 m between 2008 and 2010.
6. Aggregate our downscaling outputs, spatially, based on some geographical boundaries, such as the census tract, and temporally, such as weekly or monthly.

Biostatistics Core

1. Continued development of statistical methods for downscaling and linking ground-level pollution concentrations between models (e.g., CMAQ), monitoring data, and remote sensing.
2. Continued development and application of methods to estimate and summarize health effects of simultaneous exposure to multiple pollutants.
3. Continued development of estimation techniques for causal effects within observational data in air pollution epidemiology.
4. Continued collaboration between CLARC Biostatistics Cores on methodological development and implementation to address shared challenges.
5. Continued exploration of the impact of measurement error on estimated health effects.
6. Continued close collaboration between SCAPE projects and statistical analyses, particularly Projects 3 and 4.

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.

We have performed extensive analysis of the ACSM organics data. The aerosols in each of the three systems (POA+SOA, POA only, SOA only) exhibit fairly similar organics:carbon (O:C) ratios of ~0.5, indicating they are mildly oxidized (in the context of other ambient aerosols measured globally). We performed Positive Matrix Factorization (PMF) to deconvolve the organics mass spectra into different factors for linking to aerosol oxidative properties. For the "POA+SOA" system, we resolved three factors with unique mass spectral features. One is hydrogen-like organic aerosols (HOA) which shows strong alkane-like fragmentation patterns and is a surrogate for POA, and two oxygenated organic aerosols factors (OOA) which have higher O:C ratios and are surrogates for SOA. One of the OOA factors exhibits strong signals at *m/z* 77 and 91, which could be SOA produced from the oxidation of aromatic hydrocarbons. The same OOA factors are obtained for the "SOA only" system. Interestingly, for the "POA only" system, we also resolved an OOA factor in addition to the HOA factor. This indicates that some of the aerosols in the "POA only" system are fairly oxidized, and could be formed from evaporation of semi-volatiles from the POA which are then further oxidized in the atmosphere and re-condense as SOA. It is noted that the PMF results are consistent with offline EC/OC measurements in general. For instance, filter analysis showed that a substantial fraction of the carbon in the "POA only" system is OC. We also analyzed the filter samples with the dithiothreitol (DTT) assay. It was found that the OOA factors (i.e., SOA) exhibit the highest intrinsic DTT activity among all test atmospheres. As SOA mass often dominates fine particle matter in the atmosphere, results from this study highlight the importance of understanding the health effects of SOA formed from the photooxidation of primary emissions. We are currently preparing a manuscript of these findings.

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

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

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 was conducted September 7-17, 2013.
Two specific objectives are being addressed via this collaboration: first, intensive mobile platform measurements (CCAR) coupled with stationary site measurements using passive badges (CCAR) and ambient monitor station data (SCAPE, SEARCH, EPA) were obtained to characterize local-scale gradients at selected locations; second, urban-to-rural regional gradients are being characterized for comparison with spatial fields from fused ambient monitor and CMAQ data. A planned third objective, to address effects of vehicle infiltration on exposure via simultaneous in-vehicle (SCAPE) and out-of-vehicle (CCAR) mobile platform measurements, was not addressed as the SCAPE Project 2 investigation of in-vehicle pollution for commuters had completed its data collection phase. After an initial trip on September 7 around Georgia Tech, the Jefferson St SEARCH monitor, and downtown Atlanta, three trips were conducted multiple times, all starting and ending at the Jefferson St SEARCH monitor near Georgia Tech. The first, conducted on three days, was a northeastern loop to spaghetti junction (I-85 and I-285 north) that included the railyard. The second, conducted on five days, covered areas south of Georgia Tech to the perimeter (I-285 south), including the South Dekalb CSN monitor and the Hartsfield-Jackson International Airport. The third, conducted on two days, was a loop to Yorkville located 60 km west of Atlanta. A total of 28 passive badges were deployed at various locations on these loops. In addition to measurements at the South Dekalb CSN monitor and SEARCH monitors at Jefferson St and Yorkville, intensive measurements, including ROS measurements, were taken at the Georgia Tech roadside site (RS) during this period.

CCAR collaborators are processing the mobile platform data. SCAPE researchers have collected the fixed-site monitoring data and have obtained 4 km resolution hourly CMAQ fields for the field measurement period. Comparative analyses of the data is being performed. Results from the northeastern and southern loops to the perimeter (I-285) will be used to refine methods for downscaling CMAQ data to a 250 meter scale, coupled with detailed roadway emissions and land use terms. Results from the western loop to Yorkville will be used to assess urban-to-rural gradients.

CCAR collaborators have compared twenty eight mobile monitoring fuzzy point medians for NO_2, black carbon and particle light scattering with simultaneous ambient monitoring data at the Jefferson St. (JST), Yorkville (YRK) and South DeKalb St ambient monitors. A preliminary comparison of downscaled CMAQ predictions for NO_2 versus fuzzy point medians has been conducted. There is reasonable agreement between the two values across both time and space. Additional analyses are ongoing.

<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 are designing 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 2014, the Emory team has completed processing 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. Modeling fitting and prediction datasets were sent to UW/CCAR for evaluation in their spatiotemporal model. The Emory team has received and tested Koutrakis group's mixed effects model. Chang's spatial downscaler and Liu group's mixed effects model are ready to run. National scale evaluation of the quality of various MODIS collection 6 AOD parameters are underway. In addition, the Emory team has also received CMAQ simulated PM2.5 concentrations from Georgia Tech. Data extraction and spatial alignment are currently underway.

<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, SCAPE, Harvard)

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.
Based on inputs from UW and Harvard collaborators from the 2013 CLARC annual meeting, we have compiled an updated dataset of air quality, land use, meteorology, and Georgia birth records for the period 2001 to 2006. This new database increased the spatial resolution of the land use variables to 1km, included additional meteorological variables (e.g. boundary layer height), and extended the study region to include the entire state of Georgia. The Emory investigators have conducted PM2.5 exposure estimation using a spatio-temporal statistical model developed by the UW collaborators for the MESA Air study. The estimated PM2.5 exposures were linked to 383,695 Georgia birth records to examine associations between trimester-wide PM2.5 exposure during pregnancy and birth weight among full-term births. Preliminary health analyses have been conducted using the estimated PM2.5 exposures. We expect to begin applying measurement error approaches to the birth weight analysis in winter of 2014, starting with the parameter bootstrap methods developed by the UW collaborators, and prepare the first manuscript on associations between PM2.5 and birth weight accounting for exposure measurement error. We will next implement the SIMEX method developed by Harvard collaborators and the Bayesian approach to compare different measurement error correction methods. The SCAPE collaboration funds began supporting the Emory work on this project June 1, 2014.

Date of Report: July 31, 2014
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: 08/01/2013 – 7/31/2014

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 were deployed during SCAPE to provide a data set for investigating ROS sources, atmospheric processing and health impacts.

Progress Summary/Accomplishments:
Project 1 ambient sampling program was completed in the 3rd year, including three out-of-state sites, (Centreville AL, Birmingham AL, and St. Louis MO), and an additional Sept 2013 deployment at Roadside/GIT as part of the CCAR collaboration. This has produced a data set of roughly 310 days of sample collection. In addition to the online data collected, analysis of the 23-hour integrated filters has also been completed. This includes:

1. ROS via DTT assay of water and methanol extracts. The hydrophilic fraction was isolated for each of these solvents and DTT activity measured. Roughly 2,400 DTT measurements were performed.
2. A suite of water-soluble elements (e.g., water-soluble metals) was measured in conjunction with all DTT analyses (i.e., 2,400 samples). This was based on the development of an automated method that utilized an online XRF metals instrument (Xact 625 Monitoring System, Cooper Environmental Systems). The method's performance was verified, all high-volume filters were analyzed (total water-soluble and hydrophilic water-soluble), data quality assured and submitted to data archive.
3. Deployment of an Aerosol Mass Spectrometer (AMS) was completed providing detailed aerosol chemical characterization for 8 of the Project 1 deployment sites. The AMS data has been analyzed, including PMF for organic speciation/source tracers. All data are archived.
4. WSOC, BrC (Brown Carbon), a suite of ions, OC and EC analyses was completed.
5. GC-MS analysis was completed on a subset of the high-volume filters for a suite of PAHs and quinones.

In addition to the integrated filters, roughly 50 Whole Air Samples have been analyzed for suite of VOCs and the data archived.

All data have undergone preliminary quality checks and are archived on ftp site for use by other SCAPE investigators.

In addition, we have modified the automated DTT analytical system for Ascorbate-depletion Assay (AA), verified its performance and begun analysis of all high-volume filters.

We participated in CCAR-SCAPE collaborative project, Sept 2013, which involved our standard simultaneous deployments at two sites; in this case Road-side and GIT. The data have been analyzed and archived.

All ROS analysis for Project 2 in-vehicle filters has been completed via the DTT assay. Data are in the process of being analyzed.

In the past year, significant instrumental issues were discovered for the Aerodyne Cavity Ring Down NO2 instrument. The instrument was repaired and additional measurements of NO2 were made, after the main SCAPE sampling had been completed. NOx, NO2 and O3 were measured at the Road-side spring 2013 and a 1-month inter-comparison was conducted at the SEARCH JST site comparing two NO2 instrument from differing manufacturers.

We deployed online elements instrument (Xact 625 Monitoring System, Cooper Environmental Systems) at JST for a 3-month comparison of PM2.5 and PM10 metals to SEARCH filter-based collection method and offline ICPMS analyses.

A significant effort was made in the latter part of the 3rd year of the project on data analysis and development of manuscripts. The following papers have either been submitted and are under review, or are in the process of being completed:

1. El-Afifi, R., V. Verma, R. J. Weber, A. G. Russell, and Y. Wang (2014), Polycyclic Aromatic Hydrocarbons and Quinones in Fine Aerosols in Atlanta, *in progress*.
2. Fang, T., V. Verma, H. Guo, L. E. King, E. S. Edgerton, and R. J. Weber (2014), A Semi-automated System for Quantifying the Oxidative Potential of Ambient Particles in Aqueous Extracts Using the dithiothreitol (DTT) assay: Results from the Southeastern Center for Air Pollution and Epidemiology (SCAPE), *Atmos. Meas. Tech. Discuss., in review.*
3. Verma, V., T. Fang, X. Lu, N. Lee, R. E. Peltier, A. Russell, and R. J. Weber (2014), Identification of Organic Aerosol Components Contributing to the Particle Associated Reactive Oxygen Species based on Aerosol Mass Spectrometry and DTT Activity, *Environ. Sci. Technol.*, *in progress*.
4. Verma, V., T. Fang, H. Guo, L. King, R. E. Peltier, J. Bates, E. Edgerton, A. Russell, and R. J. Weber (2014), Reactive Oxygen Species Associated with Water-Soluble PM2.5 in the Southeastern United States - Spatiotemporal Trends and Source Apportionment, *Atm. Chem. Phys. Disc.*, *in review.*

Publications (publications with lead author underlined are a direct result of SCAPE research, those not underlined were supported by SCAPE in some manner, but were not a part of a SCAPE main research objective:

1. Liu, J., E. Scheuer, J. E. Dibb, L. D. Ziemba, K. L. Thornhill, B. E. Anderson, A. Wisthaler, T. Mikoviny, J. J. Devi, M. Bergin, and R. J. Weber (2014), Brown carbon in the continential troposphere, *Geophys. Res. Lett.*, *41*, 2191–2195, doi:2110.1002/ 2013GL058976. (Project 1)
2. 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)

3. 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. *Atmospheric Chemistry and Physics* 13:12389-12404, 2013. (Project 1)
4. 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)
5. Verma, V., R. Rico-Martinez, N. Kotra, C. Rennolds, J. Liu, T. W. Snell, and R. J. Weber (2013), Estimating the toxicity of ambient fine aerosols using freshwater rotifer Brachionus calyciflorus (Rotifera: Monogononta) *Enviromental Pollution, 182*, 379-384. (Project 1)

6. Presentations:

1. Weber, R. J., Fine particle water-soluble organic carbon over the southeastern United States, *Invited: Amer. Geophys. Union*, Dec 9-13, San Francisco, 2013.
2. Xu, L., H. Guo, K. Cerully, A. Bougiatioti, L. King, R. Weber, A. Nenes, N. Ng, A. Carlton, and K. Nguyen, Chemical characterization of water soluble organic aerosol during SOAS using high a resolution aerosol mass spectrometer, *Amer. Geophys. Union*, Dec 9-13, San Francisco, 2013.
3. 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.
4. 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.
5. 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.
6. 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.
7. 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.
8. 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.
9. 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.
10. Ng, N. L., L. Xu, L. King, H. Y. Guo, V. Verma, N. Kotra, and R. J. Weber, Aerosol composition and sources in the Atlanta area measured by high resolution mass spectrometry, *AlChE*, *Nov. 1, Pittsburgh PA,* 2012.

11. 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.
12. 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. Ascorbate-depletion assay (AA) will be measured on all high-volume filters for both the water-soluble extract and hydrophilic fraction of the water-soluble extracts. This will provide a large data set for direct comparisons between ROS measurements by the DTT (sensitive to organics) and Ascorbate assays (sensitive to metals). Water-soluble metals, quantified on the same filters, will provide further data for this comparison. We will test the hypothesis that these two assays, when combined, provide a broad measure of the aerosol ROS activity. The results will be published.
2. In the next year we hope to finish the collaboration with EPA (Bob Devlin), including DTT analysis of ultrafine, fine and coarse particle filters provided to us by the EPA. These results will be combined with CAPS DTT data already generated and the results published.
3. All data analysis will be completed and publications submitted by the end of the project. In addition to the publications in progress, listed above, we plan to publish papers on the following:
    a. King et al., Chemiluminescence measurements of NOx and NO versus cavity ring down NO2 at various sites in the southeastern US.
    b. King et al., On the spatial and seasonal distribution of a suite of air quality parameters based on paired measurements to investigate roadway emissions
    c. Xu et al., Characterization of the organic aerosol in the Southeastern US by Aerosol Mass Spectrometry
    d. Wang/Verma et al., Spatial and seasonal variation of the chemical composition of the HULIS fraction in ambient PM: implications for the source of DTT activity
    e. Verma/Devlin et al., PM generated ROS species associated with biological changes in humans exposed to fine concentrated air pollutants

Depending on availability of funds, the following projects may be attempted.

- Although the filter-based system has provided major new insights, it is recognized that online measurements of ROS by acellular assays, such as DTT and AA, could provide substantially greater insights into sources, atmospheric processing and health impacts of aerosols. An online system would provide much larger data sets, allow better integration with state-of-the art online aerosol chemical speciation instrumentation, a better assessment of variability in ROS and what drives it, and an assessment of possible artifacts associated with filter-based methods. A goal is to undertake preliminary laboratory work to assess the potential of developing an online DTT and AA assay based on PILS technology and our expertise gained through developing automated DTT and AA analytical systems used for filter extract analyses.
- To date, our work has focused on the water- and methanol-soluble components that contribute to fine particle ROS. Other studies have shown that solid particles, especially soot, can also be effective at generating ROS and are highly DTT active. Quantifying the ROS activity of soot and other insoluble components on the same integrated filter samples that have already undergone extensive analyses would provide a more complete assessment of the fine particle ROS potential. The approach would be to

modify the automated DTT/AA analysis system so that the redox chemistry can be done on an immersed filter, instead of in the filter extract. The system will be assessed by comparison to published diesel exhaust DTT intrinsic activities and contrasts between road-side to other sites (comparison between sites with high EC versus low EC concentrations).

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

Relevant Web Sites: www.scape.gatech.edu

Date of Report: July 31, 2014
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: 08/01/2013 – 7/31/2014

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. Field data collection. To date, Project 2 efforts have focused primarily on field data sampling. In August 2013, study staff completed the 16-month field data collection component of Project 2, which included 120 exposure sessions for 60 subjects. Every subject successfully completed the entire two-day study protocol, with no attrition. Review of the health and pollutant measurements indicate satisfactory data capture and completeness. Table 1 presents descriptive summary results for the complete ACE-2 panel.

Table 1

Panel Characteristics	All (n=60)	Asthma (n=30)	Non-asthma (n=30)	Diff. (p val)
Microenvironment				
Highway commute	60	30	30	
Surface street commute	30	15	15	-
Clinic	30	15	15	
Female sex (%)	45	53	37	0.15
Age, years [mean (range)]	27 (18-39)	25(18-37)	29(21-39)	<0.001
White (%)	57	53	60	0.4
BMI	23.6(3.6)	23.2(3.7)	24.1(3.5)	0.2
Asthma Medications no. (%)				
Inhaled corticosteroids	-	3(10)	-	-
Beta-agonist	-	18(60)	-	-
Systolic blood pressure mmHg	109.3(11.3)	109.9(10.9)	108.5(11.7)	0.5
Diastolic blood pressure mmHg	70.6(8.9)	70.9(10.4)	70.3(7.2)	0.7
eNO, ppb [median (range)]	23.2(5-163)	28.3 (6-163)	18.0 (5-41)	0.015
Lung function biomarkers [mean (SD)]				
FVC	4.2 (1.1)	4.1(1.1)	4.3(1.1)	0.3
FEV1	3.5(0.8)	3.4(0.8)	3.6(0.7)	0.2

2. Completed data processing for all continuously measured pollutant parameters for main Project 2 commuter study (ACE-2), including $PM_{2.5}$ mass concentration; particle number concentration; particle bound PAHs; black carbon concentration; and noise. Completed filter analysis and processing of the following integrated pollutant measurements: $PM_{2.5}$ mass concentration; particulate trace elements; elemental and organic carbon; water soluble organic carbon. Analyses pending for particulate organic (integrated) ionic species (integrated); and DTT (integrated).
3. Completed data processing for the following ACE-2 health endpoints: exhaled nitric oxide; lung function (FEV1, FVC); blood pressure; heart rate; and white blood cell count. Processing is still

pending for the following health endpoints: Inflammation biomarkers in DBS and plasma; EBC malondialdehyde and glutathione, and heart rate variability.

4. Published initial results from commuter pilot study (ACE-1) on in-vehicle pollutant exposures (Greenwald et al., AS&T, 2014) and acute cardiorespiratory response during highway commuting periods (Sarnat et al., Environ Res, 2014).
5. Completed manuscript on effect measure modification of ACE-1 results by asthma control status (Mirabelli et al). Results indicate that poorly-controlled asthmatics may be more susceptible to acute changes in lung function and pulmonary inflammation from exposures to specific in-vehicle pollutant. Manuscript is currently in CDC clearance, to be submitted to *Epidemiology*.
6. Completed preliminary epidemiologic analyses for Project 2 (ACE-2) examining associations between continuously measured pollutants (PM2.5, BC, PAHs, PNC) and corresponding respiratory endpoints.
7. Completed data processing and analysis of ACE-1 and ACE-2 salivary cortisol samples. Completed first draft of a manuscript examining relationships between self-perceived stress from commuting and biological measures of response.
8. Revised draft manuscript of analysis examining correlations between in-vehicle noise and several particulate pollutants. Results show strong correlations between noise and indicators of particle number concentration.
9. Prepared all available ACE-2 plasma samples for metabolomic analyses to be conducted in summer 2014, by Project 2 co-investigator, D Jones.

Publications:

1. **Greenwald R, Bergin MH, Yip F, Kewada P, Shafer MM, Schauer JJ, Sarnat JA. On-roadway in-cabin exposure to particulate matter: measurement results using both continuous and time-integrated sampling approaches. Aerosol Science & Technology 48:664-675, 2014. (Project 2)**
2. **Sarnat JA, Golan R, Greenwald R, Raysoni AU, Kewada P, Winquist A, Sarnat SE, Flanders WD, Mirabelli MC, Zora JE, Bergin MH, Yip F. Exposure to Traffic Pollution, Acute Inflammation and Autonomic Response in a Panel of Car Commuters. Environmental Research 133: 66-76. 2014. (Project 2, Core C)**
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, 23:606-615, 2013. (Project 2, Project 4, Core B, Core C)
4. Brown MS, Sarnat SE, DeMuth KA, Brown LAS, Whitlock DR, Brown SW, Tolbert PE, Fitzpatrick AM. Residential proximity to a major roadway is associated with features of asthma control in children. *PLoS ONE* 7(5):e37044, 2012. (Project 2, Project 4)

Presentations:

1. **Ladva CN, Greenwald R, Flanders WD, Sarnat JA. "Association between On-Road Particulate Matter Mixtures and Acute Cardiorespiratory Response in a Commuters Panel Study." Platform presentation at the International Society for Exposure Science Annual Meeting. Cincinnati, Ohio, October 2014.**
2. **Golan R, Greenwald R, Early-Jones B, Winquist A, Kewada P, Raysoni AU, Flanders WD, Sarnat S, Yip F, Sarnat JA. "Malondialdehyde in plasma and exhaled breath condensate following highway commutes." Platform presentation at the International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.**
3. **Golan R, Greenwald R, Raysoni AU, Kewada P, Ladva CN, Early-Jones B, Winquist A, Flanders WD, Sarnat JA. "Respiratory effects of exposure to car commuting in young adults– a**

randomized crossover study." Poster presentation at the International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.

4. **Golan R, Sarnat J. "Pollution Intersects Life: Acute Health Effects of Exposure to Traffic Pollution", Morning Session, 26th International Society for Environmental Epidemiology (ISEE), Seattle, Washington, August 2014.**
5. **Golan R, Greenwald R, Raysoni AU, Kewada P, Ladva CN, Early-Jones B, Winquist A, Flanders WD, Sarnat JA. "Respiratory Effects of Exposure to Car Commuting in Young Adults– A Randomized Crossover Study", Platform presentation at the 7th Postdoctoral Fellow Research Symposium, Emory University, Atlanta, March 2014.**
6. 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.
7. 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.
8. 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.
9. 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.
10. Sarnat J. "Is Commuting Really that Bad for Your Health? Initial Results from the Atlanta Commuters Exposure (ACE) Studies." Invited presentation. University of California, Irvine School of Public Health. May, 2013
11. 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.
12. 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.
13. 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.
14. Sarnat JA, Greenwald R, Sarnat SE, Kewada P, Yip F, Boehmer TK, Bergin MH. "In-vehicle pollutant exposures and acute cardiorespiratory response in a cohort of healthy and asthmatic car commuters in the Atlanta Commuters' Exposure Study." International Society for Environmental Epidemiology Annual Meeting. Barcelona, Spain, September 2011.

Future Activities*:* During the next 6 months, we expect to complete analyses of all pollutant and health endpoints, including plasma samples using novel HR-MS analyses involving the characterization of metabolomic profiles before and after ACE-2 exposures. As noted, Project 2 activities to date have

centered around intensive field data collection and processing. Moving forward, primary attention will shift to completing and submitting six draft manuscripts that are currently in preparation, as well as conducting new exposure and epidemiologic analyses of ACE-2 data.

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

Date of Report: July 31, 2014
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);
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: 08/01/2013 – 7/31/2014

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

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

1. We completed time-series epidemiological analysis assessing modification of the acute effect of ambient air pollution on pediatric asthma emergency visits across susceptible subpopulations. This paper (Strickland et al.) is in press at *Epidemiology*. We found that children born preterm and children born to African American mothers tended to have higher rate ratios than their counterparts. We are presenting these results at the 2014 International Society for Environmental Epidemiology (ISEE) conference.
2. We completed the time-series epidemiological analysis of acute effects of ambient air pollution on several different types of respiratory emergency visits among children age 0-4 years. We found several associations. This paper (Darrow et al.) has been accepted by *American Journal of Epidemiology.* A related manuscript that describes the relationship between emergency visits for bronchiolitis during infancy and subsequent risk of emergency visits for asthma after age five is currently under peer review.

3. The paper describing our method for using classification and regression trees to estimate the joint effects of pollutant mixtures (Gass et al.) was published in *Environmental Health* in April, 2014. A second paper that extends this approach to look at acute associations between air pollutants and pediatric asthma emergency visits in three cities is currently under peer review. We presented the method at the 2014 Society for Epidemiologic Research (SER) conference, and we are presenting both the method and the results of the three-city analysis at the 2014 ISEE conference.
4. We completed the Atlanta time-series analyses using the Bayesian ensemble source apportionment estimates. A manuscript based on our results, which includes propagation of air quality model uncertainty through the epidemiological analyses, is currently under peer review.
5. The manuscript describing the method for the self-organizing maps (Pearce et al.) was accepted by *Environmental Health* in June. A poster describing results of an analysis that uses the self-organizing maps in an Atlanta time-series analysis to investigate associations between mixtures and asthma emergency visits will be presented at the 2014 ISEE conference.
6. We are working to finish a Georgia-wide analysis of associations between air pollutants and preterm birth using the fused CMAQ estimates. A manuscript is being prepared. Results will be presented at the 2014 ISEE conference.
7. At the annual meeting of our external Science Advisory Committee, we presented results of a Georgia-wide analysis of acute effects of PM2.5 estimated from satellite remote sensing on several different respiratory ED visits (including ear infections). We have published the 10-year time-series of satellite-estimated PM2.5 concentrations at 1 km spatial resolution in *Atmospheric Chemistry and Physics* in June 2014. Although we have not yet generated a manuscript based on these results, it is our intention to do so during the upcoming year. One concern we had was potential confounding by ozone. Now that we have the statewide fused CMAQ results available for ozone we will create two-pollutant models for PM2.5 and ozone. A poster based on this work is being presented at the 2014 ISEE conference.
8. Progress is being made on the analysis of incident asthma in the Kaiser Permanente cohort. On the air quality side, the biostatistics core and air quality core are working to downscale the CMAQ estimates to 250-meter grids. These estimates should be available sometime in late 2014. On the health side, we have investigated misclassification of asthma due to different case definitions (a poster based on this work was presented at the 2014 Society for Pediatric Research (SPER) and 2014 SER conferences), and we have also investigated relationships between socioeconomic variables and air quality using the 4-km CMAQ estimates (a poster based on this work will be presented at the 2014 ISEE conference).
9. A manuscript to evaluate the potential of adding satellite-detected fire spots to PM2.5 exposure models in Georgia is under peer review for the *Journal of Geophysical Research*.

Publications:

1. **Strickland MJ, Klein M, Flanders WD, Chang HH, Mulholland JA, Tolbert PE, Darrow LA. Modification of the effect of ambient air pollution on pediatric asthma emergency visits: susceptible subpopulations. Epidemiology, in press. (Project 3, Core B, Core C)**
2. **Darrow LA, Klein M, Flanders WD, Mulholland JA, Tolbert PE, Strickland MJ. Air pollution and acute respiratory infections among children 0-4 years: an 18-year time-series study. Am J Epidemiol, in press. (Project 3, Core B, Core C)**
3. **Winquist A, Kirrane E, Klein M, Strickland M, Darrow LA, Sarnat SE, Gass K, Mulholland JA, Russell AG, Tolbert PE. Joint effects of ambient air pollutants on pediatric asthma emergency department visits in Atlanta, 1998-2004. Epidemiology 2014;25:666-73. (Core B, Core C, Project 3, Project 4)**

4. **Gass K, Klein M, Chang HH, Flanders WD, Strickland MJ. Classification and regression trees for epidemiologic research. Environmental Health 13:17, 2014. (Core C, Project 3, Project 4)**
5. **Russell A, Holmes H, Frieberg M, Ivey S, Hu Y, Balachandran S, Mulholland J, Tolbert P, Sarnat J, Sarnat S, Strickland M, Chang H, Liu Y. Use of Air Quality Modeling Results in Health Effects Research. In *Air Pollution Modeling and Its Application XXIII* (D. Steyn and R. Mathur eds.) 2014. (Core B, Project 3, Project 4)**
6. **Sororian S, Holmes H, Friberg M, Ivey C, Hu Y, Mulholland J, Russell A, Strickland M, Chang H. Temporally and spatially resolved air pollution in Georgia using fused ambient monitoring data and chemical transport model results. In *Air Pollution Modeling and Its Application XXIII* (D. Steyn and R. Mathur eds.) 2014. (Core B, Project 3)**
7. **Ma Z, Hu X, Huang L, Bi J, Liu Y. Estimating ground-level $PM_{2.5}$ in China using satellite remote sensing. 2014. *Environ. Sci. Technol.* dx.doi.org/10.1021/es5009399. (Core B, Project 3)**
8. **Yu C, Chen L, Zhang X, Girolamo LD, Liu Y. 2014. Effects of MODIS-retrieved Cloud Properties on PM2.5 Levels in the Southeastern United States. *J Expo Sci Environ Epidemiol*., in press. (Core B, Project 3)**
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10. 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. *Remote Sensing of Environment* 140:220-232, 2014. (Core B, Core C, Project 3)
11. Chang HH, Hu X, Liu Y. Calibrating MODIS aerosol optical depth for predicting daily $PM_{2.5}$ concentrations via statistical downscaling. *Journal of Exposure Science and Environmental Epidemiology,* doi:10.1038/jes.2013.90. (Project 3, Core B, Core C).
12. 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.
13. 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).
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15. 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)
16. 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)
17. 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.
18. Reich BJ, Chang HH, Strickland MJ. Spatial health effects analysis with uncertain residential locations. *Statistical Methods in Medical Research* 23:156-168, 2014. (Core C, Project 3)

19. 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)
20. 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)
21. 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)
22. 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. **Strickland MJ, Klein M, Flanders WD, Chang HH, Mulholland JA, Tolbert PE, Darrow LA. "Modification of the effect of ambient air pollution on pediatric asthma emergency visits: susceptible subpopulations." International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.**
2. **Strickland MJ, Gass KM, Goldman GT, Mulholland JA. "Effects of ambient air pollution measurement error on health effects estimates in single-pollutant time-series models: a simulation-based analysis." International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.**
3. **Gass K, Strickland M, Klein M, Flanders D, Chang H. Classification and regression tress for epidemiologic research." International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.**
4. **Gass K, Klein M, Sarnat S, Flanders D, Chang H, Strickland M. A three-city analysis of multipollutant joint effects: a comparison of classification and regression trees with conventional multipollutant models. International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.**
5. **Hao H, Liu Y, Hu X, Chang HH, Darrow LA, Strickland MJ. "Satellite-Derived Estimates of Ambient Fine Particulate Matter and Pediatric Emergency Department visits in Georgia, 2002-2010: A case-crossover study." Poster presentation at International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.**
6. **Hao H, Chang H, Darrow L, Holmes H, Mulholland J, Strickland M. "Ambient air pollution and preterm birth: a time-to-event analysis in Georgia, 2002-2006." Poster presentation at International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.**
7. **Pearce JL, Waller LA, Sarnat SA, Strickland M, Klein M, Chang HH, Mulholland J, Tolbert PE. "A framework for exploring the temporal associations between air quality day types and pediatric asthma: a case study of Atlanta, Georgia." Poster presentation at International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.**
8. **Flak AL, Darrow LA, Pearce JL, Hansen C, Strickland MJ. "Distribution of ambient air pollution and asthma incidence by race and socioeconomic status in a birth cohort." Poster presentation at International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.**

9. **Gass K, Klein M, Flanders WD, Chang H, Strickland M. "Classification and regression trees for epidemiologic research." Society for Epidemiologic Research Annual Meeting. Seattle, Washington, June 2014.**
10. **Flak AL, Strickland MJ, DeMuth K, Hansen C, Darrow LA. "Early-life asthma classification in an electronic medical record setting." Poster presentation at the Society for Epidemiologic Research Annual Meeting. Seattle, Washington, June 2014.**
11. **Flak AL, Strickland MJ, DeMuth K, Hansen C, Darrow LA. "Early-life asthma classification in an electronic medical record setting." Poster presentation at the Society for Pediatric and Perinatal Epidemiologic Research Annual Meeting. Seattle, Washington, June 2014.**
12. **Liu Y, Satellite-Predicted High-Resolution $PM_{2.5}$ Maps in the Southeastern United States. USEPA Work-In-Progress Webinar for the Clean Air Research Centers. May 14, 2014.**
13. 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.
14. 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.
15. 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.
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17. 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.
18. 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.
19. 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.
20. 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.
21. 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.
22. 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.

23. 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.
24. 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.
25. Darrow LA, Strickland MJ, Klein M, Tolbert PE. “Ambient air pollution and respiratory emergency department visits among children age 0-4 years.” Oral presentation at the International Society for Environmental Epidemiology Annual Conference. Columbia, South Carolina, August 2012.
26. Gass K, Strickland MJ, Darrow LA, Klein M, Mulholland JA, Tolbert PE. “Short-term associations between ambient air pollutants and pediatric asthma emergency visits and the role of seasonal interaction.” Poster presentation at the International Society for Environmental Epidemiology Annual Conference. Columbia, South Carolina, August 2012.
27. 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*:* We will continue to conduct epidemiologic analyses and produce results-based manuscripts during the upcoming year. Two priority manuscripts are the statewide preterm birth analysis (using the fused CMAQ data) and the statewide emergency visit analysis (that uses the satellite-derived PM2.5 estimates and the fused CMAQ ozone estimates). Currently the Center’s Air Quality Core is developing an approach to incorporate the ROS estimates from Project 1 into the daily source apportionment time-series. During the upcoming year we will use these ROS estimates in a time-series analysis of asthma in Atlanta and prepare a manuscript based on the results.

The Kaiser Permanente analyses will be a major focus moving forward, and once the 250 meter downscaled CMAQ estimates are in hand we will begin using them in the epidemiologic analyses. The health data are ready to analyze, although given the focus on chronic effects (rather than acute effects, on which much of our earlier work has focused) we need to spend some time to ensure these new models are working as intended.

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, 2014
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: 08/01/2013 – 7/31/2014

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

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

Database development. Database activities included air quality, health outcome, and Census data focuses:

1. From the Air Quality Core, we received and processed CMAQ-fused estimates for 12 pollutants (criteria pollutants and major PM2.5 species) for each of the five cities; this approach involves fusion of monitoring and CMAQ modeled data to enable comparison of pollutant concentrations across the five cities. These estimates are available as daily population weighted averages (i.e., 1 value per day per study area) calculated for different study area sizes in each city (e.g., 20-county, 5-county, and 2-county Atlanta) for overarching epidemiologic analyses as well as daily ZIP code level averages for use in spatially-stratified epidemiologic analyses.
2. Health outcome data for Atlanta, Dallas, and St. Louis are complete. In the past year, processing of Birmingham data was completed and a subcontract with University of Pittsburgh collaborators was initiated as planned. University of Pittsburgh collaborators have acquired and processed ED visit data from Pittsburgh-area hospitals; for sharing these data with Emory, data use agreements between Emory and relevant Pittsburgh-area hospitals are currently being negotiated.
3. For assessment of neighborhood-level socioeconomic conditions among the five cities, ZIP code tabulation area (ZCTA)-level data from the 5-yr average (2007-2011) American Community Survey were acquired and processed in addition to those previously acquired for Census 2000. With the Biostatistics core, we have made plans for appropriate merging of these data with spatially-resolved AQ and ED data, accounting for changes in ZIP code boundaries over time.

Data analyses. A number of activities were conducted over the project period:

1. Conducted single- and multi-city epidemiologic analyses of asthma/wheeze and selected cardiovascular ED visits, with a focus on model development, comparison of modeling approaches, assessment of model misspecification, and assessment of pollutant lag effects.
2. Continued efforts on application of spatially-refined modeled estimates of ambient concentrations and population exposures in Atlanta epidemiologic analyses: a) we completed work comparing exposure estimates from different exposure tiers in collaboration with EPA scientists (Baxter et al., 2013; Dionisio et al., 2013, 2014); b) we conducted preliminary analyses comparing the use of central monitor site, monitoring-based population weighted averages, and CMAQ-fused population weighted averages in epidemiologic models. In this comparison, health effect estimates among spatiotemporally homogeneous pollutants (e.g., ozone, $PM_{2.5}$) appear similar regardless of exposure assignment approach, while estimates of effect for NO_2 and CO are stronger in some cities with use of CMAQ-fused data.
3. With the Air Quality and Biostatistics Cores, continued work on methods for detecting and analyzing air pollution mixtures using multi-pollutant monitoring data: a) an approach for using classification and regression trees (C&RT) in air pollution epidemiologic research was published (Gass et al., 2014) and an extension of this approach to the multi-city context has been submitted for publication (Gass et al., submitted) and is being presented at both SER and ISEE 2014 meetings; b) our self-organizing maps approach to characterizing air pollution mixtures has been accepted for publication (Pearce et al., accepted) and an extension of this approach for use in epidemiologic analyses is in progress and will be presented at ISEE in 2014; c) an approach to estimate the joint effects of multiple pollutants was published (Winquist et al., 2014) and is being incorporated in several additional analyses throughout the project; and d) working with Project 1, we have conducted a preliminary examination of the effect of reactive oxygen species (ROS) on asthma/wheeze ED visits by retrospectively predicting DTT activity using a prediction model developed based on Project 1 data; preliminary results suggest a strong association between DTT and asthma/wheeze ED visits that is independent of the effect of $PM_{2.5}$.
4. Continued work on examining detailed $PM_{2.5}$ components data in epidemiologic analyses: a) analyses examining the impact of carbon measurement methods on epidemiologic results in St. Louis was published (Winquist et al., accepted) and a manuscript examining the health effects of a range of PM components from the St. Louis Supersite is submitted (Sarnat et al., submitted); b) we compiled a dataset of speciated gaseous and particle-phase organic components available at the Jefferson St. monitoring station in Atlanta and have applied several approaches to examining the impact of organic chemical groupings on cardiorespiratory ED visits.
5. Continued work on developing a statistical modeling approach to quantify projection uncertainties in future ambient ozone levels and their health impact due to climate change, which we have published (Chang et al., 2014) and will present at ISEE 2014.
6. Assessed potential modifiers of the effects of ambient air pollution on health: a) multi-city analyses examining modification of air pollution-health associations by age were conducted for asthma/wheeze (see Brooke et al. ISEE 2014 abstract) and congestive heart failure outcomes; b) analyses examining modification of air pollution-health associations by neighborhood socioeconomic factors were conducted for pediatric asthma/wheeze (see O'Lenick ISEE 2014 abstract) as well as for congestive heart failure outcomes; c) we extended our approach to estimate air exchange rates (previously conducted for a 4-yr period in Atlanta; see Sarnat J et al., 2013) to the full time periods in each of the five cities; application of these data in epidemiologic models is being implemented; d) finally, preliminary analyses examining modification of effects by season have been conducted.

Publications:

1. **Gass K, Klein M, Sarnat SE, Winquist A, Darrow LA, Flanders WD, Chang HH, Mulholland JA, Tolbert PE, Strickland MJ. Associations between ambient air pollutant mixtures and pediatric asthma emergency department visits in three cities: a classification and regression tree approach. *Environmental Health Perspectives*, submitted. (Core C, Project 3, Project 4)**
2. **Sarnat SE, Winquist A, Schauer JJ, Turner J, Sarnat JA. Fine particulate matter components and emergency department visits for respiratory and cardiovascular diseases in St. Louis. *Environmental Health Perspectives*, submitted. (Project 4)**
3. **Pearce JL, Waller LA, Chang H, Klein M, Mulholland J, Sarnat J, Sarnat S, Strickland M, Tolbert P. Using self-organizing maps to classify days by air quality for air pollution epidemiological mixtures research. *Environmental Health*, in press. (Core C, Core B, Project 3, Project 4)**
4. **Winquist A, Schauer JJ, Turner J, Klein M, Sarnat SE. Impact of ambient fine particulate matter carbon measurement methods on observed associations with acute cardiorespiratory morbidity. *Journal of Exposure Science and Environmental Epidemiology*, accepted. (Core C, Project 4)**
5. **Dionisio KL, Baxter LK, Chang HH. An empirical assessment of exposure measurement error and effect attenuation in bipollutant epidemiologic models. *Environmental Health Perspectives*, in press. (Core C, Project 4)**
6. **Winquist A, Kirrane E, Klein M, Strickland M, Darrow LA, Sarnat SE, Gass K, Mulholland JA, Russell AG, Tolbert PE. Joint effects of ambient air pollutants on pediatric asthma emergency department visits in Atlanta, 1998-2004. Epidemiology 2014;25:666-73. (Core B, Core C, Project 3, Project 4)**
7. **Russell A, Holmes H, Frieberg M, Ivey S, Hu Y, Balachandran S, Mulholland J, Tolbert P, Sarnat J, Sarnat S, Strickland M, Chang H, Liu Y. Use of Air Quality Modeling Results in Health Effects Research. In *Air Pollution Modeling and Its Application XXIII* (D. Steyn and R. Mathur eds.), 2014. (all cores and projects)**
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12. **Dionisio KL, Isakov V, Baxter L, Sarnat JA, Sarnat SE, Burke J, Rosenbaum A, Graham SE, Cook R, Mulholland J, Özkaynak H. Development and evaluation of alternative approaches for exposure assessment of multiple air pollutants in Atlanta, Georgia. *Journal of Exposure Science and Environmental Epidemiology* 23:581-592, 2013. (Project 4)**
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15. 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)
16. Sarnat JA, Sarnat SE, Chang H, Mulholland J, Özkaynak H, Isakov V. Spatiotemporally resolved air exchange rate as a modifier of acute air pollution-related morbidity. *Journal of Exposure Science and Environmental Epidemiology*, 23:606-615, 2013. (Project 2, Project 4)
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21. 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.
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27. 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. **Hixson B, Winquist A, Chang HH, Mulholland JA, Sarnat SE. "Ambient air pollution and emergency department visits for asthma: a multi-city assessment of effect modification by age." Oral**

presentation at International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.

2. **O'Lenick C, Winquist A, Mullholand J, Friberg M, Chang HH, Kramer M, Sarnat SE. "An evaluation of neighborhood-level socioeconomic influences on air pollution-asthma associations in Atlanta." Poster presentation at International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.**
3. **Chang HH, Hao H, Sarnat SE. "A statistical modeling framework for projecting future ambient ozone and its health impact due to climate change." International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.**
4. **Gass K, Klein M, Sarnat S, Flanders WD, Chang H, Strickland M. "A three-city analysis of multipollutant joint effects: a comparison of classification and regression trees with conventional multipollutant models." International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.**
5. **Pearce JL, Waller LA, Sarnat SA, Strickland M, Klein M, Chang HH, Mulholland J, Tolbert PE. "A framework for exploring the temporal associations between air quality day types and pediatric asthma: a case study of Atlanta, Georgia." International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.**
6. **Gass K, Klein M, Flanders WD, Chang H, Strickland M. "Classification and regression trees for epidemiologic research." Poster presentation at the Society for Epidemiologic Research Annual Meeting. Seattle, Washington, June 2014.**
7. **Russell AG, Tolbert P, Mulholland J, Hu Y, Odman T, Henneman L, Klein M, Sarnat S, Strickland M. "Impact of emissions changes on air quality and acute health effects in the Southeast 1993-2012." Poster presentation at the HEI Annual Conference. Alexandria, Virginia, May 2014.**
8. **Holmes HA, Ivey C, Friberg M, Zhai X, Balachandran S, Hu Y, Russell A, Mulholland J, Tolbert P, Sarnat S. "Use of air quality modeling results as exposure estimates in health studies." Oral presentation at the American Geophysical Union 46th Annual Fall Meeting. San Francisco, California, December 2013.**
9. **Dionisio KL, Baxter LK, Isakov V, Sarnat SE, Sarnat JA, Burke J, Ozkaynak H. "Modeling as an exposure estimation approach for use in epidemiologic studies." 12th Annual Community Modeling & Analysis System Conference. Chapel Hill, NC, October 28-30, 2013.**
10. 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.
11. 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.
12. 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.
13. 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.
14. 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.

15. 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.
16. 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.
17. 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.
18. 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.
19. 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.
20. 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.
21. 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.
22. 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.
23. 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.
24. 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.
25. 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.

26. Sarnat SE, Sarnat JA, Winquist A, Schauer JJ, Turner JR, Klein M, Tolbert PE. "Associations of source-resolved particulate air pollution mixtures and cardiorespiratory emergency department visits in St. Louis, MO-IL." International Society for Environmental Epidemiology Annual Meeting. Barcelona, Spain, September 2011. *Environmental Health Perspectives* http://dx.doi.org/10.1289/ehp.isee2011.

Future Activities*:* Over the coming year, we anticipate completing our ED visit database by incorporating data from University of Pittsburgh collaborators as well as conducting further work on merging of ZIP code level air quality, ED visit, and Census/ACS data that accounts for changing ZIP code boundaries over time. Manuscript preparation will begin and/or continue for analyses conducted over the past year. Current manuscripts in preparation include: 1) A framework for exploring the temporal associations between air quality day types and pediatric asthma using self-organizing maps; 2) An evaluation of neighborhood-level socioeconomic influences on air pollution-asthma associations in Atlanta; and 3) Ambient air pollution and emergency department visits for asthma: a multi-city assessment of effect modification by age. Additional planned manuscripts will focus on our multi-city assessment of air pollution and congestive heart failure ED visits, and an examination of retrospectively-predicted ROS on health. We will also continue our work on other analyses, including assessment of air exchange rates as a modifier of ambient air pollution health effects.

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

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Center Name: Southeastern Center for Air Pollution and Epidemiology
Project Title: Air Quality Core
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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: 08/01/2013 – 7/31/2014

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

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

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

Progress Summary/Accomplishments: During the past year, major milestones have been reached regarding the delivery of various air quality metrics by the Air Quality Core, the Georgia Birth Cohorts Study (Project 3), and the Multi-City Morbidity (Project 4). The three studies aim to apply different source apportionment (SA) methods to ambient air quality measurements and chemical transport model outputs in order to generate multi-year spatial fields of source impacts for use in health studies. SA methods include the traditional receptor models such as CMB (Chemical Mass Balance) and PMF (Positive Matrix Factorization), the source oriented approach using CMAQ-DDM (Decoupled Direct Method) and the development of novel methods including a Bayesian Ensemble SA technique and a Hybrid Kriging (HK) model.

EPA's CMB (Chemical Mass Balance) receptor model was applied to ambient aerosol concentrations observed at various regulatory monitoring sites in Georgia and two adjacent states: for Georgia, 8 sites in the CSN network (2002-2010), 2 from SEARCH (2000-2010) and 2 IMPROVE sites (2000-2010); 1 CSN site (2002-2010) in Tennessee; and 1 CSN site (2002-2010) in Florida. The 9 source categories considered in our CMB modeling effort are light duty gasoline vehicle, heavy duty diesel vehicle, soil dust, vegetative/wood burning, coal-fired power plants (primary source), ammonium sulfate, ammonium bi-sulfate, ammonium nitrate, and others. Daily CMB results by site and source type from 2000 through 2010 were posted on the SCAPE FTP site for use in health studies as part of Project 3.

We developed a novel Bayesian ensemble-averaging method to determine source impacts and to apportion sources for long-term dataset as part of Project 4. The ensemble approach uses three receptor models and one chemical transport model. We use two CMB methods: CMB-LGO which incorporates gas-based constraints, and CMB-MM which uses molecular marker observations. We use one factor analytic method, PMF and one CTM, the Community Multiscale Air Quality (CMAQ) model. Bayesian techniques were applied to estimate SA uncertainties.

We completed our OBS-CMAQ data fusion work for the Georgia Birth Cohorts Study (Project 3). Temporally and spatially resolved concentrations for 12 pollutants were calculated using fused ambient monitoring data and CMAQ outputs for Georgia. Pollutant fields include five gases (1-hour max CO, 1-hr max NO2, 1-hr max NOx, 1-hr max SO2 and 8-hr max O3) and seven PM types measures (24-hr average PM10, PM2.5, SO42-, NO3-, NH4+, EC and OC). Ambient concentrations were collected from the regulatory monitoring networks for the State and modelled concentrations were extracted from CMAQ simulations originally run for different domains:

- Contiguous US at 36 km for 2001 (CDC-funded EPA-generated PHASE runs);
- Eastern US at 12 km for 2002-2008 (CDC-funded EPA-generated PHASE runs);
- Georgia at 4 km for 2008-2010 (in-house data from the Georgia Tech Air Quality Forecasting project).

Fused data for the 12 pollutants were uploaded to the SCAPE FTP site in order for Emory to examine relationships of health outcomes with spatially and temporally resolved air pollution as part of the Project 3.

The data fusion methodology developed in Project 3 was also applied to the metropolitan areas of five cities, namely Atlanta, Birmingham, Dallas-Fort Worth, Pittsburgh and St. Louis, as part of the Multi-City Study (Project 4). For each metropolitan area, the counties we considered for OBS-CMAQ data fusion were the ones where health data were available. Ambient air quality monitoring data and CMAQ concentration fields for eastern US at 12 km (CDC funded EPA generated PHASE runs) were fused for the same 12 pollutants from 2002 through 2008. QA/QC procedures are currently applied to the spatially and temporally resolved concentrations before releasing the data to Emory.

As part of Project 3, spatially-resolved concentrations fields from mobile sources were generated for Georgia using the emission-based IMSI (Integrated Mobile Source Indicator) model. It was applied to the 24-hour average concentrations obtained from the 12-km OBS-CMAQ fused data for 2002-2008 and from the 4-km fused data for 2008-2010. EC concentration maps exhibiting the spatial variability of mobile source impact were uploaded to the SCAPE FTP site for use in health impact studies by Emory investigators.

The CMAQ-DDM (Decoupled Direct Method) model was used to determine the source impact for 40 PM2.5 species (5 ions, 35 metals) in the 36-km CONUS domain for 2006. The DDM package was used to quantify CMAQ sensitivities to emission changes for 20 source categories including biomass burning, on-road mobile sources and other combustion sources. Furthermore, to reduce impact uncertainties for each source category, the Hybrid Kriging (HK) method was applied to CMAQ-DDM concentration fields using interpolated observations from 189 monitors across CONUS. Simulation results from the coupling of CMAQ-DDM and HK models suggest that in 2006 the three dominant sources were coal combustion, biogenics and on-road gasoline combustion. Moreover, each source impact was ranked by importance of its contribution to seasonal concentrations in nine distinct climate regions. The adjusted spatial fields of concentrations and source impacts for 2006 data will be soon available for use in SCAPE health studies conducted by Emory.

In support of Project 3, we have been developing air quality metrics in a 250-m resolution grid covering the Atlanta area. Atlanta Regional Commission (ARC) provided us with the 2011 link-based emissions from the transportation sector in 15 counties. We calculated hourly NOx and PM2.5 emissions in the 250-m grid. AERMOD was applied to link-based emissions to assess daily and annual pollutant concentrations also gridded at 250 m. We are currently applying IMSI using both ARC emissions and AERMOD concentrations to both ARC emissions and AERMOD concentrations are currently being using IMSI in order to assess the influence of mobile sources at very high resolution.

As part of Project 3, Emory investigators have developed a statistical downscaling model for predicting daily spatially resolved PM2.5 concentrations at 12 km for 2003-2005. MODIS Aerosol Optical Depth (AOD) values and PM2.5 concentrations are linked in space and time by treating AOD as a predictor of PM2.5 in a linear regression setting. Spatio-temporal regression coefficients include land use and meteorological components. We have been applying the same downscaling approach by replacing AOD with our 12 km CMAQ outputs for 2002-2005. We will be providing Emory with our daily concentration fields calculated with the downscaler by early fall 2014.

In addition to our modeling effort, various field measurements have been undertaken or are currently under way. We are currently quantifying major ROS-associated emission sources by determining DTT activity in the water-soluble fraction of atmospheric fine aerosols. A large number of samples were collected at two Atlanta urban sites, one rural site, and a site adjacent to a major traffic route, from June 2012 through April 2013. Preliminary results indicate strong associations between PM ROS generation potential and water soluble organic carbon in the summertime and biomass burning markers in the wintertime.

Sixteen PAHs and ten quinones also were analyzed in the same samples. Small amounts of quinones are known to initiate atmospheric reactions that produce large concentrations of reactive oxygen species (ROS) which is known to exert oxidative stress upon inhalation. Analysis is still under way.
Finally, as part of Project 2, mobile platform measurements coupled with stationary site observations are used to investigate the spatial distribution of vehicle emission impacts from downtown Atlanta to Yorkville rural area. Results are coupled with our detailed roadway emissions and land use terms in our downscaling model to refine PM2.5 estimates at 250-m resolution.

Publications:

1. **Hu Y, Balachandran S, Pachon J, Baek J, Ivey C, Holmes H, Odman M, Mulholland J, Russell A, Fine particulate matter source apportionment using a hybrid chemical transport and receptor model approach. Atmospheric Chemistry and Physics 2013-704, 2014. (Core B)**
2. **Hu X, Waller LA, Lyapustin A, Wang Y, Liu Y. 2014. 10-Year Spatial and Temporal Trends of PM2.5 Concentrations in the Southeastern U.S. Estimated Using High-Resolution Satellite Data. Atmos Chem Phys (14) 6301-6314. (Core B, Core C, Project 3).**
3. **Ma Z, Hu X, Huang L, Bi J, Liu Y. Estimating ground-level PM2.5 in China using satellite remote sensing. 2014. Environ. Sci. Technol. dx.doi.org/10.1021/es5009399. (Core B, Project 3)**
4. **Pearce JL, Waller LA, Chang H, Klein M, Mulholland J, Sarnat J, Sarnat S, Strickland M, Tolbert P. Using self-organizing maps to classify days by air quality for air pollution epidemiological mixtures research. Environmental Health, in press. (Core C, Core B, Project 3, Project 4)**
5. **Russell A, Holmes H, Frieberg M, Ivey S, Hu Y, Balachandran S, Mulholland J, Tolbert P, Sarnat J, Sarnat S, Strickland M, Chang H, Liu Y. Use of Air Quality Modeling Results in Health Effects**

Research. In Air Pollution Modeling and Its Application XXIII (D. Steyn and R. Mathur eds.) 2014. (Core B, Project 3, Project 4)

6. **Sororian S, Holmes H, Friberg M, Ivey C, Hu Y, Mulholland J, Russell A, Strickland M, Chang H. Temporally and spatially resolved air pollution in Georgia using fused ambient monitoring data and chemical transport model results. In Air Pollution Modeling and Its Application XXIII (D. Steyn and R. Mathur eds.) 2014. (Core B, Project 3)**
7. **Strickland MJ, Klein M, Flanders WD, Chang HH, Mulholland JA, Tolbert PE, Darrow LA. Modification of the effect of ambient air pollution on pediatric asthma emergency visits: susceptible subpopulations. Epidemiology, in press. (Project 3, Core B, Core C)**
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9. **Yu C, Chen L, Zhang X, Girolamo LD, Liu Y. 2014. Effects of MODIS-retrieved Cloud Properties on PM2.5 Levels in the Southeastern United States. J Expo Sci Environ Epidemiol. In press. (Core B, Project 3)**
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12. Chang HH, Hu X, Liu Y. Calibrating MODIS aerosol optical depth for predicting daily $PM_{2.5}$ concentrations via statistical downscaling. *Journal of Exposure Science and Environmental Epidemiology,* doi:10.1038/jes.2013.90. (Project 3, Core B, Core C).
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17. 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)
18. 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)
19. 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. (Core B, Project 3).

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23. 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, Lavoue D, Davis A, Hu Y, Russell A. "CMAQ Simulations using Fire Inventory of NCAR (FINN) Emissions." *13th Annual Community Modeling & Analysis System (CMAS) Conference.* Chapel Hill, North Carolina, October 2014**
2. **Ivey C, Holmes H, Hu Y, Mulholland J, Russell A. "Python Data Assimilation Routine for CMAQ-DDM and Observations for Spatiotemporal PM2.5 Source Impacts." *13th Annual Community Modeling & Analysis System (CMAS) Conference.* Chapel Hill, North Carolina, October 2014.**
3. **Bates, J., Abrams, J., Tolbert, P., Gass, K., Klein, M., Verma, V., Weber, R., Mulholland, J., Russell, A. "Sources and health effects of reactive oxygen species in Atlanta air pollution." Poster at the 9th Annual Georgia Environmental Conference. Jekyll Island, Georgia, August 2014.**
4. **El-Afifi R, Wang Y, Verma V, Weber R, Russell A. "Seasonal and temporal assessment of organic aerosols in Atlanta". Poster presentation at the 107th Annual Air & Waste Management Association's Conference and Exhibition. Long Beach, CA, June 2014.**
5. **Friberg M, Sororian S, Holmes H, Hu Y, Russell A, Mulholland J. "Spatiotemporal air quality metrics developed for Georgia for use in health studies". Oral presentation at the 107th Annual Air & Waste Management Association's Conference & Exhibition. Long Beach, CA, June 2014.**
6. **Ivey C, Holmes H, Hu Y, Mulholland J. "Novel Data Assimilation Technique for Spatiotemporal PM2.5 Source Impact Estimates". Oral presentation at the Goldschmidt Conference. Sacramento, CA, June 2014.**
7. **Holmes H, Ivey C, Hu Y, Russell A, Sriramasamudram J, Pardyjak E. "Wintertime high PM events in the western United States". Poster presentation at the Goldschmidt Conference, Sacramento, CA, June 2014.**
8. **Ivey C, Holmes H, Hu Y, Mulholland J, Russell A. "Novel Data Assimilation Technique for Spatiotemporal PM2.5 Source Impact Estimates." Oral Presentation at the *Goldschmidt Conference,* Sacramento, CA, June 2014.**
9. **Ivey C, Holmes H, Hu Y, Mulholland J, Russell A. "What Air Pollution Sources Contribute to Your Personal Exposure to Ambient Particulate Matter?" Poster presentation at the Georgia Tech Innovation and Research Conference. Atlanta, GA. Feb 2014.**

10. **Ivey C, Holmes H, Hu Y, Mulholland J, Russell A. "A novel hybrid source apportionment method for ambient particulate matter". Poster presentation at the 107th Annual Air & Waste Management Association's Annual Conference & Exhibition. Long Beach, CA, June 2014.**
11. **Russell A, Tolbert P, Mulholland J, Hu Y, Odman T, Henneman L, Klein M, Sarnat S, Strickland M. "Impacts of emission changes on air quality and acute health effects in the Southeast 1993–2012". Oral presentation at the Health Effects Institute Annual Conference. Alexandria, VA, May 2014.**
12. **Holmes H, Ivey C, Friberg M, Zhai X, Balachandran S, Hu Y, Russell A, Mulholland J, Tolbert P, Sarnat S (2013). "Use of air quality modeling results as exposure estimates in health studies". Oral presentation at the American Geophysical Union 46th Annual Fall Meeting. San Francisco, CA, December 2013.**
13. **Ivey C, Holmes H, Hu Y, Mulholland J, Russell A. "Spatiotemporal Comparison of Novel Hybrid Source Apportionment and Receptor Modeling Results". Poster presentation at the 12th Annual Community Modeling & Analysis System (CMAS) Conference. Chapel Hill, NC, October 2013.**
14. **Zhai X, Sororian S, Friberg M, Holmes H, Hu Y, Mulholland J, Russell A."Generating spatially-resolved mobile source impacts using an observation-CMAQ data fusion technique and an emission-based indicator source apportionment approach". Poster presentation at the 12th annual Community Modeling & Analysis System (CMAS) Conference. Chapel Hill, NC, October 2013.**
15. 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.
16. **Sororian S, Holmes H, Friberg M, Ivey C, Hu Y, Mulholland J, Russell A, Strickland M, Chang H. "Temporally and spatially resolved air pollution in Georgia using fused ambient monitoring data and chemical transport model results". Poster presentation at the International Technical Meeting on Air Pollution Modeling and its Application. Miami, FL, August 2013.**
17. Hu X, Waller L, Lyapustin A, Liu Y. "A Time Series Analysis of PM2.5 Concentrations in the Southeastern U.S. Using MAIAC AOD in a Two-stage Spatial Statistical Model." Oral presentation at the Joint Annual Conference of the International Society for Environmental Epidemiology and Exposure Science and Indoor Air Quality. Basel, Switzerland, August 2013.
18. 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.
19. 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.
20. 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.
21. 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.

22. 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.
23. 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.
24. 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.
25. 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.
26. 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.
27. 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.
28. 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.
29. 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.
30. 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.
31. 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.
32. 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.
33. 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.
34. 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.

35. 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*:* We will apply our OBS-CMAQ data fusion method to the Atlanta metropolitan area using the 4-km CMAQ runs for 2008-2010. We showed that the HK SA approach can reduce the errors in estimate biomass burning impacts solely determined from CMAQ runs. However, we felt that HK model outputs may be biased due to the use of inadequate biomass burning emissions in NEI2005. Therefore, we decided to integrate in all our CMAQ runs new daily fire emissions based on FINN emission inventories developed by NCAR. We will apply CMAQ-DDM using 36-km CONUS domain nested with 12-km Eastern US and 4-km Georgia grids for 2004-2007. Source impacts determined in both nested domains might be utilized in the health studies for the 5 cities of Project 4. We will be replacing the default on-road mobile emissions in our 4-km CMAQ-DDM runs with the ARC mobile emissions for the Atlanta area. We will apply the statistical downscaling of PM2.5 and NOx to the 4-km CMAQ outputs and ARC mobile emissions to get daily concentrations at 250 m between 2008 and 2010. We are planning to aggregate our downscaling outputs, spatially, based on some geographical boundaries, such as the census tract, and temporally, such as weekly or monthly.

Supplemental Keywords: Air Quality, Chemical Transport Modeling, Receptor Modeling, Data Fusion, Statistical Downscaling, Exposure Measurement Error

Relevant Web Sites: www.scape.gatech.edu

Date of Report: July 31, 2014
EPA Agreement Number: R834799
Center Name: Southeastern Center for Air Pollution and Epidemiology
Project Title: Biostatistics Core
Investigator(s): PI -- Lance Waller, PhD (lwaller@sph.emory.edu); W. Dana Flanders, MD, ScD (wflande@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: 08/01/2013 – 7/31/2014

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

Progress Summary/Accomplishments: In the past year, the Biostatistics Core collaborated with SCAPE members across all studies with particular emphasis on the development and application of novel statistical or epidemiologic methods in several areas including the quantification of health effects due to simultaneous exposure to multiple pollutants; model-based estimates of pollutant concentrations fusing ground measurements, large-scale computational models, and remote sensing observations; measures of accuracy in estimates of causal effects from observation data; and identification of critical exposure windows during gestation. The Biostatistics Core presented recent accomplishments and work in progress to the Scientific Advisory Committee (SAC) and refined research in several areas (e.g., the quantification of joint effects of multiple pollutants and the impact of measurement error) due to constructive comments from the SAC.

More specifically, the Biostatistics Core has provided support and methodological development in the following areas:

1. Initiated development of methods addressing causal effect definitions and estimation (in progress, Klein and Flanders).
2. Developed statistical methods to assess critical exposure and outcome windows in the analyses of ambient air pollution and preterm birth (Chang, Waller, manuscript under revision for *Biostatistics*, joint work with Projects 3 and 4).
3. Expanded methods to estimate ground-level $PM_{2.5}$ concentrations from remote sensing (MODIS) data via geographically weighted regression (Hu et al. 2014).
4. Developed a novel statistical modeling framework for projecting future ozone levels due to climate change with an emphasis on uncertainty quantification (Chang et al. 2014, joint work with Project 4, and Cores B and C).
5. Investigated and quantified impact of exposure measurement errors in time series analysis of air pollution and health (Dionisio et al., to appear, joint work with Projects 3 and 4). Core members have also initiated a follow-up simulation study to provide more comprehensive results on sensitivity and specificity of the approach in such studies (Chang).
6. Facilitated analyses in CLARC collaborative Project 3 and Project 4.
7. Expanded statistical methods for statistical downscaling of pollutant concentrations including application to source apportionment studies (Chang et al, 2014, Reich et al., to appear, joint work with Project 3, and Cores B and C).
8. Initiated development of data fusion methods to combine satellite-derived aerosol optical depth and CMAQ outputs (Balachandran et al., 2013, joint work with Project 3 and Cores B and C).

9. Developed, applied, and published approaches for the analysis of joint effects of multiple pollutant using classification and regression trees (Gass et al. 2014, Winquist et al., in press) and self-organising maps (Pearce et al., in press). Joint work with Projects 3 and 4.
10. Developed and applied spatio-temporal hurdle models for zero-inflated data. (Neelon et al., in press, joint work with Core C and Project 4).

Publications:

1. **Chang HH, Hao H, Sarnat SE. A statistical modeling framework for projecting future ambient ozone and its health impact due to climate change. Atmospheric Environment 89:290-297, 2014. (Core C, Project 4)**
2. **Darrow LA, Klein M, Flanders WD, Mulholland JA, Tolbert PE, Strickland MJ. Air pollution and acute respiratory infections among children 0-4 years: an 18-year time-series study. Am J Epidemiol, in press. (Project 3, Core B, Core C)**
3. **Dionisio KL, Baxter LK, Chang HH. An empirical assessment of exposure measurement error and effect attenuation in bipollutant epidemiologic models. Environmental Health Perspectives, in press. (Core C, Project 4)**
4. **Gass K, Klein M, Chang HH, Flanders WD, Strickland MJ. Classification and regression trees for epidemiologic research. Environmental Health 13:17, 2014. (Core C, Project 3, Project 4)**
5. **Balachandran S, Chang HH, Pachon JE, Holmes HA, Mulholland JA, Russell AG. Bayesian-based ensemble technique for source apportionment of PM2.5. Environmental Science & Technology. 47, 13511-13518, 2013. (Core B, Core C)**
6. **Dionisio KL, Baxter LK, Chang HH. An empirical assessment of exposure measurement error and effect attenuation in bi-pollutant epidemiologic models. Environmental Health Perspectives, in press. (Core C)**
7. **Winquist A, Kirrane E, Klein M, Strickland M, Darrow LA, Sarnat SE, Gass K, Mulholland JA, Russell AG, Tolbert PE. Joint effects of ambient air pollutants on pediatric asthma emergency department visits in Atlanta, 1998-2004. Epidemiology 2014;25:666-73. (Core B, Core C, Project 3, Project 4)**
8. **Hu X, Waller LA, Lyapustin A, Wang Y, Liu Y. 2014. 10-Year Spatial and Temporal Trends of PM2.5 Concentrations in the Southeastern U.S. Estimated Using High-Resolution Satellite Data. Atmos Chem Phys (14) 6301-6314. (Core B, Core C, Project 3).**
9. **Russell A, Holmes H, Frieberg M, Ivey S, Hu Y, Balachandran S, Mulholland J, Tolbert P, Sarnat J, Sarnat S, Strickland M, Chang H, Liu Y. Use of Air Quality Modeling Results in Health Effects Research. In *Air Pollution Modeling and Its Application XXIII* (D. Steyn and R. Mathur eds.), 2014. (Core B, Core C, Project 1, Project 2, Project 3, Project 4)**
10. **Neelon B, Chang HH, Ling Q, Hastings SN. Flexible space-time hurdle models for zero-inflated count data: exploring spatiotemporal trends in emergency department visits. *Statistical Methods and Medical Research*, 2014, DOI: 10.1177/0962280214527079. (Core C, Project 4)**
11. **Reich BJ, Chang HH, Foley K. A spectral method for spatial downscaling. Biometrics, in press.**
12. **Pearce JL, Waller LA, Chang H, Klein M, Mulholland J, Sarnat J, Sarnat S, Strickland M, Tolbert P. Using self-organizing maps to classify days by air quality for air pollution epidemiological mixtures research. *Environmental Health*, accepted. (Core C, Core B, Project 3, Project 4)**
13. **Sarnat JA, Golan R, Greenwald R, Raysoni AU, Kewada P, Winquist A, Sarnat SE, Flanders WD, Mirabelli MC, Zora JE, Bergin MH, Yip F. Exposure to Traffic Pollution, Acute Inflammation and Autonomic Response in a Panel of Car Commuters. Environmental Research 133: 66-76. 2014. (Project 2, Core C)**

14. **Strickland MJ, Klein M, Flanders WD, Chang HH, Mulholland JA, Tolbert PE, Darrow LA. Modification of the effect of ambient air pollution on pediatric asthma emergency visits: susceptible subpopulations. Epidemiology, in press. (Project 3, Core B, Core C)**
15. **Winquist A, Schauer JJ, Turner J, Klein M, Sarnat SE. Impact of ambient fine particulate matter carbon measurement methods on observed associations with acute cardiorespiratory morbidity. Journal of Exposure Science and Environmental Epidemiology, accepted. (Core C, Project 4)**
16. Hu X, Waller LA, Lyapustin A, Wang Y, Al-Hamdan MZ, Crosson WL, Estes MG, Estes SM, Quattrochi DA, Puttaswamy SJ, Liu Y. Estimating ground-level PM2.5 concentrations in the Southeastern United States using MAIAC AOD retrievals and a two-stage model. *Remote Sensing of Environment* 140:220-232, 2014. (Core B, Core C, Project 3)
17. Chang HH, Hu X, Liu Y. Calibrating MODIS aerosol optical depth for predicting daily $PM_{2.5}$ concentrations via statistical downscaling. *Journal of Exposure Science and Environmental Epidemiology,* doi:10.1038/jes.2013.90. (Project 3, Core B, Core C).
18. Hu X, Waller LA, Lyapustin A, Wang Y, Liu Y. 10 yr spatial and temporal trends of PM2.5 concentrations in the southeastern US estimated using high-resolution satellite data. *Atmospheric Chemistry and Physics Discussion* 13:25617-25648, 2013. (Core B, Core C, Project 3)
19. 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.
20. Sarnat JA, Sarnat SE, Chang H, Mulholland J, Özkaynak H, Isakov V. Spatiotemporally resolved air exchange rate as a modifier of acute air pollution-related morbidity. *Journal of Exposure Science and Environmental Epidemiology*, 23:606-615, 2013. (Core C, Project 2, Project 4)
21. Sarnat SE, Sarnat JA, Mulholland J, Isakov V, Özkaynak H, Chang H, Klein M, Tolbert PE. Application of alternative spatiotemporal metrics of ambient air pollution exposure in a time-series epidemiological study in Atlanta. *Journal of Exposure Science and Environmental Epidemiology*, 23:593-605, 2013. (Core C, Project 4)
22. Waller LA. Commentary: Regarding assessments of chance in investigations of `cluster series'. *International Journal of Epidemiology* 42:449-452, 2013. (Core C, Project 3)
23. 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)
24. 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)
25. 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. **Hao H, Liu Y, Hu X, Chang HH, Darrow LA, Strickland MJ. "Satellite-Derived Estimates of Ambient Fine Particulate Matter and Pediatric Emergency Department visits in Georgia, 2002-2010: A case-crossover study." Poster presentation at International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.**
2. **Hao H, Chang H, Darrow L, Holmes H, Mulholland J, Strickland M. "Ambient air pollution and preterm birth: a time-to-event analysis in Georgia, 2002-2006." Poster presentation at**

International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.

3. **Hixson B, Winquist A, Chang HH, Mulholland JA, Sarnat SE. "Ambient air pollution and emergency department visits for asthma: a multi-city assessment of effect modification by age." Oral presentation at International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.**
4. **Gass K, Strickland M, Klein M, Flanders D, Chang H. Classification and regression trees for epidemiologic research." International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.**
5. **Gass K, Klein M, Sarnat S, Flanders D, Chang H, Strickland M. A three-city analysis of multipollutant joint effects: a comparison of classification and regression trees with conventional multipollutant models. International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.**
6. **Pearce JL, Waller LA, Sarnat SA, Strickland M, Klein M, Chang HH, Mulholland J, Tolbert PE. "A framework for exploring the temporal associations between air quality day types and pediatric asthma: a case study of Atlanta, Georgia." International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.**
7. **Strickland MJ, Klein M, Flanders WD, Chang HH, Mulholland JA, Tolbert PE, Darrow LA. "Modification of the effect of ambient air pollution on pediatric asthma emergency visits: susceptible subpopulations." International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.**
8. **O'Lenick C, Winquist A, Mullholand J, Friberg M, Chang HH, Kramer M, Sarnat SE. "An evaluation of neighborhood-level socioeconomic influences on air pollution-asthma associations in Atlanta." Poster presentation at International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.**
9. **Chang HH, Hao H, Sarnat SE. "A statistical modeling framework for projecting future ambient ozone and its health impact due to climate change." International Society for Environmental Epidemiology Annual Meeting. Seattle, Washington, August 2014.**
10. **Gass K, Klein M, Flanders WD, Chang H, Strickland M. "Classification and regression trees for epidemiologic research." Poster presentation at the Society for Epidemiologic Research Annual Meeting. Seattle, Washington, June 2014.**
11. **Pearce JL, Waller LA, Mulholland J, Tolbert PE. "Use of self-organizing maps to classify multi-pollutant exposure areas in an urban environment." Oral presentation at the Association of American Geographers Annual Meeting. Tampa, Florida, April 2014.**
12. 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.
13. 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.
14. 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.

15. 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.
16. 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.
17. 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.
18. 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.
19. 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.
20. 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.
21. 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.
22. 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.
23. 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.
24. Waller LA. “Spatial uncertainty in regression associations” Oral presentation at the International Society for Environmental Epidemiology Annual Conference. Columbia, South Carolina, August 2012.
25. 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.
26. 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.
27. 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.
28. 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: In the coming year, the Biostatistics Core will continue the development and assessment of methodologies for the estimation of health effects of exposure to multiple pollutants; the estimation of causal effects from observation studies; the fusion of monitored, modeled, and remotely sensed concentration levels; and the continued analysis of data from each SCAPE project and core.

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

Relevant Web Sites: www.scape.gatech.edu